101943106

# UNIFORM BUILDING CODE

## 1988 EDITION

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# Preface

**THE UNIFORM BUILDING CODE™** is dedicated to the development of better building construction and greater safety to the public by uniformity in building laws. The code is founded on broad-based performance principles that make possible the use of new materials and new construction systems.

**THE UNIFORM BUILDING CODE** was first enacted by the International Conference of Building Officials at the Sixth Annual Business Meeting held in Phoenix, Arizona, October 18-21, 1927. Revised editions of this code have been published since that time at approximate three-year intervals. New editions incorporate changes approved since the last edition.

**THE UNIFORM BUILDING CODE** is designed to be compatible with related publications listed on the following pages to provide a complete set of documents for regulatory use.

Anyone may propose amendments to this code. For more information, write to the International Conference of Building Officials at the address on the copyright page.

Changes to the code are processed each year and published in supplements in a form permitting ready adoption by local communities. These changes are carefully reviewed in public hearings by professional experts in the field of building construction and fire and life safety.

Solid vertical lines in the margins within the body of the code indicate a change from the requirements of the 1985 edition except where the entire chapter was revised, a new chapter was added or the change was minor. Where an entire chapter is changed or new chapter was added, a notation appears at the beginning of that chapter. Vertical lines in the table of contents indicate that a new chapter or section was added. Vertical lines in the margins that are interrupted by the letter "F" indicate that the provision is maintained under the code change procedures of the Western Fire Chiefs Association. Deletion indicators (➽) are provided in the margin where a paragraph or item listing has been deleted if the deletion resulted in a change of requirements.

An analysis of changes between editions is published in pamphlet form by the Conference.



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# RELATED PUBLICATIONS

Known widely for its Uniform Building Code, the International Conference of Building Officials publishes other related codes as well as textbooks to enable the user to improve his knowledge of code enforcement and the administration of a building inspection program. Publications are continually being added, so inquiries should be directed to Conference headquarters for a list of those available. At the time of this publication, the following publications were available:

**Uniform Building Code.** Covers the fire, life and structural safety aspects of all buildings and related structures.

**Handbook to the Uniform Building Code—An illustrative commentary.** A new publication containing a description of the purpose and intent of individual code sections appearing in the 1988 edition of the Building Code. Where appropriate, provides historical background and references other documents for additional information. Also included are numerous drawings and figures clarifying the application and intent of the 1988 code provisions.

**Uniform Building Code Standards.** Presents in a compact and concise manner national test, material and special design standards referred to in the Uniform Building Code.

**Uniform Mechanical Code.** Contains requirements for the installation and maintenance of heating, ventilating, cooling and refrigeration systems. This publication is sponsored jointly by the the International Conference of Building Officials and the International Association of Plumbing and Mechanical Officials.

**Uniform Plumbing Code.** Published by the International Association of Plumbing and Mechanical Officials, the Uniform Plumbing Code covers all aspects of plumbing, including requirements for plumbing materials, and IAPMO installation standards. It is endorsed by the Conference as a companion document to ICBO's model codes and is available from either organization.

**Uniform Housing Code.** Provides complete requirements affecting conservation and rehabilitation of housing. Its regulations are compatible with the Uniform Building Code.

**Uniform Code for the Abatement of Dangerous Buildings.** Sets forth orderly procedures for remedying dangerous buildings. Follows due process provisions which reflect the latest court decisions in such matters. This code covers all structures and may be used to supplement the Uniform Housing Code and the Uniform Building Code.

**Uniform Sign Code.** Dedicated to the development of better sign regulation. Its requirements pertain to all signs and sign construction attached to buildings.

**Uniform Administrative Code.** This code covers administration areas in connection with adoption of the Uniform Building Code, Uniform Mechanical Code and related codes by a jurisdiction. It contains provisions which relate to site preparation, construction, alteration, moving, repair and use and occupancies of buildings or structures and building service equipment including plumbing, electrical and mechanical. The code is compatible with the administrative provisions of all codes published by the Conference.

**Uniform Building Security Code.** This code establishes minimum standards to make dwelling units resistant to unlawful entry. It regulates swinging doors, sliding doors, windows and hardware in connection with dwelling units of apartment houses or one- and two-family dwellings. The code gives consideration to the concerns of police, fire and building officials in establishing requirements for resistance to burglary which are compatible with fire and life safety.

**Uniform Code for Building Conservation.** A building conservation guideline presented in code format which will provide a community with the means to preserve their existing buildings while achieving appropriate levels of safety. It is formatted in the same manner as the Uniform Building Code, compatible with other Uniform Codes, and may be adopted as a code or used as a guideline.



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**Dwelling Construction Under the Uniform Building Code.** Designed to acquaint the home builder with basic Building Code requirements relating to dwelling construction. A useful text for apprentice training programs.

**Uniform Fire Code.** Sets out provisions necessary for fire prevention while achieving uniformity in terms and requirements with other codes published by the Conference. This code is sponsored jointly by the Western Fire Chiefs Association and the International Conference of Building Officials.

**Uniform Fire Code Standards.** This publication is a companion to the Uniform Fire Code. It contains standards of the American Society for Testing and Materials and of the National Fire Protection Association referenced by the Uniform Fire Code.

**U.B.C. Supplements.** Between new editions of the codes, changes approved each year are incorporated in the supplements.

**Analysis of Revisions.** Discusses the changes included in the latest codes published by the Conference as compared to the prior editions.

**Uniform Building Code—1927 Edition.** A special 60th anniversary printing of the first published Uniform Building Code.

**CABO One and Two Family Dwelling Code.** This code is jointly sponsored by the International Conference of Building Officials, Building Officials and Code Administrators International, Inc., and Southern Building Code Congress International, Inc. It eliminates conflicts and duplications among the model codes to achieve national uniformity. Covers mechanical and plumbing requirements as well as construction and occupancy.

**Application and Commentary CABO One and Two Family Dwelling Code.** An interpretive commentary on the CABO One and Two Family Dwelling Code intended to enhance uniformity of interpretation and application of the code nationwide. Developed by the three model code organizations under contract with the Department of Housing and Urban Development (HUD) and in cooperation with the National Association of Home Builders (NAHB).

**CABO Model Energy Code.** This code sets forth minimum requirements for effective use of energy in the design of new buildings and structures and additions to existing buildings. It is based on ASHRAE Standard 90A-1980 and was originally developed jointly by ICBO, BOCA, SBCCI and the National Conference of States on Building Codes and Standards (NCSBCS) under a contract funded by the U.S. Department of Energy. The code is now maintained by the Council of American Building Officials (CABO) and is adopted by reference in the Uniform Building Code.

**Uniform Disaster Mitigation Plan.** A plan developed to aid building departments in coping with major disasters such as fires, floods and earthquakes. Defines standard operating procedures for initiating disaster assessment and mitigation and includes samples of records, reports, entry signs, etc.

**National Electrical Code.** The National Electrical Code is the electrical code for the majority of states, counties and cities in the United States. Researched and published every three years by the National Fire Protection Association, it is an indispensable aid to every electrician, electrical inspector, electrical equipment manufacturer, architect, builder, consulting engineer, contractor, fire marshal, fire chief, building inspector and anyone who must specify or certify electrical installations.

**Building Department Administration.** An excellent guide for improvement of skills in departmental management and in the enforcement and application of the Building Code and other regulations administered by a building inspection department. Recommended for both undergraduate and advanced study.

**Uniform Building Code Application/Interpretation Manual.** A manual discussing sections of the Uniform Building Code with a question/answer format, providing a comprehensive analysis of the intent of the code section. Most sections include illustrative exam-



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ples. The manual is in loose-leaf form so that code interpretations published in *Building Standards* may be inserted.

**Plan Review Manual.** Provides an understanding of the extent of Building Code provisions and illustrates application to given situations. Covers nonstructural aspects as well as providing an insight into the basic engineering considerations a plan examiner or checker must utilize.

**Field Inspection Manual.** Designed to improve inspection skills and techniques. A fundamental important text for courses of study at the community college and trade or technical school level.

**Building Official Management Manual.** This manual addresses the unique nature of code administration and the managerial duties of the building official. A supplementary insert addresses the budgetary and financial aspects of a building department. It is also an ideal resource for those preparing for the management module of the CABO Building Official Certification Examination.

**Legal Aspects of Code Administration.** A manual developed by the three model code organizations to inform the building official on the legal aspects of the profession. The text is written in a logical sequence with explanation of legal terminology and is designed to serve as a refresher to those preparing to take the legal module of the CABO Building Official Certification Examination.

**Illustrated Mechanical Manual.** Contains a series of illustrations with explanatory text covering requirements in the Uniform Mechanical Code which respond to graphic treatment. It is highly useful for code application and for training purposes.

**Concrete Manual.** A publication on concrete to be used for reference or as a text on concrete inspection. Of particular interest to inspectors, it is also useful to concrete technicians and craftsmen who are more concerned with the physical and practical aspects of concrete than the design.

**You Can Build It!** Sponsored by ICBO in cooperation with the Council of American Building Officials (CABO), this booklet contains information and advice to aid "do-it-yourselfers" with building projects. Provides guidance in necessary procedures such as permit requirements, codes, plans, cost estimation, etc.

**Guidelines for Manufactured Housing Installations.** A guideline in code form implementing the Uniform Building Code and its companion code documents to regulate the permanent installation of a manufactured home on a privately owned nonrental site. A commentary is included to explain specific provisions, and codes applying to each component part are defined.

**Tabulated Fire-Resistive Requirements by Occupancy.** Related code requirements are assembled for quick access. The tabulations assemble the limitations in Tables Nos. 5-A, 5-B, 5-C, and 17-A and the provisions of the 01 through 03 sections of the occupancy and type of construction chapters in the Uniform Building Code.

**Introduction to the Uniform Building Code Workbook.** A student workbook containing a series of exercises designed to compliment the course "Introduction to the Uniform Building Code, BIT-100." Assignments are arranged to provide an overview of the basics of the Uniform Building Code.

**Plan Reading and Nonstructural Plan Review Workbook.** A series of exercises intended to be a useful tool in understanding the concepts developed in "Plan Reading and Nonstructural Plan Review, BIT-101." The student exercises include assignments on code requirements and plan reading.



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# EFFECTIVE USE OF THE UNIFORM BUILDING CODE

The following procedure may be helpful in using the Uniform Building Code:

1. Classify the building:

   A. **OCCUPANCY CLASSIFICATION:** Compute the floor area and occupant load of the building or portion thereof. See Sections 407, 3302 and Table No. 33-A. Determine the occupancy group which the use of the building or portion thereof most nearly resembles. See the '01 sections of Chapters 5 through 12. See Section 503 for buildings with mixed occupancies.

   B. **TYPE OF CONSTRUCTION:** Determine the type of construction of the building by the building materials used and the fire resistance of the parts of the building. See Chapters 17 through 22.

   C. **LOCATION ON PROPERTY:** Determine the location of the building on the site and clearances to property lines and other buildings from the plot plan. See Table No. 5-A and '03 sections of Chapters 18 through 22 for fire resistance of exterior walls and wall opening requirements based on proximity to property lines. See Section 504.

   D. **ALLOWABLE FLOOR AREA:** Determine the allowable floor area of the building. See Table No. 5-C for basic allowable floor area based on occupancy group and type of construction. See Section 506 for allowable increases based on location on property and installation of an approved automatic fire-sprinkler system. See Section 505 (b) for allowable floor area of multistory buildings.

   E. **HEIGHT AND NUMBER OF STORIES:** Compute the height of the building, Section 409 and determine the number of stories, Section 420. See Table No. 5-D for the maximum height and number of stories permitted based on occupancy group and type of construction. See Section 507 for allowable story increase based on the installation of an approved automatic fire-sprinkler system.

2. Review the building for conformity with the occupancy requirements in Chapters 6 through 12.

3. Review the building for conformity with the type of construction requirements in Chapters 17 through 22.

4. Review the building for conformity with the exiting requirements in Chapter 33.

5. Review the building for other detailed code regulations in Chapters 29 through 54, Chapter 56, and the Appendix.

6. Review the building for conformity with engineering regulations and requirements for materials of construction. See Chapters 23 through 28.



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# SAMPLE ORDINANCE FOR ADOPTION OF THE UNIFORM BUILDING CODE AND UNIFORM BUILDING CODE STANDARDS

## ORDINANCE NO. _____

An ordinance of the _____ (jurisdiction) _____ adopting the 1988 edition of the Uniform Building Code and the 1988 edition of the Uniform Building Code Standards regulating the erection, construction, enlargement, alteration, repair, moving, removal, demolition, conversion, occupancy, equipment, use, height, area and maintenance of all buildings or structures in the _____ (jurisdiction) _____; providing for the issuance of permits and collection of fees therefor; providing for penalties for the violation thereof, repealing Ordinance No. _____ of the _____ (jurisdiction) _____ and all other ordinances and parts of the ordinances in conflict therewith.

The _____ (governing body) _____ of the _____ (jurisdiction) _____ does ordain as follows:

**Section 1.** That certain documents, three (3) copies of which are on file and are open for inspection of the public in the office of the _____ (jurisdiction's keeper of records) _____ of the _____ (jurisdiction) _____, being marked and designated as:

*Uniform Building Code, 1988 Edition*, published by the International Conference of Building Officials, including the generic fire-resistive assemblies listed in the Fire Resistance Design Manual, Eleventh Edition, dated October, 1984, published by the Gypsum Association as referenced in Tables Nos. 43-A, 43-B and 43-C (also reference Appendix Chapter 35, if adopted) of the specified Uniform Building Code, including Appendix Chapters _____. *[Fill in the applicable Appendix chapters (see Uniform Building Code Section 103, last paragraph). If reference is made to Appendix Chapter 51, an additional reference to ANSI/ASME A17.1, 1984, Safety Code for Elevators and Escalators, including Supplements A17.1a-1985, A17.1b-1985, A17.1c-1986, A17.1d-1986 and A17.1e-1987, published by the American Society of Mechanical Engineers, should be added and three (3) copies of this code should also be on file (see Appendix Sections 5109 and 5111)]*, and

*Uniform Building Code Standards, 1988 Edition*, published by the International Conference of Building Officials, including (i) Structural Welding Code—Reinforcing Steel, AWS D1.4-79 (U.B.C. Standard No. 26-8); (ii) Structural Welding Code—Steel, ANSI/AWS D1.1-84 (U.B.C. Standard No. 27-6); and (iii) Structural Welding Code—Sheet Steel, ANSI/AWS D1.3-81 (U.B.C. Standard No. 27-13) published by the American Welding Society, Inc., as modified or amended in the Uniform Building Code Standards referenced herein;

be and the same are hereby adopted as the code of the _____ (jurisdiction) _____ for regulating the erection, construction, enlargement, alteration, repair, moving, removal, demolition, conversion, occupancy, equipment, use, height, area and maintenance of all buildings or structures in the _____ (jurisdiction) _____ providing for issuance of permits and collection of fees therefor; and each and all of the regulations, provisions, conditions and terms of such *Uniform Building Code*,



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*1988 Edition*, and *Uniform Building Code Standards, 1988 Edition*, published by the International Conference of Building Officials, and the secondary publications referenced above, all of which are on file in the office of the (jurisdiction) are hereby referred to, adopted and made a part hereof as if fully set out in this ordinance.

**Section 2.** (Incorporate penalties for violations. See Section 205).

**Section 3.** That Ordinance No. _____ of (jurisdiction) entitled *(fill in the title of building ordinance or ordinances in effect at the present time)* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

**Section 4.** That if any section, subsection, sentence, clause or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The (governing body) hereby declares that it would have passed this ordinance, and each section, subsection, clause or phrase hereof, irrespective of the fact that any one or more sections, subsections, sentenees, clauses and phrases be declared unconstitutional.

**Section 5.** That the (jurisdiction's keeper of records) is hereby ordered and direeted to cause this ordinance to be published. *(An additional provision may be required to direct the number of times the ordinance is to be published and to specify that it is to be in a newspaper in general circulation. Posting may also be required.)*

**Section 6.** That this ordinance and the rules, regulations, provisions, requirements, orders and matters established and adopted hereby shall take effect and be in full force and effect (time period) from and after the date of its final passage and adoption.



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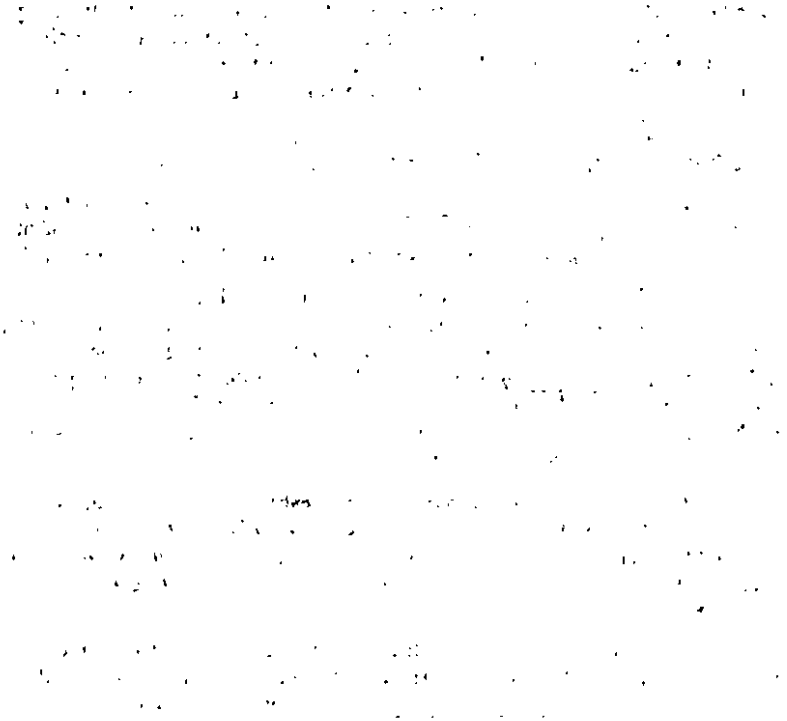

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# *Part I*

# ADMINISTRATIVE

## Chapter 1

## TITLE, SCOPE AND GENERAL

### Title

**Sec. 101.** These regulations shall be known as the "Uniform Building Code," may be cited as such and will be referred to herein as "this code."

### Purpose

**Sec. 102.** The purpose of this code is to provide minimum standards to safeguard life or limb, health, property and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures within this jurisdiction and certain equipment specifically regulated herein.

The purpose of this code is not to create or otherwise establish or designate any particular class or group of persons who will or should be especially protected or benefited by the terms of this code.

### Scope

**Sec. 103.** The provisions of this code shall apply to the construction, alteration, moving, demolition, repair and use of any building or structure within this jurisdiction, except work located primarily in a public way, public utility towers and poles, mechanical equipment not specifically regulated in this code, and hydraulic flood control structures.

Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

Wherever in this code reference is made to the appendix, the provisions in the appendix shall not apply unless specifically adopted.

### Application to Existing Buildings and Structures

**Sec. 104.** (a) **General.** Buildings and structures to which additions, alterations or repairs are made shall comply with all the requirements of this code for new facilities except as specifically provided in this section. See Section 1210 for provisions requiring installation of smoke detectors in existing Group R, Division 3 Occupancies.

(b) **Additions, Alterations or Repairs.** Additions, alterations or repairs may be made to any building or structure without requiring the existing building or structure to comply with all the requirements of this code, provided the addition, alteration or repair conforms to that required for a new building or structure. Additions or alterations shall not be made to an existing building or structure



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which will cause the existing building or structure to be in violation of any of the provisions of this code nor shall such additions or alterations cause the existing building or structure to become unsafe. An unsafe condition shall be deemed to have been created if an addition or alteration will cause the existing building or structure to become structurally unsafe or overloaded; will not provide adequate egress in compliance with the provisions of this code or will obstruct existing exits; will create a fire hazard; will reduce required fire resistance or will otherwise create conditions dangerous to human life. Any building so altered, which involves a change in use or occupancy, shall not exceed the height, number of stories and area permitted for new buildings. Any building plus new additions shall not exceed the height, number of stories and area specified for new buildings. Additions or alterations shall not be made to an existing building or structure when such existing building or structure is not in full compliance with the provisions of this code except when such addition or alteration will result in the existing building or structure being no more hazardous based on life safety, fire safety and sanitation, than before such additions or alterations are undertaken. [See also Section 911 (c) for Group H, Division 6 Occupancies.]

Alterations or repairs to an existing building or structure which are nonstructural and do not adversely affect any structural member or any part of the building or structure having required fire resistance may be made with the same materials of which the building or structure is constructed. The installation or replacement of glass shall be as required for new installations.

(c) **Existing Installations.** Buildings in existence at the time of the adoption of this code may have their existing use or occupancy continued, if such use or occupancy was legal at the time of the adoption of this code, provided such continued use is not dangerous to life.

Any change in the use or occupancy of any existing building or structure shall comply with the provisions of Sections 307 and 502 of this code.

For existing buildings, see Appendix Chapter 1.

(d) **Maintenance.** All buildings and structures, both existing and new, and all parts thereof, shall be maintained in a safe and sanitary condition. All devices or safeguards which are required by this code shall be maintained in conformance with the code edition under which installed. The owner or his designated agent shall be responsible for the maintenance of buildings and structures. To determine compliance with this subsection, the building official may cause any structure to be reinspected.

(e) **Moved Buildings and Temporary Buildings.** Buildings or structures moved into or within the jurisdiction shall comply with the provisions of this code for new buildings or structures.

Temporary structures such as reviewing stands and other miscellaneous structures, sheds, canopies or fences used for the protection of the public around and in conjunction with construction work may be erected by special permit from the building official for a limited period of time. Such buildings or structures need not comply with the type of construction or fire-resistive time periods required by this



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code. Temporary buildings or structures shall be completely removed upon the expiration of the time limit stated in the permit.

(f) **Historic Buildings.** Repairs, alterations and additions necessary for the preservation, restoration, rehabilitation or continued use of a building or structure may be made without conformance to all the requirements of this code when authorized by the building official, provided:

1. The building or structure has been designated by official action of the legally constituted authority of this jurisdiction as having special historical or architectural significance.
2. Any unsafe conditions as described in this code are corrected.
3. The restored building or structure will be no more hazardous based on life safety, fire safety and sanitation than the existing building.

## Alternate Materials and Methods of Construction

**Sec. 105.** The provisions of this code are not intended to prevent the use of any material or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.

The building official may approve any such alternate, provided he finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.

The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

## Modifications

**Sec. 106.** Whenever there are practical difficulties involved in carrying out the provisions of this code, the building official may grant modifications for individual cases, provided he shall first find that a special individual reason makes the strict letter of this code impractical and that the modification is in conformity with the intent and purpose of this code and that such modification does not lessen any fire-protection requirements or any degree of structural integrity. The details of any action granting modifications shall be recorded and entered in the files of the code enforcement agency.

## Tests

**Sec. 107.** Whenever there is insufficient evidence of compliance with any of the provisions of this code or evidence that any material or construction does not conform to the requirements of this code, the building official may require tests as proof of compliance to be made at no expense to this jurisdiction.

Test methods shall be as specified by this code or by other recognized test standards. If there are no recognized and accepted test methods for the proposed alternate, the building official shall determine test procedures.



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All tests shall be made by an approved agency. Reports of such tests shall be retained by the building official for the period required for the retention of public records.



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# Chapter 2
# ORGANIZATION AND ENFORCEMENT

## Creation of Enforcement Agency

**Sec. 201:** There is hereby established in this jurisdiction a code enforcement agency which shall be under the administrative and operational control of the building official.

## Powers and Duties of Building Official

**Sec. 202.** (a) **General.** The building official is hereby authorized and directed to enforce all the provisions of this code. For such purposes, he shall have the powers of a law enforcement officer.

The building official shall have the power to render interpretations of this code and to adopt and enforce rules and regulations supplemental to this code as he may deem necessary in order to clarify the application of the provisions of this code. Such interpretations, rules and regulations shall be in conformity with the intent and purpose of this code.

(b) **Deputies.** In accordance with prescribed procedures and with the approval of the appointing authority, the building official may appoint such number of technical officers and inspectors and other employees as shall be authorized from time to time. He may deputize such inspectors or employees as may be necessary to carry out the functions of the code enforcement agency.

(c) **Right of Entry.** Whenever neeessary to make an inspection to enforce any of the provisions of this code, or whenever the building official or his authorized representative has reasonable cause to believe that there exists in any building or upon any premises any condition or code violation which makes such building or premises unsafe, dangerous or hazardous, the building official or his authorized representative may enter such building or premises at all reasonable times to inspect the same or to perform any duty imposed upon the building official by this code, provided that if such building or premises be occupied, he shall first present proper credentials and request entry; and if such building or premises be unoccupied, he shall first make a reasonable effort to locate the owner or other persons having charge or control of the building or premises and request entry. If such entry is refused, the building official or his authorized representative shall have recourse to every remedy provided by law to secure entry.

(d) **Stop Orders.** Whenever any work is being done contrary to the provisions of this code, the building official may order the work stopped by notice in writing served on any persons engaged in the doing or causing such work to be done, and any such persons shall forthwith stop such work until authorized by the building official to proceed with the work.

(e) **Occupancy Violations.** Whenever any building or structure or equipment therein regulated by this eode is being used contrary to the provisions of this code, the building offieial may order such use discontinued and the structure, or portion thereof, vacated by notice served on any person eausing such use to be continued. Such person shall discontinue the use within the time prescribed by the building



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official after receipt of such notice to make the structure, or portion thereof, comply with the requirements of this code.

(f) **Liability.** The building official, or his authorized representative charged with the enforcement of this code, acting in good faith and without malice in the discharge of his duties, shall not thereby render himself personally liable for any damage that may accrue to persons or property as a result of any act or by reason of any act or omission in the discharge of his duties. Any suit brought against the building official or employee because of such act or omission performed by him in the enforcement of any provision of such codes or other pertinent laws or ordinances implemented through the enforcement of this code or enforced by the code enforcement agency shall be defended by this jurisdiction until final termination of such proceedings, and any judgment resulting therefrom shall be assumed by this jurisdiction.

This code shall not be construed to relieve from or lessen the responsibility of any person owning, operating or controlling any building or structure for any damages to persons or property caused by defects, nor shall the code enforcement agency or its parent jurisdiction be held as assuming any such liability by reason of the inspections authorized by this code or any permits or certificates issued under this code.

(g) **Cooperation of Other Officials and Officers.** The building official may request, and shall receive so far as is required in the discharge of his duties, the assistance and cooperation of other officials of this jurisdiction.

## Unsafe Buildings or Structures

**Sec. 203.** All buildings or structures regulated by this code which are structurally unsafe or not provided with adequate egress, or which constitute a fire hazard, or are otherwise dangerous to human life are, for the purpose of this section, unsafe. Any use of buildings or structures constituting a hazard to safety, health or public welfare by reason of inadequate maintenance, dilapidation, obsolescence, fire hazard, disaster, damage or abandonment is, for the purpose of this section, an unsafe use. Parapet walls, cornices, spires, towers, tanks, statuary and other appendages or structural members which are supported by, attached to, or a part of a building and which are in deteriorated condition or otherwise unable to sustain the design loads which are specified in this code are hereby designated as unsafe building appendages.

All such unsafe buildings, structures or appendages are hereby declared to be public nuisances and shall be abated by repair, rehabilitation, demolition or removal in accordance with the procedures set forth in the Dangerous Buildings Code or such alternate procedures, as may have been or as may be adopted by this jurisdiction. As an alternative, the building official, or other employee or official of this jurisdiction as designated by the governing body, may institute any other appropriate action to prevent, restrain, correct or abate the violation.

## Board of Appeals

**Sec. 204.** (a) **General.** In order to hear and decide appeals of orders, decisions or determinations made by the building official relative to the application and



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interpretation of this code, there shall be and is hereby created a Board of Appeals consisting of members who are qualified by experience and training to pass upon matters pertaining to building construction and who are not employees of the jurisdiction. The building official shall be an ex officio member of and shall act as secretary to said board but shall have no vote upon any matter before the board. The Board of Appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt rules of procedure for conducting its business and shall render all decisions and findings in writing to the appellant with a duplicate copy to the building official.

(b) **Limitations of Authority.** The Board of Appeals shall have no authority relative to interpretation of the administrative provisions of this code nor shall the Board be empowered to waive requirements of this code.

## Violations

**Sec. 205.** It shall be unlawful for any person, firm or corporation to erect, construct, enlarge, alter, repair, move, improve, remove, convert or demolish, equip, use, occupy or maintain any building or structure or cause or permit the same to be done in violation of this code.



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# Chapter 3
# PERMITS AND INSPECTIONS

## Permits

**Sec. 301.** (a) **Permits Required.** Except as specified in Subsection (b) of this section, no building or structure regulated by this code shall be erected, constructed, enlarged, altered, repaired, moved, improved, removed, converted or demolished unless a separate permit for each building or structure has first been obtained from the building official.

(b) **Exempted Work.** A building permit shall not be required for the following:

1. One-story detached accessory buildings used as tool and storage sheds, playhouses and similar uses, provided the projected roof area does not exceed 120 square feet.
2. Fences not over 6 feet high.
3. Oil derricks.
4. Movable cases, counters and partitions not over 5 feet 9 inches high.
5. Retaining walls which are not over 4 feet in height measured from the bottom of the footing to the top of the wall, unless supporting a surcharge or impounding Class I, II or III-A liquids.
6. Water tanks supported directly upon grade if the capacity does not exceed 5000 gallons and the ratio of height to diameter or width does not exceed two to one.
7. Platforms, walks and driveways not more than 30 inches above grade and not over any basement or story below.
8. Painting, papering and similar finish work.
9. Temporary motion picture, television and theater stage sets and scenery.
10. Window awnings supported by an exterior wall of Group R, Division 3, and Group M Occupancies when projecting not more than 54 inches.
11. Prefabricated swimming pools accessory to a Group R, Division 3 Occupancy in which the pool walls are entirely above the adjacent grade and if the capacity does not exceed 5000 gallons.

Unless otherwise exempted, separate plumbing, electrical and mechanical permits will be required for the above exempted items.

Exemption from the permit requirements of this code shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of this code or any other laws or ordinances of this jurisdiction.

## Application for Permit

**Sec. 302.** (a) **Application.** To obtain a permit, the applicant shall first file an application therefor in writing on a form furnished by the code enforcement agency for that purpose. Every such application shall:

1. Identify and describe the work to be covered by the permit for which application is made.



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2. Describe the land on which the proposed work is to be done by legal description, street address or similar description that will readily identify and definitely locate the proposed building or work.

3. Indicate the use or occupancy for which the proposed work is intended.

4. Be accompanied by plans, diagrams, computations and specifications and other data as required in Subsection (b) of this section.

5. State the valuation of any new building or structure or any addition, remodeling or alteration to an existing building.

6. Be signed by the permittee, or his authorized agent.

7. Give such other data and information as may be required by the building official.

(b) **Plans and Specifications.** Plans, engineering calculations, diagrams and other data shall be submitted in one or more sets with each application for a permit. The building official may require plans, computations and specifications to be prepared and designed by an engineer or architect licensed by the state to practice as such. Submittals shall include construction inspection requirements as defined in Section 302 (c).

> **EXCEPTION:** The building official may waive the submission of plans, calculations, construction inspection requirements, etc., if he finds that the nature of the work applied for is such that reviewing of plans is not necessary to obtain compliance with this code.

(c) **Construction Inspection.** The engineer or architect in responsible charge of the structural design work shall include in the construction documents the following:

1. Special inspections required by Section 306.
2. Other structural inspections required by the engineer or architect in responsible charge of the structural design work.

(d) **Information on Plans and Specifications.** Plans and specifications shall be drawn to scale upon substantial paper or cloth and shall be of sufficient clarity to indicate the location, nature and extent of the work proposed and show in detail that it will conform to the provisions of this code and all relevant laws, ordinances, rules and regulations.

Plans for buildings more than two stories in height of other than Groups R, Division 3 and M Occupancies shall indicate how required structural and fire-resistive integrity will be maintained where a penetration will be made for electrical, mechanical, plumbing and communication conduits, pipes and similar systems.

## Permits Issuance

**Sec. 303.** (a) **Issuance.** The application, plans, specifications, computations and other data filed by an applicant for permit shall be reviewed by the building official. Such plans may be reviewed by other departments of this jurisdiction to verify compliance with any applicable laws under their jurisdiction. If the building official finds that the work described in an application for a permit and the



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plans, specifications and other data filed therewith conform to the requirements of this code and other pertinent laws and ordinances, and that the fees specified in Section 304 have been paid, he shall issue a permit therefor to the applicant.

When the building official issues the permit where plans are required, he shall endorse in writing or stamp the plans and specifications "APPROVED." Such approved plans and specifications shall not be changed, modified or altered without authorizations from the building official, and all work regulated by this code shall be done in accordance with the approved plans.

The building official may issue a permit for the construction of part of a building or structure before the entire plans and specifications for the whole building or structure have been submitted or approved, provided adequate information and detailed statements have been filed complying with all pertinent requirements of this code. The holder of such permit shall proceed at his own risk without assurance that the permit for the entire building or structure will be granted.

(b) **Retention of Plans.** One set of approved plans, specifications and computations shall be retained by the building official for a period of not less than 90 days from date of completion of the work covered therein; and one set of approved plans and specifications shall be returned to the applicant, and said set shall be kept on the site of the building or work at all times during which the work authorized thereby is in progress.

(c) **Validity of Permit.** The issuance or granting of a permit or approval of plans, specifications and computations shall not be construed to be a permit for, or an approval of, any violation of any of the provisions of this code or of any other ordinance of the jurisdiction. Permits presuming to give authority to violate or cancel the provisions of this code or other ordinances of the jurisdiction shall not be valid.

The issuance of a permit based upon plans, specifications and other data shall not prevent the building official from thereafter requiring the correction of errors in said plans, specifications and other data, or from preventing building operations being carried on thereunder when in violation of this code or of any other ordinances of this jurisdiction.

(d) **Expiration.** Every permit issued by the building official under the provisions of this code shall expire by limitation and become null and void if the building or work authorized by such permit is not commenced within 180 days from the date of such permit, or if the building or work authorized by such permit is suspended or abandoned at any time after the work is commenced for a period of 180 days. Before such work can be recommenced, a new permit shall be first obtained to do so, and the fee therefor shall be one half the amount required for a new permit for such work, provided no changes have been made or will be made in the original plans and specifications for such work; and provided further that such suspension or abandonment has not exceeded one year. In order to renew action on a permit after expiration, the permittee shall pay a new full permit fee.

Any permittee holding an unexpired permit may apply for an extension of the time within which he may commence work under that permit when he is unable to



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commence work within the time required by this section for good and satisfactory reasons. The building official may extend the time for action by the permittee for a period not exceeding 180 days upon written request by the permittee showing that circumstances beyond the control of the permittee have prevented action from being taken. No permit shall be extended more than once.

(e) **Suspension or Revocation.** The building official may, in writing, suspend or revoke a permit issued under the provisions of this code whenever the permit is issued in error or on the basis of incorrect information supplied, or in violation of any ordinance or regulation or any of the provisions of this code.

## Fees

**Sec. 304.** (a) **General.** Fees shall be assessed in accordance with the provisions of this section or shall be as set forth in the fee schedule adopted by the jurisdiction.

(b) **Permit Fees.** The fee for each permit shall be as set forth in Table No. 3-A.

The determination of value or valuation under any of the provisions of this code shall be made by the building official. The value to be used in computing the building permit and building plan review fees shall be the total value of all construction work for which the permit is issued as well as all finish work, painting, roofing, electrical, plumbing, heating, air conditioning, elevators, fire-extinguishing systems and any other permanent equipment.

(c) **Plan Review Fees.** When a plan or other data are required to be submitted by Subsection (b) of Section 302, a plan review fee shall be paid at the time of submitting plans and specifications for review. Said plan review fee shall be 65 percent of the building permit fee as shown in Table No. 3-A.

The plan review fees specified in this subsection are separate fees from the permit fees specified in Section 304 (a) and are in addition to the permit fees.

Where plans are incomplete or changed so as to require additional plan review, an additional plan review fee shall be charged at the rate shown in Table No. 3-A.

(d) **Expiration of Plan Review.** Applications for which no permit is issued within 180 days following the date of application shall expire by limitation, and plans and other data submitted for review may thereafter be returned to the applicant or destroyed by the building official. The building official may extend the time for action by the applicant for a period not exceeding 180 days upon request by the applicant showing that circumstances beyond the control of the applicant have prevented action from being taken. No application shall be extended more than once. In order to renew action on an application after expiration, the applicant shall resubmit plans and pay a new plan review fee.

(e) **Investigation Fees: Work Without a Permit.** 1. **Investigation.** Whenever any work for which a permit is required by this code has been commenced without first obtaining said permit, a special investigation shall be made before a permit may be issued for such work.

2. **Fee.** An investigation fee, in addition to the permit fee, shall be collected whether or not a permit is then or subsequently issued. The investigation fee shall be equal to the amount of the permit fee required by this code. The minimum



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investigation fee shall be the same as the minimum fee set forth in Table No. 3-A. The payment of such investigation fee shall not exempt any person from compliance with all other provisions of this code nor from any penalty prescribed by law.

(f) **Fee Refunds.** 1. The building official may authorize the refunding of any fee paid hereunder which was erroneously paid or collected.

2. The building official may authorize the refunding of not more than 80 percent of the permit fee paid when no work has been done under a permit issued in accordance with this code.

3. The building official may authorize the refunding of not more than 80 percent of the plan review fee paid when an application for a permit for which a plan review fee has been paid is withdrawn or canceled before any plan reviewing is done.

The building official shall not authorize the refunding of any fee paid except upon written application filed by the original permittee not later than 180 days after the date of fee payment.

## Inspections

**Sec. 305.** (a) **General.** All construction or work for which a permit is required shall be subject to inspection by the building official and all such construction or work shall remain accessible and exposed for inspection purposes until approved by the building official. In addition, certain types of construction shall have continuous inspection as specified in Section 306.

Approval as a result of an inspection shall not be construed to be an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction. Inspections presuming to give authority to violate or cancel the provisions of this code or of other ordinances of the jurisdiction shall not be valid.

It shall be the duty of the permit applicant to cause the work to remain accessible and exposed for inspection purposes. Neither the building official nor the jurisdiction shall be liable for expense entailed in the removal or replacement of any material required to allow inspection.

A survey of the lot may be required by the building official to verify that the structure is located in accordance with the approved plans.

(b) **Inspection Record Card.** Work requiring a permit shall not be commenced until the permit holder or his agent shall have posted or otherwise made available an inspection record card such as to allow the building official conveniently to make the required entries thereon regarding inspection of the work. This card shall be maintained available by the permit holder until final approval has been granted by the building official.

(c) **Inspection Requests.** It shall be the duty of the person doing the work authorized by a permit to notify the building official that such work is ready for inspection. The building official may require that every request for inspection be filed at least one working day before such inspection is desired. Such request may be in writing or by telephone at the option of the building official.

It shall be the duty of the person requesting any inspections required by this code to provide access to and means for inspection of such work.



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(d) **Approval Required.** Work shall not be done beyond the point indicated in each successive inspeetion without first obtaining the approval of the building official. The building official, upon notification, shall makc the requested inspeetions and shall either indicate that portion of the construction is satisfactory as eompleted or shall notify the permit holder or his agent wherein the same fails to comply with this code. Any portions which do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the building official.

There shall be a final inspection and approval of all buildings and structures when completed and ready for occupancy and use.

(e) **Required Inspections.** Reinforcing steel or structural framework of any part of any building or structure shall not bc covered or concealed without first obtaining the approval of the building official.

The building official, upon notification, shall make the following inspections:

1. **FOUNDATION INSPECTION:** To bc made after excavations for footings are complete and any required reinforcing steel is in place. For concrete foundations, any required forms shall be in place prior to inspection. All materials for the foundation shall be on the job, except where concrete is ready mixed in accordance with U.B.C. Standard No. 26-13, the concrete need not bc on the job. Where the foundation is to be constructed of approved treated wood, additional inspections may be required by the building official.

2. **CONCRETE SLAB OR UNDER-FLOOR INSPECTION:** To be made after all in-slab or under-floor building service equipment, conduit, piping accessories and other ancillary equipment items are in place but before any concrete is placed or floor sheathing installed, including the subfloor.

3. **FRAME INSPECTION:** To be made after the roof, all framing, fire blocking and bracing are in place and all pipes, chimneys and vents are complete and the rough electrical, plumbing, and heating wires, pipes and ducts are approved.

4. **LATH AND/OR GYPSUM BOARD INSPECTION:** To bc made after all lathing and gypsum board, interior and exterior, is in place but before any plastering is applied or before gypsum board joints and fasteners are taped and finished.

5. **FINAL INSPECTION:** To be made after finish grading and the building is completed and ready for occupaney.

(f) **Other Inspections.** In addition to the called inspections specified above, the building official may makc or require other inspections of any construction work to ascertain compliance with the provisions of this code and other laws which are enforced by the code enforcement agency.

(g) **Reinspections.** A reinspection fcc may be assessed for each inspection or



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reinspection when such portion of work for which inspection is called is not complete or when corrections called for are not made.

This subsection is not to be interpreted as requiring reinspection fees the first time a job is rejected for failure to comply with the requirements of this code, but as controlling the practice of calling for inspections before the job is ready for such inspection or reinspection.

Reinspection fees may be assessed when the permit card is not properly posted on the work site, the approved plans are not readily available to the inspector, for failure to provide access on the date for which inspection is requested, or for deviating from plans requiring the approval of the building official.

To obtain a reinspection, the applicant shall file an application therefor in writing upon a form furnished for that purpose and pay the reinspection fee in accordance with Table No. 3-A or as set forth in the fee schedule adopted by the jurisdiction.

In instances where reinspection fees have been assessed, no additional inspection of the work will be performed until the required fees have been paid.

## Special Inspections

**Sec. 306.** (a) **General.** In addition to the inspections required by Section 305, the owner or the engineer or architect of record acting as the owner's agent shall employ one or more special inspectors who shall provide inspections during construction on the following types of work:

1. **CONCRETE:** During the taking of test specimens and placing of reinforced concrete.

**EXCEPTIONS:** 1. Concrete for foundations conforming to minimum requirements of Table No. 29-A or for Group R, Division 3 or Group M, Division 1 Occupancies, provided the building official finds that a special hazard does not exist.

2. For foundation concrete when the structural design is based on a $f'_c$ no greater than 2500 psi.

3. Nonstructural slabs on grade, including prestressed slabs on grade when effective prestress in concrete is less than 150 pounds per square inch.

4. Site work concrete fully supported on earth and concrete where no special hazard exists.

2. **BOLTS INSTALLED IN CONCRETE:** During installation of bolts and placing of concrete around such bolts when stress increases permitted by Footnote No. 5 of Table No. 26-F are utilized.

3. **DUCTILE MOMENT-RESISTING CONCRETE FRAME:** As required by Section 2625 (j) of this code.

4. **REINFORCING STEEL AND PRESTRESSING STEEL:** A. During all stressing and grouting of prestressed concrete.

B. During placing of reinforcing steel, placing of tendons and prestressing steel for all concrete required to have special inspection by Item No. 1.

**EXCEPTION:** The special inspector need not be present during entire reinforcing steel- and prestressing steel-placing operations, provided he has inspected for



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conformance with the approved plans, prior to the closing of forms or the delivery of concrete to the jobsite.

5. **WELDING:** A. Ductile moment-resisting steel frames. As required by Section 2722 (j) of this code.

B. All structural welding, including welding of reinforcing steel.

**EXCEPTIONS:** 1. When welding is done in an approved fabricator's shop.

2. When approved by the building official, single-pass fillet welds when stressed to less than 50 percent of allowable stresses and floor and roof deck welding and welded studs when used for structural diaphragm or composite systems may have periodic inspections in accordance with Section 306 (e) of this code. For periodic inspection, the inspector shall check qualifications of welders at the start of work and then make final inspection of all welds for compliance prior to completion of welding.

6. **HIGH-STRENGTH BOLTING:** During all bolt installations and tightening operations.

**EXCEPTIONS:** 1. The special inspector need not be present during the entire installation and tightening operation, provided he has:

(i) Inspected the surfaces and bolt type for conformance to plans and specifications prior to start of bolting,

(ii) And will, upon completion of all bolting, verify the minimum specified bolt tension for 10 percent of the bolts for each connection with a minimum of two bolts per connection.

2. In bearing-type connections when threads are not required by design to be excluded from the shear plane, inspection prior to or during installation will not be required.

7. **STRUCTURAL MASONRY:** During preparation of masonry wall prisms, sampling and placing of all masonry units, placement of reinforcement, inspection of grout space, immediately prior to closing of cleanouts, and during all grouting operations.

**EXCEPTIONS:** 1. Special inspection need not be provided when design stresses have been adjusted to permit noncontinuous inspection.

2. For hollow-unit masonry where the $f'_m$ is no more than 1500 psi for concrete units or 2600 psi for clay units, special inspection for placing of units may be performed on a periodic basis in accordance with Section 306 (e).

8. **REINFORCED GYPSUM CONCRETE:** When cast-in-place Class B gypsum concrete is being mixed and placed.

9. **INSULATING CONCRETE FILL:** During the application of insulating concrete fill when used as part of a structural system.

**EXCEPTION:** The special inspections may be limited to an initial inspection to check the deck surface and placement of reinforcing. The special inspector shall supervise the preparation of compression test specimens during this initial inspection.

10. **SPRAY-APPLIED FIREPROOFING:** As required by U.B.C. Standard No. 43-8.



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11. **PILING, DRILLED PIERS AND CAISSONS:** During driving and testing of piles and construction of cast-in-place drilled piles or caissons. See Items Nos. 1 and 4 for concrete and reinforcing steel inspection.

12. **SHOTCRETE:** During the taking of test specimens and placing of all shotcrete and as required by Section 2621 (j) and (k).

**EXCEPTION:** Shotcrete work fully supported on earth, minor repairs and when, in opinion of the building official, no special hazard exists.

13. **SPECIAL GRADING, EXCAVATION AND FILLING:** During earthwork excavations, grading and filling operations inspection to satisfy requirements of Chapter 29 and Chapter 70 (Appendix) of this code.

14. **SPECIAL CASES:** Work which, in the opinion of the building official, involves unusual hazards or conditions.

(b) **Special Inspector.** The special inspector shall be a qualified person who shall demonstrate his competence, to the satisfaction of the building official, for inspection of the particular type of construction or operation requiring special inspection.

(c) **Duties and Responsibilities of the Special Inspector.** 1. The special inspector shall observe the work assigned for conformance with the approved design drawings and specifications.

2. The special inspector shall furnish inspection reports to the building official, the engineer or architect of record, and other designated persons. All discrepancies shall be brought to the immediate attention of the contractor for correction, then, if uncorrected, to the proper design authority and to the building official.

3. The special inspector shall submit a final signed report stating whether the work requiring special inspection was, to the best of his knowledge, in conformance with the approved plans and specifications and the applicable workmanship provision of this code.

(d) **Waiver of Special Inspection.** The building official may waive the requirement for the employment of a special inspector if he finds that the construction is of minor nature.

(e) **Periodic Special Inspection.** Some inspections may be made on a periodic basis and satisfy the requirements of continuous inspection, provided this periodic scheduled inspection is performed as outlined in the project plans and specifications and approved by the building official.

(f) **Structural Observation.** During the construction of a structure located in Seismic Zone No. 3 or No. 4 in which construction inspection, as defined in Section 302 (c), Item 2, is required, the owner shall employ the engineer or architect responsible for the structural design or his designated engineer or architect to make visits to the site to observe general compliance with the approved structural plans, specifications and change orders. The engineer or architect shall submit a statement in writing to the building official stating the site visits have been made and that any deficiencies noted have been corrected.



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(g) **Approved Fabricators.** Special inspections required by this section and elsewhere in this code shall not be required where the work is done on the premises of a fabricator registered and approved by the building official to perform such work without special inspection. The certificate of registration shall be subject to revocation by the building official if it is found that any work done pursuant to the approval is in violation of this code. The approved fabricator shall submit a Certificate of Compliance that the work was performed in accordance with the approved plans and specifications to the building official and to the engineer or architect of record. The approved fabricator's qualifications shall be contingent on compliance with the following:

1. The fabricator has developed and submitted a detailed fabrication procedural manual reflecting key quality control procedures which will provide a basis for inspection control of workmanship and the fabricator plant.

2. Verification of the fabricator's quality control capabilities, plant and personnel as outlined in the fabrication procedural manual shall be by an approved inspection or quality control agency.

3. Periodic plant inspections shall be conducted by an approved inspection or quality control agency to monitor the effectiveness of the quality control program.

4. It shall be the responsibility of the inspection or quality control agency to notify the approving authority in writing of any change to the procedural manual. Any fabricator approval may be revoked for just cause. Reapproval of the fabricator shall be contingent on compliance with quality control procedures during the past year.

## Certificate of Occupancy

**Sec. 307.** (a) **Use and Occupancy.** No building or structure shall be used or occupied, and no change in the existing occupancy classification of a building or structure or portion thereof shall be made until the building official has issued a Certificate of Occupancy therefor as provided herein.

**EXCEPTION:** Group R, Division 3, and M Occupancies.

Issuance of a Certificate of Occupancy shall not be construed as an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction. Certificates presuming to give authority to violate or cancel the provisions of this code or of other ordinances of the jurisdiction shall not be valid.

(b) **Change in Use.** Changes in the character or use of a building shall not be made except as specified in Section 502 of this code.

(c) **Certificate Issued.** After the building official inspects the building or structure and finds no violations of the provisions of this code or other laws which are enforced by the code enforcement agency, the building official shall issue a Certificate of Occupancy which shall contain the following:

1. The building permit number.
2. The address of the building.
3. The name and address of the owner.



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4. A description of that portion of the building for which the certificate is issued.
5. A statement that the described portion of the building has been inspected for compliance with the requirements of this code for the group and division of occupancy and the use for which the proposed occupancy is classified.
6. The name of the building official.

(d) **Temporary Certificate.** If the building official finds that no substantial hazard will result from occupancy of any building or portion thereof before the same is completed, he may issue a temporary Certificate of Occupancy for the use of a portion or portions of a building or structure prior to the completion of the entire building or structure.

(e) **Posting.** The Certificate of Occupancy shall be posted in a conspicuous place on the premises and shall not be removed except by the building official.

(f) **Revocation.** The building official may, in writing, suspend or revoke a Certificate of Occupancy issued under the provisions of this code whenever the certificate is issued in error, or on the basis of incorrect information supplied, or when it is determined that the building or structure or portion thereof is in violation of any ordinance or regulation or any of the provisions of this code.



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## TABLE NO. 3-A—BUILDING PERMIT FEES

| TOTAL VALUATION | FEE |
|---|---|
| $1.00 to $500.00 | $15.00 |
| $501.00 to $2,000.00 | $15.00 for the first $500.00 plus $2.00 for each additional $100.00 or fraction thereof, to and including $2,000.00 |
| $2,001.00 to $25,000.00 | $45.00 for the first $2,000.00 plus $9.00 for each additional $1,000.00 or fraction thereof, to and including $25,000.00 |
| $25,001.00 to $50,000.00 | $252.00 for the first $25,000.00 plus $6.50 for each additional $1,000.00 or fraction thereof, to and including $50,000.00 |
| $50,001.00 to $100,000.00 | $414.50 for the first $50,000.00 plus $4.50 for each additional $1,000.00 or fraction thereof, to and including $100,000.00 |
| $100,001.00 to $500,000.00 | $639.50 for the first $100,000.00 plus $3.50 for each additional $1,000.00 or fraction thereof |
| $500,001.00 to $1,000,000.00 | $2039.50 for the first $500,000.00 plus $3.00 for each additional $1,000.00 or fraction thereof, to and including $1,000,000.00. |
| $1,000,001.00 and up | $3539.50 for the first $1,000,000.00 plus $2.00 for each additional $1,000.00 or fraction thereof |

**Other Inspections and Fees:**

1. Inspections outside of normal business hours ..... $30.00 per hour* (minimum charge—two hours)
2. Reinspection fees assessed under provisions of Section 305 (g) ..... $30.00 per hour*
3. Inspections for which no fee is specifically indicated ..... $30.00 per hour* (minimum charge—one-half hour)
4. Additional plan review required by changes, additions or revisions to approved plans ..... $30.00 per hour* (minimum charge—one-half hour)

*Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.



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# *Part II*

# DEFINITIONS AND ABBREVIATIONS

## Chapter 4
## DEFINITIONS AND ABBREVIATIONS

### Definitions

**Sec. 401. General.** For the purpose of this code, certain terms, phrases, words and their derivatives shall be construed as specified in this chapter. Words used in the singular include the plural and the plural the singular. Words used in the masculine gender include the feminine and the feminine the masculine.

Where terms are not defined, they shall have their ordinary accepted meanings within the context with which they are used. *Webster's Third New International Dictionary of the English Language, Unabridged*, copyright 1981, shall be considered as providing ordinarily accepted meanings.

### A

**Sec. 402. ACCESS FLOOR SYSTEM** is an assembly consisting of panels mounted on pedestals to provide an under-floor space for the installations of mechanical, electrical, communication or similar systems or to serve as an air-supply or return-air plenum.

**ADDITION** is an extension or increase in floor area or height of a building or structure.

**AGRICULTURAL BUILDING** is a structure designed and constructed to house farm implements, hay, grain, poultry, livestock or other horticultural products. This structure shall not be a place of human habitation or a place of employment where agricultural products are processed, treated or packaged; nor shall it be a place used by the public.

**ALLEY** is any public way or thoroughfare less than 16 feet but not less than 10 feet in width which has been dedicated or deeded to the public for public use.

**ALTER** or **ALTERATION** is any change, addition or modification in construction or occupancy.

**APARTMENT HOUSE** is any building or portion thereof which contains three or more dwelling units and, for the purpose of this code, includes residential condominiums.

**APPROVED,** as to materials and types of construction, refers to approval by the building official as the result of investigation and tests conducted by him, or by reason of accepted principles or tests by recognized authorities, technical or scientific organizations.

**APPROVED AGENCY** is an established and recognized agency regularly



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engaged in conducting tests or furnishing inspection services, when such agency has been approved by the building official.

**APPROVED FABRICATOR** is an established and qualified person, firm or corporation approved by the building official pursuant to Section 306 (g) of this code.

**AREA.** (See "Floor Area.")

**ASSEMBLY BUILDING** is a building or portion of a building used for the gathering together of 50 or more persons for such purposes as deliberation, education, instruction, worship, entertainment, amusement, drinking or dining or awaiting transportation.

**ATRIUM** is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning or other equipment, which is closed at the top and not defined as a mall. Floor levels, as used in this definition, do not include balconies within assembly occupancies nor mezzanines which comply with Section 1716.

**AUTOMATIC,** as applied to fire protection devices, is a device or system providing an emergency function without the necessity of human intervention and activated as a result of a predetermined temperature rise, rate of rise of temperature or increase in the level of combustion products such as is incorporated in an automatic sprinkler system, automatic fire door, etc.

## B

**Sec. 403. BALCONY** is that portion of the seating space of an assembly room, the lowest part of which is raised 4 feet or more above the level of the main floor and shall include the area providing access to the seating area or serving only as a foyer.

**BALCONY, EXTERIOR EXIT.** See Section 3301 (b).

**BASEMENT** is any floor level below the first story in a building, except that a floor level in a building having only one floor level shall be classified as a basement unless such floor level qualifies as a first story as defined herein.

**BOILER, HIGH PRESSURE,** is a boiler furnishing steam at pressures in excess of 15 pounds per square inch or hot water at temperatures in excess of 250°F., or at pressures in excess of 160 pounds per square inch.

**BOILER, LOW-PRESSURE HOT WATER AND LOW-PRESSURE STEAM,** is a boiler furnishing hot water at pressures not exceeding 160 pounds per square inch and at temperatures not more than 250°F., or steam at pressures not more than 15 pounds per square inch.

**BOILER ROOM** is any room containing a steam or hot-water boiler.

**BUILDING** is any structure used or intended for supporting or sheltering any use or occupancy.

**BUILDING, EXISTING,** is a building erected prior to the adoption of this code, or one for which a legal building permit has been issued.

**BUILDING OFFICIAL** is the officer or other designated authority charged



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with the administration and enforcement of this code, or his duly authorized representative.

## C

**Sec. 404. CAST STONE** is a precast building stone manufactured from portland cement concrete and used as a trim, veneer or facing on or in buildings or structures.

**CENTRAL HEATING PLANT** is environmental heating equipment which directly utilizes fuel to generate heat in a medium for distribution by means of ducts or pipes to areas other than the room or space in which the equipment is located.

**CHIEF OF THE FIRE DEPARTMENT** is the head of the fire department or his regularly authorized deputy.

**COMBUSTIBLE LIQUID.** See Fire Code.

**CONDOMINIUM, RESIDENTIAL.** See "Apartment House."

**CONTROL AREA** is a space bounded by not less than a one-hour fire-resistive occupancy separation within which the exempted amounts of hazardous materials may be stored, dispensed, handled or used.

**CORROSIVE** is a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. A chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described in the U.S. Department of Transportation in Appendix A to CFR 49 Part 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces.

**COURT** is a space, open and unobstructed to the sky, located at or above grade level on a lot and bounded on three or more sides by walls of a building.

## D

**Sec. 405. DANGEROUS BUILDINGS CODE** is the Uniform Code for the Abatement of Dangerous Buildings promulgated by the International Conference of Building Officials, as adopted by this jurisdiction.

**DISPENSING** is the pouring or transferring of any material from a container, tank or similar vessel, whereby vapors, dusts, fumes, mists or gases may be liberated to the atmosphere.

**DISPERSAL AREA, SAFE.** See Section 3323 (b).

**DORMITORY** is a room occupied by more than two guests.

**DWELLING** is any building or portion thereof which contains not more than two dwelling units.

**DWELLING UNIT** is any building or portion thereof which contains living facilities, including provisions for sleeping, eating, cooking and sanitation, as required by this code, for not more than one family.



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## E

**Sec. 406. EFFICIENCY DWELLING UNIT** is a dwelling unit containing only one habitable room.

**ELECTRICAL CODE** is the National Electrical Code promulgated by the National Fire Protection Association, as adopted by this jurisdiction.

**ELEVATOR CODE** is the safety code for elevators, dumbwaiters, escalators and moving walks as adopted by this jurisdiction (see Appendix Chapter 51).

**EMERGENCY CONTROL STATION** is an approved location on the premises of a Group H, Division 6 Occupancy where signals from emergency equipment are received and which is continually staffed by trained personnel.

**EXISTING BUILDINGS.** (See "Building, Existing.")

**EXIT.** See Section 3301 (b).

**EXIT COURT.** See Section 3301 (b).

**EXIT PASSAGEWAY.** See Section 3301 (b).

## F

**Sec. 407. FABRICATION AREA (fab area)** is an area within a Group H, Division 6 Occupancy in which there are processes involving hazardous production materials and may include ancillary rooms or areas such as dressing rooms and offices that are directly related to the fab area processes.

**FAMILY** is an individual or two or more persons related by blood or marriage or a group of not more than five persons (excluding servants) who need not be related by blood or marriage living together in a dwelling unit.

**FIRE ASSEMBLY.** See Section 4306 (b).

**FIRE CODE** is the Uniform Fire Code promulgated jointly by the Western Fire Chiefs Association and the International Conference of Building Officials, as adopted by this jurisdiction.

**FIRE RESISTANCE** or **FIRE-RESISTIVE CONSTRUCTION** is construction to resist the spread of fire, details of which are specified in this code.

**FIRE-RETARDANT-TREATED WOOD** is any wood product impregnated with chemicals by a pressure process or other means during manufacture, and which, when tested in accordance with U.B.C. Standard No. 42-1 for a period of 30 minutes, shall have a flame spread of not over 25 and show no evidence of progressive combustion. In addition, the flame front shall not progress more than 10½ feet beyond the center line of the burner at any time during the test. Materials which may be exposed to the weather shall pass the accelerated weathering test and be identified as Exterior type, in accordance with U.B.C. Standard No. 25-28. Where material is not directly exposed to rainfall but exposed to high humidity conditions, it shall be subjected to the hygroscopic test and identified as Interior Type A in accordance with U.B.C. Standard No. 25-28.

All materials shall bear identification showing the fire performance rating thereof. Such identifications shall be issued by an approved agency having a service for inspection of materials at the factory.



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**FLAMMABLE LIQUID.** See Fire Code.

**FLOOR AREA** is the area included within the surrounding exterior walls of a building or portion thereof, exclusive of vent shafts and courts. The floor area of a building, or portion thereof, not provided with surrounding exterior walls shall be the usable area under the horizontal projection of the roof or floor above.

**FOAM PLASTIC INSULATION** is a plastic which is intentionally expanded by the use of a foaming agent to produce a reduced density plastic containing voids consisting of hollow spheres or interconnected cells distributed throughout the plastic for thermal insulating purposes and which has a density less than 20 pounds per cubic foot.

**FOOTING** is that portion of the foundation of a structure which spreads and transmits loads directly to the soil or the piles.

**FRONT OF LOT** is the front boundary line of a lot bordering on the street and, in the case of a corner lot, may be either frontage.

## G

**Sec. 408. GARAGE** is a building or portion thereof in which a motor vehicle containing flammable or combustible liquids or gas in its tank is stored, repaired or kept.

**GARAGE, PRIVATE,** is a building or a portion of a building, not more than 1000 square feet in area, in which only motor vehicles used by the tenants of the building or buildings on the premises are stored or kept. (See Section 1101.)

**GARAGE, PUBLIC,** is any garage other than a private garage.

**GRADE (Adjacent Ground Elevation)** is the lowest point of elevation of the finished surface of the ground, paving or sidewalk within the area between the building and the property line or, when the property line is more than 5 feet from the building, between the building and a line 5 feet from the building.

**GRADE (Lumber)** is the classification of lumber in regard to strength and utility.

**GUARDRAIL** is a system of building components located near the open sides of elevated walking surfaces for the purpose of minimizing the possibility of an accidental fall from the walking surface to the lower level.

**GUEST** is any person hiring or occupying a room for living or sleeping purposes.

**GUEST ROOM** is any room or rooms used or intended to be used by a guest for sleeping purposes. Every 100 square feet of superficial floor area in a dormitory shall be considered to be a guest room.

## H

**Sec. 409. HABITABLE SPACE (ROOM)** is space in a structure for living, sleeping, eating or cooking. Bathrooms, toilet compartments, closets, halls, storage or utility space, and similar areas, are not considered habitable space.



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**HANDLING** is the deliberate transport of materials by any means to a point of storage or use.

**HAZARDOUS PRODUCTION MATERIAL (HPM)** is a solid, liquid or gas that has a degree of hazard rating in health, flammability or reactivity of 3 or 4 as ranked by U.F.C. Standard No. 79-3 and which is used directly in research, laboratory or production processes which have, as their end product, materials which are not hazardous.

**HEALTH HAZARD** is a classification of a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed persons. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes.

**HEIGHT OF BUILDING** is the vertical distance above a reference datum measured to the highest point of the coping of a flat roof or to the deck line of a mansard roof or to the average height of the highest gable of a pitched or hipped roof. The reference datum shall be selected by either of the following, whichever yields a greater height of building:

1. The elevation of the highest adjoining sidewalk or ground surface within a 5-foot horizontal distance of the exterior wall of the building when such sidewalk or ground surface is not more than 10 feet above lowest grade.
2. An elevation 10 feet higher than the lowest grade when the sidewalk or ground surface described in Item 1 above is more than 10 feet above lowest grade.

The height of a stepped or terraced building is the maximum height of any segment of the building.

**HELIPORT** is an area of land or water or a structural surface which is used, or intended for use, for the landing and takeoff of helicopters, and any appurtenant areas which are used, or intended for use, for heliport buildings and other heliport facilities.

**HELISTOP** is the same as a heliport, except that no refueling, maintenance, repairs or storage of helicopters is permitted.

**HIGHLY TOXIC MATERIAL** is a material which produces a lethal dose or a lethal concentration falls within any of the following categories:

1. A chemical that has a median lethal dose ($LD_{50}$) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

2. A chemical that has a median lethal dose ($LD_{50}$) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.



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3. A chemical that has a median lethal concentration ($LC_{50}$) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Mixtures of these materials with ordinary materials, such as water, may not warrant a classification of highly toxic. While this system is basically simple in application, any hazard evaluation which is required for the precise categorization of this type of material shall be performed by experienced, technically competent persons.

**HORIZONTAL EXIT.** See Section 3301 (b).

**HOTEL** is any building containing six or more guest rooms intended or designed to be used, or which are used, rented or hired out to be occupied, or which are occupied for sleeping purposes by guests.

**HOT-WATER SUPPLY BOILER** is a boiler having volume exceeding 120 gallons, or a heat input exceeding 200,000 Btu/h, or an operating temperature exceeding 210°F. that provides hot water to be used externally to itself.

**HPM STORAGE ROOM** is a room used for the storage or dispensing of hazardous production material (HPM) and which is classified as Group H, Divisions 2, 3 or 7 Occupancies.

I

**Sec. 410. IRRITANT** is a chemical which is not corrosive but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41 for four hours' exposure or by other appropriate techniques, it results in an empirical score of 5 or more. A chemical is an eye irritant if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques.

J

**Sec. 411. JURISDICTION,** as used in this code, is any political subdivision which adopts this code for administrative regulations within its sphere of authority.

K

**Sec. 412.** No definitions.

L

**Sec. 413. LINTEL** is a structural member placed over an opening or a recess in a wall and supporting construction above.

**LIQUID** is any material which has a fluidity greater than that of 300 penetration asphalt when tested in accordance with the Uniform Fire Code Standards.



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When not otherwise identified, the term "liquid" is both flammable and combustible liquids.

**LIQUID STORAGE ROOM** is a Group H, Division 3 Occupancy in which the quantities of flammable or combustible liquids do not exceed the limits set forth in the Fire Code.

**LIQUID STORAGE WAREHOUSE** is a Group H, Division 3 Occupancy used for the storage of flammable or combustible liquids in an unopened condition only in unlimited quantities.

**LISTED** and **LISTING** are terms referring to equipment and materials which are shown in a list published by an approved testing agency, qualified and equipped for experimental testing and maintaining an adequate periodic inspection of current productions and whose listing states that the equipment complies with recognized safety standards.

**LOADS.** See Chapter 23.

**LODGING HOUSE** is any building or portion thereof containing not more than five guest rooms where rent is paid in money, goods, labor or otherwise.

## M

**Sec. 414. MARQUEE** is a permanent roofed structure attached to and supported by the building and projecting over public property. Marquees are regulated in Chapter 45.

**MASONRY** is that form of construction composed of stone, brick, concrete, gypsum, hollow clay tile, concrete block or tile or other similar building units or materials or combination of these materials laid up unit by unit and set in mortar.

**MASONRY, SOLID,** is masonry of solid units built without hollow spaces.

**MECHANICAL CODE** is the Uniform Mechanical Code promulgated jointly by the International Conference of Building Officials and the International Association of Plumbing and Mechanical Officials, as adopted by this jurisdiction.

**MEZZANINE** or **MEZZANINE FLOOR** is an intermediate floor placed within a room.

**MOTEL** shall mean hotel as defined in this code.

## N

**Sec. 415. NONCOMBUSTIBLE** as applied to building construction material means a material which, in the form in which it is used, is either one of the following:

1. Material of which no part will ignite and burn when subjected to fire. Any material conforming to U.B.C. Standard No. 4-1 shall be considered noncombustible within the meaning of this section.
2. Material having a structural base of noncombustible material as defined in Item No. 1 above, with a surfacing material not over 1/8 inch thick which has a flame-spread rating of 50 or less.



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"Noncombustible" does not apply to surface finish materials. Material required to be noncombustible for reduced clearances to flues, heating appliances or other sources of high temperature shall refer to material conforming to Item No. 1. No material shall be classed as noncombustible which is subject to increase in combustibility or flame-spread rating, beyond the limits herein established, through the effects of age, moisture or other atmospheric condition.

. . Flame-spread rating as used herein refers to rating obtained according to tests conducted as specified in U.B.C. Standard No. 42-1.

O

**Sec. 416. OCCUPANCY** is the purpose for which a building, or part thereof, is used or intended to be used.

**ORIEL WINDOW** is a window which projects from the main line of an enclosing wall of a building and is carried on brackets or corbels.

**OWNER** is any person, agent, firm or corporation having a legal or equitable interest in the property.

P

**Sec. 417. PANIC HARDWARE.** See Section 3301,(b).

**PEDESTRIAN WALKWAY** is a walkway used exclusively as a pedestrian trafficway.

**PERMIT** is an official document or certificate issued by the building official authorizing performance of a specified activity.

**PERSON** is a natural person, his heirs, executors, administrators or assigns, and also includes a firm, partnership or corporation, its or their successors or assigns, or the agent of any of the aforesaid.

**PLASTIC MATERIALS, APPROVED,** other than foam plastics regulated under Sections 1705 (c) and 1712, are those having a self-ignition temperature 650°F or greater when tested in accordance with U.B.C. Standard No. 52-3 and a smoke-density rating not greater than 450 when tested in accordance with U.B.C. Standard No. 42-1, in the way intended for use, or a smoke-density rating no greater than 75 when tested in the thickness intended for use by U.B.C. Standard No. 52-2. Approved plastics shall be classified as either CC1 or CC2, in accordance with U.B.C. Standard No. 52-4.

**PLATFORM.** See Chapter 39.

**PLUMBING CODE** is the Uniform Plumbing Code promulgated by the International Association of Plumbing and Mechanical Officials as adopted by this jurisdiction.

**PUBLIC WAY.** See Section 3301 (b).

Q

**Sec. 418.** No definitions.



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R

**Sec. 419. REPAIR** is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance.

S

**Sec. 420. SENSITIZER** is a chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

**SERVICE CORRIDOR** is a fully enclosed passage used for transporting HPM and for purposes other than required exiting.

**SHAFT** is a vertical opening through a building for elevators, dumbwaiters, mechanical equipment or similar purposes.

**SHALL,** as used in this code, is mandatory.

**SMOKE DETECTOR** is an approved device that senses visible or invisible particles of combustion. The detector shall bear a label or other identification issued by an approved testing agency having a service for inspection of materials and workmanship at the factory during fabrication and assembly.

**STAGE** See Chapter 39.

**STORY** is that portion of a building included between the upper surface of any floor and the upper surface of the floor next above, except that the topmost story shall be that portion of a building included between the upper surface of the topmost floor and the ceiling or roof above. If the finished floor level directly above a usable or unused under-floor space is more than 6 feet above grade as defined herein for more than 50 percent of the total perimeter or is more than 12 feet above grade as defined herein at any point, such usable or unused under-floor space shall be considered as a story.

**STORY, FIRST,** is the lowest story in a building which qualifies as a story, as defined herein, except that a floor level in a building having only one floor level shall be classified as a first story, provided such floor level is not more than 4 feet below grade, as defined herein, for more than 50 percent of the total perimeter, or not more than 8 feet below grade, as defined herein, at any point.

**STREET** is any thoroughfare or public way not less than 16 feet in width which has been dedicated or deeded to the public for public use.

**STRUCTURE** is that which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner.

T

**Sec. 421.** No definitions.

U

**Sec. 422. U.B.C. STANDARDS** is the Uniform Building Code Standards



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promulgated by the International Conference of Building Officials, as adopted by this jurisdiction. (See Chapter 60.)

**USE with reference to flammable or combustible liquids** is the placing in action or service flammable or combustible liquids whereby flammable vapors may be liberated to the atmosphere.

**USE with reference to hazardous materials other than flammable or combustible liquids** is the placing in action or making available for service by opening or connecting any container utilized for confinement of material whether a solid, liquid or gas.

## V

**Sec. 423. VALUE or VALUATION** of a building shall be the estimated cost to replace the building and structure in kind, based on current replacement costs, as determined in Section 304 (a).

**VENEER.** See Section 3002.

## W

**Sec. 424. WALLS** shall be defined as follows:

**Bearing Wall** is any wall meeting either of the following classifications:

1. Any metal or wood stud wall which supports more than 100 pounds per lineal foot of superimposed load.
2. Any masonry or concrete wall which supports more than 200 pounds per lineal foot superimposed load, or any such wall supporting its own weight for more than one story.

**Exterior Wall** is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane.

**Faced Wall** is a wall in which the masonry facing and backing are so bonded as to exert a common action under load.

**Nonbearing Wall** is any wall that is not a bearing wall.

**Parapet Wall** is that part of any wall entirely above the roof line.

**Retaining Wall** is a wall designed to resist the lateral displacement of soil or other materials.

**WATER HEATER** is an appliance designed primarily to supply hot water and is equipped with automatic controls limiting water temperature to a maximum of 210°F.

**WEATHER-EXPOSED SURFACES** are all surfaces of walls, ceilings, floors, roofs, soffits and similar surfaces exposed to the weather, excepting the following:

1. Ceilings and roof soffits enclosed by walls or by beams which extend a minimum of 12 inches below such ceiling or roof soffits.
2. Walls or portions of walls within an unenclosed roof area, when located a



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horizontal distance from an exterior opening equal to twice the height of the opening.

3. Ceiling and roof soffits beyond a horizontal distance of 10 feet from the outer edge of the ceiling or roof soffits.

## X

**Sec. 425.** No definitions.

## Y

**Sec. 426. YARD** is an open, unoccupied space, other than a court, unobstructed from the ground to the sky, except where specifically provided by this code, on the lot on which a building is situated.

## Z

**Sec. 427.** No definitions.



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# *Part III*

# REQUIREMENTS BASED ON OCCUPANCY

## Chapter 5

## CLASSIFICATION OF ALL BUILDINGS BY USE OR OCCUPANCY AND GENERAL REQUIREMENTS FOR ALL OCCUPANCIES

### Occupancy Classified

**Sec. 501.** Every building, whether existing or hereafter erected, shall be classified by the building official, according to its use or the character of its occupancy, as a building of Group A, B, E, H, I, M or R as defined in Chapters 6, 7, 8, 9, 10, 11 and 12. (See Table No. 5-A.)

Any occupancy not mentioned specifically or about which there is any question shall be classified by the building official and included in the group which its use most nearly resembles, based on the existing or proposed life and fire hazard.

### Change In Use

**Sec. 502.** No change shall be made in the character of occupancies or use of any building which would place the building in a different division of the same group of occupancy or in a different group of occupancies, unless such building is made to comply with the requirements of this code for such division or group of occupancy.

**EXCEPTION:** The character of the occupancy of existing buildings may be changed subject to the approval of the building official, and the building may be occupied for purposes in other groups without conforming to all the requirements of this code for those groups, provided the new or proposed use is less hazardous, based on life and fire risk, than the existing use.

No change in the character of occupancy of a building shall be made without a Certificate of Occupancy, as required in Section 307 of this code. The building official may issue a Certificate of Occupancy pursuant to the intent of the above exception without certifying that the building complies with all provisions of this code.

### Mixed Occupancy

**Sec. 503.** (a) **General.** When a building is used for more than one occupancy purpose, each part of the building comprising a distinct "Occupancy," as described in Chapters 5 through 12, shall be separated from any other occupancy as specified in Section 503 (d).

**EXCEPTIONS:** 1. Where an approved spray booth constructed in accordance with the Fire Code is installed, such booth need not be separated from other Group H Occupancies or from Group B Occupancies.



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2. The following occupancies need not be separated from the uses to which they are accessory:

A. Assembly rooms having a floor area of not over 750 square feet.

B. Administrative and clerical offices and similar rooms which do not exceed 25 percent of the floor area of the major use when not related to Group H, Division 2 and Group H, Division 3 Occupancies.

C. Gift shops, administrative offices and similar rooms in Group R, Division 1 Occupancies not exceeding 10 percent of the floor area of the major use.

D. The kitchen serving the dining area of which it is a part.

3. An occupancy separation need not be provided between a Group R, Division 3 Occupancy and a carport having no enclosed uses above, provided the carport is entirely open on two or more sides.

4. A Group B, Division 1 Occupancy used exclusively for the parking or storage of private or pleasure-type motor vehicles need not be separated from a Group B, Division 3 Occupancy open parking garage as defined in Section 709.

When a building houses more than one occupancy, each portion of the building shall conform to the requirements for the occupancy housed therein. The area of the building shall be such that the sum of the ratios of the actual area for each separate occupancy divided by the total allowable area for each separate occupancy shall not exceed one.

Where minor accessory uses do not occupy more than 10 percent of the area of any floor of a building, nor more than the basic area permitted in the occupancy by Table No. 5-C for such minor use, for the purpose of determining allowable area the major use of the building shall determine the occupancy classification, provided the uses are separated as specified in Section 503 (d).

An occupancy shall not be located above the story or height set forth in Table No. 5-D, except as provided in Seetion 507. When a mixed occupancy building contains a Group H, Division 6 Occupancy, the portion containing the Group H, Division 6 Occupancy shall not exceed three stories nor 55 feet in height.

(b) **Forms of Occupancy Separations.** Occupancy separations shall be vertical or horizontal or both or, when necessary, of such other form as may be required to afford a complete separation between the various occupancy divisions in the building.

Where the occupancy separation is horizontal, structural members supporting the separation shall be protected by equivalent fire-resistive construction.

(c) **Types of Occupancy Separations.** Occupancy separations shall be classed as "four-hour fire-resistive," "three-hour fire-resistive," "two-hour fire-resistive," and "one-hour fire-resistive." (See U.B.C. Standard No. 43-7 for fire dampers in air ducts piercing occupancy separations.)

1. A "four-hour fire-resistive occupancy separation" shall have no openings therein and shall be of not less than four-hour fire-resistive construction.

2. A "three-hour fire-resistive occupancy separation" shall be of not less than three-hour fire-resistive construction. All openings in walls forming such separation shall be protected by a fire assembly having a three-hour fire-protection rating. The total width of all openings in any three-hour fire-resistive occupancy separation wall in any one story shall not exceed 25 percent of the length of the



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wall in that story and no single opening shall have an area greater than 120 square feet.

All openings in floors forming a "three-hour fire-resistive occupancy separation" shall be protected by vertical enclosures extending above and below such openings. The walls of such vertical enclosures shall be of not less than two-hour fire-resistive construction and all openings therein shall be protected by a fire assembly having a one and one-half-hour fire-protection rating.

3. A "two-hour fire-resistive occupancy separation" shall be of not less than two-hour fire-resistive construction. All openings in such separation shall be protected by a fire assembly having a one and one-half-hour fire-protection rating.

4. A "one-hour fire-resistive occupaney separation" shall be of not less than one-hour fire-resistive construction. All openings in such separation shall be protected by a fire assembly having a one-hour fire-protection rating.

(d) **Fire Ratings for Occupancy Separations.** Occupancy separations shall be provided between the various groups and divisions of occupancies as set forth in Table No. 5-B.

**EXCEPTIONS:** 1. A three-hour occupancy separation may be used between a Group A, Division 1 or a Group I Occupancy and a Group B, Division 1 Occupancy used exclusively for the parking or storage of private or pleasure-type motor vehicles and provided no repair or fueling is done. A two-hour occupancy separation may be used between a Group A, Division 2, 2.1, 3 or 4 or E Occupancy and a Group B, Division 1 Occupancy that is used exclusively for the parking or storage of private or pleasure-type motor vehicles and provided no repair or fueling is done.

2. Unless required by Section 702 (a), the three-hour occupancy separation between a Group R, Division 1 Occupancy and a Group B, Division 1 Occupancy used only for the parking or storage of private or pleasure-type motor vehicles with no repair or fueling may be reduced to two hours. Such occupancy separation may be further reduced to one hour where the area of such Group B, Division 1 Occupancy does not exceed 3000 square feet.

3. In the one-hour occupancy separation between a Group R, Division 3 and M Occupancy, the separation may be limited to the installation of materials approved for one-hour fire-resistive construction on the garage side and a self-closing, tight-fitting solid wood door 1 3/8 inches in thickness will be permitted in lieu of a one-hour fire assembly. Fire dampers need not be installed in air ducts passing through the wall, floor or ceiling separating a Group R, Division 3 Occupancy from a Group M Occupancy, provided such ducts within the Group M Occupancy are constructed of steel having a thickness not less than 0.019 inch (No. 26 galvanized sheet gauge) and have no openings into the Group M Occupancy.

## Location on Property

**Sec. 504.** (a) **General.** Buildings shall adjoin or have access to a public way or yard on not less than one side. Required yards shall be permanently maintained.

For the purpose of this section, the center line of an adjoining public way shall be considered an adjacent property line.

Eaves over required windows shall be not less than 30 inches from the side and rear property lines. For eaves, see Section 1710.



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(b) **Fire Resistance of Walls.** Exterior walls shall have fire resistance and opening protection as set forth in Table No. 5-A, Part III, and in accordance with such additional provisions as are set forth in Part IV and Part VII. Distance shall be measured at right angles from the property line. The above provisions shall not apply to walls at right angles to the property line.

Projections beyond the exterior wall shall not extend beyond:

1. A point one-third the distance to the property line from an exterior wall; or
2. A point one-third the distance to the property line from an assumed vertical plane located where fire-resistive protection of openings is first required due to location on property;

whichever is the least restrictive.

When openings in exterior walls are required to be protected due to distance from property line, the sum of the area of such openings shall not exceed 50 percent of the total area of the wall in each story.

(c) **Buildings on Same Property and Buildings Containing Courts.** For the purposes of determining the required wall and opening protection and roof-covering requirements, buildings on the same property and court walls of buildings over one story in height shall be assumed to have a property line between them.

**EXCEPTION:** In court walls where opening protection is required such protection may be omitted, provided (1) not more than two levels open into the court, (2) the aggregate area of the building including the court is within the allowable area and (3) the building is not classified as a Group I Occupancy.

When a new building is to be erected on the same property as an existing building, the location of the assumed property line with relation to the existing building shall be such that the exterior wall and opening protection of the existing building meet the criteria as set forth in Table No. 5-A and Part IV.

**EXCEPTION:** Two or more buildings on the same property may be considered as portions of one building if the aggregate area of such buildings is within the limits specified in Section 505 for a single building.

When the buildings so considered house different occupancies or are of different types of construction, the area shall be that allowed for the most restricted occupancy or construction.

## Allowable Floor Areas

**Sec. 505.** (a) **One-story Areas.** The area of a one-story building shall not exceed the limits set forth in Table No. 5-C except as provided in Section 506. For mixed occupancies, see Section 503 (a).

(b) **Areas of Buildings Over One Story.** The total combined floor area for multistory buildings may be twice that permitted by Table No. 5-C for one-story buildings, and the floor area of any single story shall not exceed that permitted for a one-story building. For mixed occupancies, see Section 503 (a).

(c) **Mezzanines.** Unless considered as a separate story, the floor area of all mezzanines shall be included in calculating the allowable floor area of the stories in which the mezzanines are located.



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(d) **Basements.** A basement need not be included in the total allowable area, provided such basement does not exceed the area permitted for a one-story building.

(e) **Area Separation Walls.** Each portion of a building separated by one or more area separation walls may be considered a separate building, provided the area separation walls meet the following requirements:

1. Area separation walls shall be not less than four-hour fire-resistive construction in Types I, II-F.R., III and IV buildings and two-hour fire-resistive construction in Types II One-hour, II-N or V buildings. The total width of all openings in such walls shall not exceed 25 percent of the length of the wall in each story. All openings shall be protected by a fire assembly having a three-hour fire-protection rating in four-hour fire-resistive walls and one and one-half-hour fire-protection rating in two-hour fire-resistive walls.

2. Area separation walls shall extend to the outer edges of horizontal projecting elements such as balconies, roof overhangs, canopies, marquees or architectural projections.

**EXCEPTION:** When horizontal projecting elements do not contain concealed spaces, the area separation wall may terminate at the exterior wall.

When the horizontal projecting elements contain concealed spaces, the area separation wall need only extend through the concealed space to the outer edges of the projecting elements.

The exterior walls and the projecting elements above shall be of not less than one-hour fire-resistive construction for a distance not less than the depth of the projecting elements on both sides of the area separation wall. Openings within such widths shall be protected by fire assemblies having a fire-protection rating of not less than three-fourths hour.

3. Area separation walls shall extend from the foundation to a point at least 30 inches above the roof.

**EXCEPTIONS:** 1. Area separation walls may terminate at the underside of the roof sheathing, deck or slab, provided the roof-ceiling assembly is of at least two-hour fire-resistive construction.

2. Two-hour area separation walls may terminate at the underside of the roof sheathing, deck or slab, provided:

A. Where the roof-ceiling framing elements are parallel to the walls, such framing and elements supporting such framing shall be of not less than one-hour fire-resistive construction for a width of not less than 5 feet on each side of the wall.

B. Where roof-ceiling framing elements are perpendicular to the wall, the entire span of such framing and elements supporting such framing shall be of not less than one-hour fire-resistive construction.

C. Openings in the roof shall not be located within 5 feet of the area separation wall.

D. The entire building shall be provided with not less than a Class B roof covering as specified in Table No. 32-A or a special purpose roof complying with Section 3204 (e).

3. Two-hour area separation walls may terminate at roofs of entirely noncombustible construction.



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4. Parapets of area separation walls shall have noncombustible faces for the uppermost 18 inches, including counterflashing and coping materials.

5. Where an area separation wall separates portions of a building having different heights, such wall may terminate at a point 30 inches above the lower roof level, provided the exterior wall for a height of 10 feet above the lower roof is of one-hour fire-resistive construction with openings protected by assemblies having a three-fourths-hour fire-protection rating.

**EXCEPTION:** The area separation wall may terminate at the underside of the roof sheathing, deck or slab of the lower roof, provided:

A. Where the roof-ceiling framing elements are parallel to the wall, such framing and elements supporting such framing shall be of not less than one-hour fire-resistive construction for a width of 10 feet along the wall at the lower roof.

B. Where the lower roof-ceiling framing elements are perpendicular to the wall, the entire span of such framing and elements supporting such framing shall be of not less than one-hour fire-resistive construction.

C. Openings in the lower roof shall not be located within 10 feet of the area separation wall.

See Chapters 6 to 12 inclusive for special occupancy provisions.

## Allowable Area Increases

**Sec. 506.** (a) **General.** The floor areas specified in Section 505 may be increased by one of the following:

1. **Separation on two sides.** Where public ways or yards more than 20 feet in width extend along and adjoin two sides of the building, floor areas may be increased at a rate of 1¼ percent for each foot by which the minimum width exceeds 20 feet, but the increase shall not exceed 50 percent.

2. **Separation on three sides.** Where public ways or yards more than 20 feet in width extend along and adjoin three sides of the building, floor areas may be increased at a rate of 2½ percent for each foot by which the minimum width exceeds 20 feet, but the increase shall not exceed 100 percent.

3. **Separation on all sides.** Where public ways or yards more than 20 feet in width extend on all sides of a building and adjoin the entire perimeter, floor areas may be increased at a rate of 5 percent for each foot by which the minimum exceeds 20 feet. Such increases shall not exceed 100 percent, except that greater increases shall be permitted for the following occupancies:

A. Group B, Division 3 aircraft storage hangars not exceeding one story in height.

B. Group B, Division 4 Occupancies not exceeding two stories in height.

C. Group H, Division 5 aircraft repair hangars not exceeding one story in height. Area increases shall not exceed 500 percent for aircraft repair hangars except as provided in Section 506 (b).

(b) **Unlimited Area.** The area of any one- or two-story building of Group B and Group H, Division 5 Occupancies shall not be limited, if the building is provided with an approved automatic sprinkler system throughout, as specified in Chapter



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38, and entirely surrounded and adjoined by public ways or yards not less than 60 feet in width.

The area of a Group B, Division 4 Occupancy in a one-story Type II, Type III One-hour or Type IV building shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet in width.

(c) **Automatic Sprinkler Systems.** The areas specified in Table No. 5-C and Section 505 (b) may be tripled in one-story buildings and doubled in buildings of more than one story if the building is provided with an approved automatic sprinkler system throughout. The area increases permitted in this subsection may be compounded with that specified in paragraphs 1, 2 or 3 of Subsection (a) of this section. The increases permitted in this subsection shall not apply when automatic sprinkler systems are installed under the following provisions:

1. Section 507 for an increase in allowable number of stories.
2. Section 3802 (f) for Group H, Divisions 1, 2 and 3 Occupancies.
3. Substitution for one-hour fire-resistive construction pursuant to Section 508.
4. Section 1715, Atria.

## Maximum Height of Buildings and Increases

**Sec. 507.** The maximum height and number of stories of every building shall be dependent upon the character of the occupancy and the type of construction and shall not exceed the limits set forth in Table No. 5-D, except as provided in this section and as specified in Section 503 (a) for mixed occupancy buildings.

**EXCEPTIONS:** 1. Towers, spires and steeples erected as a part of a building and not used for habitation or storage are limited as to height only by structural design if completely of noncombustible materials, or may extend not to exceed 20 feet above the height limit in Table No. 5-D if of combustible materials.

2. The height of one-story aircraft hangars shall not be limited if the building is provided with automatic sprinkler systems throughout as specified in Chapter 38 and is entirely surrounded by public ways or yards not less in width than one and one-half times the height of the building.

The story limits set forth in Table No. 5-D may be increased by one story if the building is provided with an approved automatic sprinkler system throughout. The increase in the number of stories for automatic sprinkler systems shall not apply when the automatic sprinkler systems throughout are installed under the following provisions:

1. Section 3802 (f) for Group H, Divisions 1, 2, 3, 6 and 7 Occupancies.
2. Section 506, for an increase in allowable area.
3. Substitution for one-hour fire-resistive construction pursuant to Section 508.
4. Section 1715, Atria.
5. Section 3802 (g) for Group I, Division 1 Occupancies used for hospitals or



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nursing homes in Type II One-hour; Type III One-hour; Type IV or Type V One-hour construction.

See Chapters 6 to 12 inclusive for special occupancy provisions.

## Fire-resistive Substitution

**Sec. 508.** Where one-hour fire-resistive construction throughout is required by this code, an approved automatic sprinkler system, as specified in Chapter 38, may be substituted, provided such system is not otherwise required throughout the building.

**EXCEPTION:** Such substitution shall not waive nor reduce required fire-resistive construction for:

1. Occupancy separations [Section 503 (c)].
2. Exterior wall protection due to proximity of property lines [Section 504 (b)].
3. Area separations [Section 505 (e)].
4. Dwelling Unit Separations [Section 1202 (b)].
5. Shaft enclosures (Section 1706).
6. Corridors [Section 3305 (g) and (h)].
7. Stair enclosures (Section 3309).
8. Exit passageways [Section 3312 (a)].
9. Type of construction separation (Section 1701).
10. Atria constructed in accordance with Section 1715.

## Pedestrian Walkways

**Sec. 509.** (a) **General.** A pedestrian walkway shall be considered a building when determining the roof covering permitted by Table No. 32-A. Pedestrian walkways connecting separate buildings need not be considered as buildings and need not be considered in the determination of the allowable floor area of the connected buildings when the pedestrian walkway complies with the provisions of this section.

(b) **Construction.** Pedestrian walkways shall be constructed of noncombustible materials.

**EXCEPTIONS:** 1. Pedestrian walkways connecting buildings of Type III, IV or V construction may be constructed of one-hour fire-resistive construction or of heavy timber construction in accordance with Section 2106.

2. Pedestrian walkways located on grade having both sides open by at least 50 percent and connecting buildings of Type III, IV or V construction may be constructed with any materials allowed by this code.

(c) **Openings Between Pedestrian Walkways and Buildings.** Openings from buildings to pedestrian walkways shall conform to the requirements of Table No. 5-A and Sections 1803 (b), 1903 (b), 2003 (b), 2103 (b) and 504 (c). In addition pedestrian walkways connecting buildings shall be either provided with opening protection at connections to buildings in accordance with Section 3305 (h) or constructed with both sides of the pedestrian walkway at least 50 percent open with the open area distributed so as to prevent the accumulation of smoke and toxic gases.



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(d) **Width.** The unobstructed width of pedestrian walkways shall be not less than 44 inches. The total width of a pedestrian walkway shall not exceed 30 feet.

(e) **Maximum Length.** The length of a pedestrian walkway shall not exceed 300 feet.

**EXCEPTIONS:** 1. Pedestrian walkways that are fully sprinklered may be 400 feet in length..

2. Unenclosed walkways at grade.

(f) **Multiple Pedestrian Walkways.** The distance between any two pedestrian walkways on the same horizontal plane shall be not less than 40 feet.

(g) **Required Exits.** Pedestrian walkways at other than grade shall not be used as required exits. Pedestrian walkways at grade level used as required exits shall provide an unobstructed means of egress to a public way and shall have a minimum width in accordance with Section 3303 (b).

**EXCEPTION:** Pedestrian walkways conforming to the requirements of a horizontal exit may be used as a required exit.

(h) **Pedestrian Walkways Over Public Streets.** Pedestrian walkways over public streets shall be subject to the approval of local jurisdictions.

## Sanitation

**Sec. 510.** (a) **Water Closet Room Separation.** A room in which a water closet is located shall be separated from food preparation or storage rooms by a tight-fitting door.

(b) **Floors and Walls in Water Closet Compartment and Showers.** In other than dwelling units, toilet room floors shall have a smooth, hard, nonabsorbent surface such as portland cement, concrete, ceramic tile or other approved material which extends upward onto the walls at least 5 inches. Walls within water closet compartments and walls within 2 feet of the front and sides of urinals shall be similarly finished to a height of 4 feet and, except for structural elements, the materials used in such walls shall be of a type which is not adversely affected by moisture. See Section 4712 for other limitations.

In all occupancies, accessories such as grab bars, towel bars, paper dispensers and soap dishes, etc., provided on or within walls, shall be installed and sealed to protect structural elements from moisture.

Showers in all occupancies shall be finished as specified above to a height of not less than 70 inches above the drain inlet. Materials other than structural elements used in such walls shall be of a type which is not adversely affected by moisture. See Section 4712 for other limitations.

## Access to Toilets and Other Facilities

**Sec. 511.** (a) **Access to Water Closets.** Each water closet stool shall be located in a clear space not less than 30 inches in width and have a clear space in front of the water closet stool of not less than 24 inches.

Where toilet facilities are provided on any floor where access by the physically handicapped is required by Table No. 33-A, at least one such facility for each sex



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or a separate facility usable by either sex shall comply with the requirement of this section. Except in dwelling units and guest rooms, such facilities must be available to all occupants and both sexes. All doorways leading to such toilet rooms shall have a clear and unobstructed width of not less than 32 inches. Each such toilet room shall have the following:

1. A clear space of not less than 44 inches on each side of doors providing access to toilet rooms. This distance shall be measured at right angles to the face of the door when in the closed position. Not more than one door may encroach into the 44-inch space.
2. Except in dwelling units and guest rooms, a clear space within the toilet room of sufficient size to inscribe a circle with a diameter not less than 60 inches. Doors in any position may encroach into this space by not more than 12 inches.
3. A clear space not less than 42 inches wide and 48 inches long in front of at least one water closet stool for the use of the handicapped. When such water closet stool is within a compartment, entry to the compartment shall have a clear width of 32 inches when located at the end and a clear width of 34 inches when located at the side. A door, if provided, shall not encroach into the required space in front of the water closet. Except for door swing, a clear unobstructed access not less than 48 inches in width shall be provided to toilet compartments designed for use by the handicapped.
4. The height of water closets shall be 17 to 19 inches measured to the top of the seat. Seats shall not be sprung to return to a lifted position.
5. Grab bars near each side or one side and the back of the toilet stool securely attached at a height to the top of bar of 33 inches to 36 inches above and parallel to the floor. Grab bars at the side shall be 42 inches long with the front end positioned 24 inches in front of the water closet stool. Grab bars at the back shall be not less than 24 inches long for room installations and 36 inches long where the water closet is installed in a stall. Grab bars shall have an outside diameter of not less than 1 1/4 inch nor more than 1 1/2 inches and shall provide a clearance of 1 1/2 inches between the grab bar and adjacent surface. Grab bars need not be provided in Group R, Division 1 apartment houses.
6. When it can be established that the facilities are usable by a person in a wheelchair, dimensions other than those above shall be acceptable.

(b) **Access to Lavatories, Mirrors and Towel Fixtures.** In other than Group R, Division 3; Group M; Group R, Division 1 apartment houses and Group B, Divisions 2 and 4 storage occupancies, toilet room facilities shall be as follows:

1. Except for the projection of bowls and waste piping, a clear unobstructed space 30 inches in width, 29 inches in height and 17 inches in depth shall be provided under at least one lavatory.
2. Where mirrors are provided, at least one shall be installed so that the bottom of the mirror is within 40 inches of the floor.
3. Where towel and disposal fixtures are provided, they shall be accessible to



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the physically handicapped and at least one shall be within 40 inches of the floor.

(c) **Water Fountains.** Where water fountains are provided, at least one shall have a spout within 33 inches of the floor and shall have up-front, hand-operated controls. When fountains are located in an alcove, the alcove shall be not less than 32 inches in width.

(d) **Telephones.** Where public telephones are provided, at least one shall be installed so that the handset, dial and coin receiver are within 54 inches of the floor. Unobstructed access within 12 inches of the telephone shall be provided. Such access shall be not less than 30 inches in width.

## Compressed Gases

**Sec. 512.** The storage and handling of compressed gases shall comply with the Fire Code.

## Premises Identification

**Sec. 513.** Approved numbers or addresses shall be provided for all new buildings in such a position as to be plainly visible and legible from the street or road fronting the property.



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## TABLE NO. 5-A—WALL AND OPENING PROTECTION OF OCCUPANCIES BASED ON LOCATION ON PROPERTY

**TYPES II ONE-HOUR, II-N AND V CONSTRUCTION: For exterior wall and opening protection of Typea II One-hour, II-N and V buildings, see table below and Sections 504, 709, 1903 and 2203.**

**This table does not apply to Types I, II-F.R., III and IV construction, see Sectiona 1803, 1903, 2003 and 2103.**

| GROUP | DESCRIPTION OF OCCUPANCY | FIRE RESISTANCE OF EXTERIOR WALLS | OPENINGS IN EXTERIOR WALLS |
|---|---|---|---|
| A<br>See also Section 602 | 1—Any assembly building or portion of a building with a legitimate stage and an occupant load of 1000 or more. | Not applicable (See Sections 602 and 603) | |
| | 2—Any building or portion of a building having an assembly room with an occupant load of less than 1000 and a legitimate stage<br>2.1—Any building or portion of a building having an assembly room with an occupant load of 300 or more without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B, Division 2 Occupancy | 2 hours less than 10 feet, 1 hour less than 40 feet | Not permitted less than 5 feet<br>Protected less than 10 feet |
| | 3—Any building or portion of a building having an assembly room with an occupant load of less than 300 without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B, Division 2 Occupancy | 2 hours less than 5 feet, 1 hour less than 40 feet | Not permitted less than 5 feet<br>Protected less than 10 feet |
| | 4—Stadiums, reviewing stands and amusement park structures not included within other Group A Occupancies | 1 hour less than 10 feet | Protected less than 10 feet |
| B<br>See also Section 702 | 1—Gasoline service stations, garages where no repair work is done except exchange of parts and maintenance requiring no open flame, welding, or use of Class I, II or III-A liquids<br>2—Drinking and dining establishments having an occupant load of less than 50, wholesale and retail stores, office buildings, printing plants, municipal police and fire stations, factories and workshops using material not highly flammable or combustible, storage and sales rooms for combustible goods, paint stores without bulk handling<br>Buildings or portions of buildings having rooms used for educational purposes, beyond the 12th grade, with less than 50 occupants in any room | 1 hour less than 20 feet. | Not permitted less than 5 feet<br>Protected less than 10 feet |

*(Continued)*





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## TABLE NO. 5-A—Continued
## TYPES II ONE-HOUR, II-N AND V ONLY

| GROUP | DESCRIPTION OF OCCUPANCY | FIRE RESISTANCE OF EXTERIOR WALLS | OPENINGS IN EXTERIOR WALLS |
|---|---|---|---|
| B (Cont.) | 3—Aircraft hangars where no repair work is done except exchange of parts and maintenance requiring no open flame, welding, or the use of Class I or II liquids<br>Open parking garages (For requirements, See Section 709.)<br>Helistops | 1 hour less than 20 feet | Not permitted less than 5 feet<br>Protected less than 20 feet |
| | 4—Ice plants, power plants, pumping plants, cold storage and creameries<br>Factories and workshops using noncombustible and nonexplosive materials<br>Storage and sales rooms of noncombustible and nonexplosive materials that are not packaged or crated in or supported by combustible material | 1 hour less than 5 feet | Not permitted less than 5 feet |
| E<br>See also Section 802 | 1—Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or four hours in any one day<br>2—Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or four hours in any one day<br>3—Any building used for day-care purposes for more than six children | 2 hours less than 5 feet, 1 hour less than 10 feet[1] | Not permitted less than 5 feet<br>Protected less than 10 feet[1] |
| H | See Chapter 9 | | |

[1]Group E, Divisions 2 and 3 Occupancies having an occupant load of not more than 20 may have exterior wall and opening protection as required for Group R, Division 3 Occupancies.



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| | | | |
|---|---|---|---|
| I<br>See also Section 1002 | 1—Nurseries for the full-time care of children under the age of six (each accommodating more than five persons)<br>Hospitals, sanitariums, nursing homes with nonambulatory patients and similar buildings (each accommodating more than five persons) | 2 hours less than 5 feet, 1 hour elsewhere | Not permitted less than 5 feet<br>Protected less than 10 feet |
| | 2—Nursing homes for ambulatory patients, homes for children six years of age or over (each accommodating more than five persons) | 1 hour | |
| | 3—Mental hospitals, mental sanitariums, jails, prisons, reformatories and buildings where personal liberties of inmates are similarly restrained | 2 hours less than 5 feet, 1 hour elsewhere | Not permitted less than 5 feet, protected less than 10 feet |
| M[2] | 1—Private garages, carports, sheds and agricultural buildings (See also Section 1101, Division 1.) | 1 hour less than 3 feet (or may be protected on the exterior with materials approved for 1-hour fire-resistive construction) | Not permitted less than 3 feet |
| | 2—Fences over 6 feet high, tanks and towers | Not regulated for fire resistance | |
| R<br>See also Section 1202 | 1—Hotels and apartment houses<br>Convents and monasteries (each accommodating more than 10 persons) | 1 hour less than 5 feet | Not permitted less than 5 feet |
| | 3—Dwellings and lodging houses | 1 hour less than 3 feet | Not permitted less than 3 feet |

[2]For agricultural buildings, see Appendix Chapter 11.

**NOTES:** (1) See Section 504 for types of walls affected and requirements covering percentage of openings permitted in exterior walls.
(2) For additional restrictions, see chapters under Occupancy and Types of Construction.
(3) For walls facing yards and public ways, see Part IV.
(4) Openings shall be protected by a fire assembly having a three-fourths-hour fire-protection rating.





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## TABLE NO. 5-B—REQUIRED SEPARATION IN BUILDINGS OF MIXED OCCUPANCY
(In Hours)

| | A-1 | A-2 | A-2.1 | A-3 | A-4 | B-1 | B-2 | B-3 | B-4 | E | H-1 | H-2 | H-3 | H-4-5 | H-6-7[1] | I | M[2] | R-1 | R-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | | N | N | N | N | 4 | 3 | 3 | 3 | N | Not Permitted in Mixed Occupancies. See Chapter 9. | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 1 |
| A-2 | N | | N | N | N | 3 | 1 | 1 | 1 | N | | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 1 |
| A-2.1 | N | N | | N | N | 3 | 1 | 1 | 1 | N | | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 1 |
| A-3 | N | N | N | | N | 3 | N | 1 | N | N | | 4 | 4 | 4 | 3 | 3 | 1 | 1 | 1 |
| A-4 | N | N | N | N | | 3 | 1 | 1 | 1 | N | | 4 | 4 | 4 | 4 | 3 | 1 | 1 | 1 |
| B-1 | 4 | 3 | 3 | 3 | 3 | | 1 | 1 | 1 | 3 | | 2 | 1 | 1 | 1 | 4 | 1 | 3[3] | 1 |
| B-2 | 3 | 1 | 1 | N | 1 | 1 | | 1 | 1 | 1 | | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| B-3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 2 | 1 | 1 | 1 | 4 | 1 | 1 | 1 |
| B-4 | 3 | 1 | 1 | N | 1 | 1 | 1 | 1 | | 1 | | 2 | 1 | 1 | 1 | 4 | N | 1 | 1 |
| E | N | N | N | N | N | 3 | 1 | 1 | 1 | | | 4 | 4 | 4 | 3 | 1 | 1 | 1 | 1 |
| H-1 | Not Permitted in Mixed Occupancies. See Chapter 9. | | | | | | | | | | | | | | | | | | |
| H-2 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 4 | | | 1 | 1 | 2 | 4 | 1 | 4 | 4 |
| H-3 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | | 1 | | 1 | 1 | 4 | 1 | 3 | 3 |
| H-4-5 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | | 1 | 1 | | 1 | 4 | 1 | 3 | 3 |
| H-6-7[1] | 4 | 4 | 4 | 3 | 4 | 1 | 1 | 1 | 1 | 3 | | 2 | 1 | 1 | | 4 | 3 | 4 | 4 |
| I | 3 | 3 | 3 | 3 | 3 | 4 | 2 | 4 | 4 | 1 | | 4 | 4 | 4 | 4 | | 1 | 1 | 1 |
| M[2] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | N | 1 | | 1 | 1 | 1 | 3 | 1 | | 1 | 1 |
| R-1 | 1 | 1 | 1 | 1 | 1 | 3[3] | 1 | 1 | 1 | 1 | | 4 | 3 | 3 | 4 | 1 | 1 | | N |
| R-3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 4 | 3 | 3 | 4 | 1 | 1 | N | |

**Note:** For detailed requirements and exceptions, see Section 503.

[1]For special provisions on highly toxic materials, see Fire Code.

[2]For agricultural buildings, see also Appendix Chapter 11.

[3]For reduction in fire-resistive rating, see Section 503 (d).



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## TABLE NO. 5-C—BASIC ALLOWABLE FLOOR AREA FOR BUILDINGS ONE STORY IN HEIGHT[1]
(In Square Feet)

| | TYPES OF CONSTRUCTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | | | III | | IV | V | |
| OCCUPANCY | F.R. | F.R. | ONE-HOUR | N | ONE-HOUR | N | H.T. | ONE-HOUR | N |
| A-1 | Unlimited | 29,900 | Not Permitted | | | | | | |
| A) 2-2:1 | Unlimited | 29,900 | 13,500 | Not Permitted | 13,500 | Not Permitted | 13,500 | 10,500 | Not Permitted |
| A) 3-4[2] | Unlimited | 29,900 | 13,500 | 9,100 | 13,500 | 9,100 | 13,500 | 10,500 | 6,000 |
| B) 1-2-3[3] | Unlimited | 39,900 | 18,000 | 12,000 | 18,000 | 12,000 | 18,000 | 14,000 | 8,000 |
| B-4 | Unlimited | 59,900 | 27,000 | 18,000 | 27,000 | 18,000 | 27,000 | 21,000 | 12,000 |
| E | Unlimited | 45,200 | 20,200 | 13,500 | 20,200 | 13,500 | 20,200 | 15,700 | 9,100 |
| H-1 | 15,000 | 12,400 | 5,600 | 3,700 | Not Permitted | | | | |
| H-2[4] | 15,000 | 12,400 | 5,600 | 3,700 | 5,600 | 3,700 | 5,600 | 4,400 | 2,500 |
| H-3-4-5[4] | Unlimited | 24,800 | 11,200 | 7,500 | 11,200 | 7,500 | 11,200 | 8,800 | 5,100 |
| H-6-7 | Unlimited | 39,900 | 18,000 | 12,000 | 18,000 | 12,000 | 18,000 | 14,000 | 8,000 |
| I) 1-2 | Unlimited | 15,100 | 6,800 | Not Permitted[8] | 6,800 | Not Permitted | 6,800 | 5,200 | Not Permitted |
| I-3 | Unlimited | 15,100 | Not Permitted[5] | | | | | | |
| M[6] | See Chapter 11 | | | | | | | | |
| R-1 | Unlimited | 29,900 | 13,500 | 9,100[7] | 13,500 | 9,100[7] | 13,500 | 10,500 | 6,000[7] |
| R-3 | Unlimited | | | | | | | | |

[1]For multistory buildings, see Section 505 (b).
[2]For limitations and exceptions, see Section 602 (a).
[3]For open parking garages, see Section 709.
[4]See Section 903.
[5]See Section 1002 (b).
[6]For agricultural buildings, see also Appendix Chapter 11.
[7]For limitations and exceptions, see Section 1202 (b).
[8]In hospitals and nursing homes, see Section 1002 (a) for exception.

N—No requirements for fire resistance
F.R.—Fire Resistive
H.T.—Heavy Timber





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## TABLE NO. 5-D—MAXIMUM HEIGHT OF BUILDINGS

| OCCUPANCY | TYPES OF CONSTRUCTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | | | III | | IV | V | |
| | F.R. | F.R. | ONE-HOUR | N | ONE-HOUR | N | H.T. | ONE-HOUR | N |
| | MAXIMUM HEIGHT IN FEET | | | | | | | | |
| | Unlimited | 160 | 65 | 55 | 65 | 55 | 65 | 50 | 40 |
| | MAXIMUM HEIGHT IN STORIES | | | | | | | | |
| A-1 | Unlimited | 4 | Not Permitted | | | | | | |
| A) 2-2.1 | Unlimited | 4 | 2 | Not Permitted | 2 | Not Permitted | 2 | 2 | Not Permitted |
| A) 3-4[4] | Unlimited | 12 | 2 | 1 | 2 | 1 | 2 | 2 | 1 |
| B) 1-2-3[2] | Unlimited | 12 | 4 | 2 | 4 | 2 | 4 | 3 | 2 |
| B-4 | Unlimited | 12 | 4 | 2 | 4 | 2 | 4 | 3 | 2 |
| E[3] | Unlimited | 4 | 2 | 1 | 2 | 1 | 2 | 2 | 1 |
| H-1[4] | 1 | 1 | 1 | 1 | Not Permitted | | | | |
| H-2[4] | Unlimited | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H-3-4-5[4] | Unlimited | 5 | 2 | 1 | 2 | 1 | 2 | 2 | 1 |
| H-6-7 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 |
| I-1[5] | Unlimited | 3 | 1 | Not Permitted | 1 | Not Permitted | 1 | 1 | Not Permitted |
| I-2 | Unlimited | 3 | 2 | Not Permitted | 2 | Not Permitted | 2 | 2 | Not Permitted |
| I-3 | Unlimited | 2 | Not Permitted[6] | | | | | | |
| M[7] | See Chapter 11 | | | | | | | | |
| R-1 | Unlimited | 12 | 4 | 2[8] | 4 | 2[8] | 4 | 3 | 2[8] |
| R-3 | Unlimited[9] | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |



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[1]For limitations and exceptions, see Section 602 (a).
[2]For open parking garages, see Section 709.
[3]See Section 802 (c).
[4]See Section 902.
[5]See Section 1002 (a) for exception to the number of stories in hospitals and nursing homes.
[6]See Section 1002 (b).
[7]For agricultural buildings, see also Appendix Chapter 11.
[8]For limitations and exceptions, see Section 1202 (b).

N—No requirements for fire resistance
F.R.—Fire Resistive
H.T.—Heavy Timber



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# Chapter 6
# REQUIREMENTS FOR GROUP A OCCUPANCIES

## Group A Occupancies Defined

**Sec. 601.** Group A Occupancies shall be:

**Division 1.** Any assembly building or portion of a building with a legitimate stage and an occupant load of 1000 or more.

**Division 2.** Any building or portion of a building having an assembly room with an occupant load of less than 1000 and a legitimate stage.

**Division 2.1.** Any building or portion of a building having an assembly room with an occupant load of 300 or more without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B, Division 2 Occupancy.

**Division 3.** Any building or portion of a building having an assembly room with an occupant load of less than 300 without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B, Division 2 Occupancy.

**Division 4.** Stadiums, reviewing stands and amusement park structures not included within other Group A Occupancies. Specific and general requirements for grandstands, bleachers and reviewing stands are to be found in Chapter 33.

For occupancy separations, see Table No. 5-B.

## Construction, Height and Allowable Area

**Sec. 602.** (a) **General.** Buildings or parts of buildings classed in Group A because of the use or character of the occupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507.

**EXCEPTIONS:** 1. Grandstands, bleachers or reviewing stands of Type III One-hour, Type IV or Type V One-hour construction shall not exceed 40 feet to the highest level of seat boards; 20 feet in cases where construction is Type III-N or Type V-N; and 12 feet in cases where construction is with combustible members in the structural frame and located indoors.

2. Division 4 structures other than Type III-N and Type V-N grandstands, bleachers and reviewing stands of open skeleton-frame type without roof, cover or enclosed usable space shall not be limited in area or height.

3. A fire-resistive ceiling for the roof-ceiling assembly in one-story portions of buildings of Type II One-hour, Type III One-hour or Type V One-hour construction may be omitted, provided the roof framing system is open to the room and does not contain concealed spaces.

(b) **Special Provisions.** Stages and platforms shall be constructed in accordance with the provisions of Chapter 39.

The slope of the main floor of the assembly room shall not exceed the slopes permitted by Section 3307.

Division 2.1 Occupancies with an occupant load of 1000 or more shall be of



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Type I, Type II-F.R., Type II One-hour, Type III One-hour or Type IV construction, except that the roof framing system for one-story portions of buildings of Type II One-hour or Type III One-hour construction may be of unprotected construction when such roof framing system is open to the room and does not contain concealed spaces.

Division 3 Occupancies located in a basement or above the first story shall be of not less than one-hour fire-resistive construction.

Group A assembly rooms having an occupant load of 1000 or more shall not be located in the basement.

**EXCEPTION:** Basements of buildings of Type I or II-F.R. construction.

Division 3 Occupancies with an occupant load of 50 or more which are located over usable space shall be separated from such space by not less than one-hour fire-resistive construction.

For attic space partitions and draft stops, see Section 2516 (f).

(c) **Division 4 Provisions.** Erection and structural maintenance shall conform to these special requirements as well as with other applicable provisions of this code.

When the space under a Division 4 Occupancy is used for any purpose, including exits, it shall be separated from all parts of such Division 4 Occupancy, including exits, by walls, floor and ceiling of not less than one-hour fire-resistive construction.

**EXCEPTIONS:** 1. Exits under temporary grandstands need not be separated.

2. The underside of continuous steel deck grandstands when erected outdoors need not be fire protected when occupied for public toilets.

The building official may cause Division 4 structures to be reinspected at least once every six months.

Grandstands or bleachers may have seat boards, toeboards, bearing or base pads and footboards of combustible materials regardless of construction type.

Seating and exiting requirements for reviewing stands, grandstands and bleachers are provided under Section 3323. Requirements for folding and telescoping seating are provided under Section 3324.

## Location on Property

**Sec. 603.** Buildings housing Group A Occupancies shall front directly upon or have access to a public street not less than 20 feet in width. The access to the public street shall be a minimum 20-foot-wide right-of-way, unobstructed and maintained only as access to the public street. The main entrance to the building shall be located on a public street or on the access way. The main assembly floor of Division 1 Occupancies shall be located at or near the adjacent ground level.

For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Exit Facilities

**Sec. 604.** (a) **General.** Stairs, exits and smokeproof enclosures shall be provided as specified in Chapter 33. (See also Sections 3317 and 3318.)



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(b) **Amusement Structures.** Exits and exit signs for Division 4, Amusement Structures, shall be approved by the building official and, where practicable, shall comply with the requirements specified in Chapter 33.

## Light, Ventilation and Sanitation

**Sec. 605.** All enclosed portions of Group A Occupancies customarily used by human beings and all dressing rooms shall be provided with natural light by means of exterior glazed openings with an area not less than one tenth of the total floor area, and natural ventilation by means of openable exterior openings with an area of not less than one twentieth of the total floor area, or shall be provided with artificial light and a mechanically operated ventilating system. The mechanically operated ventilating system shall be capable of supplying a minimum of 5 cubic feet per minute of outside air per occupant with a total circulated of not less than 15 cubic feet per minute per occupant in all portions of the building during such time as the building is occupied. If the velocity of the air at the register exceeds 10 feet per second, the register shall be placed more than 8 feet above the floor directly beneath.

Toilet rooms shall be provided with a fully openable exterior window at least 3 square feet in area; or a vertical duct not less than 100 square inches in area for the first toilet facility, with 50 additional square inches for each additional facility; or a mechanically operated exhaust system capable of providing a complete change of air every 15 minutes. Such systems shall be connected directly to the outside, and the point of discharge shall be at least 5 feet from any openable window.

There shall be provided in an approved location at least one lavatory for each two water closets for each sex, and at least one drinking fountain for each floor level.

**EXCEPTION:** A drinking fountain need not be provided in a drinking or dining establishment.

For other requirements on water closets, see Sections 510 and 511.

## Shaft and Exit Enclosures

**Sec. 606.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 1706.

## Sprinkler and Standpipe Systems

**Sec. 607.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

## Special Hazards

**Sec. 608.** Stages shall be equipped with automatic ventilators as required in Section 3903 (c).

Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

Motion picture machine booths shall conform to the requirements of Chapter 40.



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Proscenium curtains shall conform to the requirements set forth in U.B.C. Standard No. 6-1.

Class I, II or III-A liquids shall not be placed or stored in any Group A Occupancy.

All exterior openings in a boiler room or room containing central heating equipment if located below openings in another story or if less than 10 feet from other doors or windows of the same building shall be protected by a fire assembly having a three-fourths-hour fire-protection rating. Such fire assemblies shall be fixed, automatic or self-closing. Every room containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

**EXCEPTION:** Boilers, central heating plants or hot-water supply boilers where the largest piece of fuel equipment does not exceed 400,000 Btu per hour input.

## Modifications

**Sec. 609.** Gymnasiums and similar occupancies may have running tracks constructed of wood or unprotected steel or iron.

In gymnasiums or in multipurpose schoolrooms having an area not greater than 3200 square feet, 1-inch nominal tight tongue-and-grooved or 3/4-inch plywood wall covering may be used on the inner side in lieu of fire-resistive plaster.



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# Chapter 7
# REQUIREMENTS FOR GROUP B OCCUPANCIES

## Group B Occupancies Defined

**Sec. 701.** Group B Occupancies shall be:

**Division 1.** Gasoline service stations, garages where no repair work is done except exchange of parts and maintenance requiring no open flame, welding or use of Class I, II or III-A liquids.

**Division 2.** Drinking and dining establishments having an occupant load of less than 50, wholesale and retail stores, office buildings, printing plants, municipal police and fire stations, factories and workshops using materials not highly flammable or combustible, storage and sales rooms for combustible goods, paint stores without bulk handling. (See Section 402 for definition of assembly buildings.)

Buildings or portions of buildings having rooms used for educational purposes beyond the 12th grade with less than 50 occupants in any room.

**Division 3.** Aircraft hangars where no repair work is done except exchange of parts and maintenance requiring no open flame, welding or the use of Class I or II liquids.

Open parking garages.

Helistops.

**Division 4.** Ice plants, power plants, pumping plants, cold storage and creameries.

Factories and workshops using noncombustible and nonexplosive materials.

Storage and sales rooms containing only noncombustible and nonexplosive materials that are not packaged or crated in or supported by combustible material.

For occupancy separations, see Table No. 5-B.

## Construction, Height and Allowable Area

**Sec. 702.** (a) **General.** Buildings or parts of buildings classed in Group B Occupancy because of the use or character of the occupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507.

Other provisions of this code notwithstanding, a Group B, Division 1 Occupancy located in the basement or first story of a building housing a Group B, Division 2 or a Group R, Division 1 Occupancy may be classed as a separate and distinct building for the purpose of area limitation, limitation of number of stories and type of construction, when all of the following conditions are met:

1. The Group B, Division 1 Occupancy is of Type I construction.
2. There is a three-hour occupancy separation between the Group B, Division 1 Occupancy and all portions of the Group B, Division 2 or Group R, Division 1 Occupancy.



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3. The basement or first story is restricted to the storage of passenger vehicles (having a capacity of not more than nine persons per vehicle), but may contain entry lobbies, laundry rooms and mechanical equipment rooms incidental to the operation of the building.
4. The maximum building height in feet shall not exceed the limits set forth in Table No. 5-D for the least type of construction involved.

Other provisions of this code notwithstanding, a Group B, Division 1 Occupancy, located in the basement or first story below a Group B, Division 3 open parking garage, as defined in Section 709, may be classified as a separate and distinct building for the purpose of determining the type of construction when all of the following conditions are met:

1. The allowable area of the structure shall be such that the sum of the ratios of the actual area divided by the allowable area for each separate occupancy shall not exceed 1.
2. The Group B, Division 1 Occupancy is of Type I or II construction and is at least equal to the fire resistance of the Group B, Division 3 Occupancy.
3. The height and the number of the tiers above the basement shall be limited as specified in Table No. 7-A or Section 709 (e).
4. The floor-ceiling assembly separating the Group B, Division 1 and Group B, Division 3 Occupancies shall be protected as required for the floor-ceiling assembly of the Group B, Division 1 Occupancy. Openings between the Group B, Division 1 and Group B, Division 3 Occupancies, except exit openings, need not be protected.
5. The Group B, Division 1 Occupancy is used exclusively for the parking or storage for private or pleasure-type motor vehicles but may contain (a) mechanical equipment rooms incidental to the operation of the building and (b) an office, waiting and toilet rooms having a total area of not more than 1,000 square feet.

(b) **Special Provisions.** 1. **Group B, Divisions 1 and 3.** Marine or motor vehicle service stations including canopies and supports over pumps shall be of noncombustible, fire-retardant-treated wood or of one-hour fire-resistive construction.

**EXCEPTIONS:** 1. Roofs of one-story service stations may be of heavy-timber construction.

2. Canopies conforming to Section 5213 may be erected over pumps.

In areas where motor vehicles, boats or aircraft are stored, and in gasoline service stations, floor surfaces shall be of noncombustible, nonabsorbent materials. Floors shall drain to an approved oil separator or trap discharging to sewers in accordance with the Plumbing Code.

**EXCEPTION:** Floors may be surfaced or waterproofed with asphaltic paving materials in areas where motor vehicles or airplanes are stored or operated.

2. **Group B, Division 2, storage areas.** Storage areas in connection with wholesale or retail sales in Division 2 Occupancies shall be separated from the public area by a one-hour fire-resistive occupancy separation.



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**EXCEPTION:** Occupancy separation need not be provided when any one of the following conditions exists:

1. The storage area does not exceed 1000 square feet, or
2. The storage area is sprinklered and does not exceed 3000 square feet, or
3. The building is provided with an approved automatic sprinkler system throughout. Area increases as specified in Section 506 (c) are permitted.

3. **Laboratories and vocational shops.** Laboratories and vocational shops in buildings used for educational purposes and similar areas containing hazardous materials shall be separated from each other and other portions of the building by not less than a one-hour fire-resistive occupancy separation. When the quantities of hazardous materials in such uses does not exceed those listed in Table No. 9-A or No. 9-B, the requirements of Sections 905 and 908 shall apply. When the quantities of hazardous materials in such uses exceed those allowed by Table No. 9-A or No. 9-B, the use shall be classified as the appropriate Group H Occupancy.

Occupants in laboratories having an area in excess of 200 square feet shall have access to at least two exits from the room and all portions of the room shall be within 75 feet of an exit.

4. **Medical gas systems.** Medical gas systems shall be installed and maintained in accordance with the Fire Code. When nonflammable supply cylinders for such systems are located inside buildings they shall be in a separate room or enclosure separated from the rest of the building by not less than one-hour fire-resistive construction. Doors to the room or enclosure shall be self-closing smoke- and draft-control assemblies having a fire-protection rating of not less than one hour. Rooms shall have at least one exterior wall in which there are not less than two vents of not less than 36 square inches in area. One vent shall be within 6 inches of the floor and one shall be within 6 inches of the ceiling.

**EXCEPTION:** When an exterior wall cannot be provided for the room, automatic sprinklers shall be installed within the room and the room shall be vented to the exterior through ducting contained within a one-hour-rated shaft enclosure. Approved mechanical ventilation shall provide six air changes per hour for the room.

5. **Parking garage headroom.** Parking garages shall have an unobstructed headroom clearance of not less than 7 feet above the finish floor to any ceiling, beam, pipe or similar construction, except for wall-mounted shelves, storage surfaces, racks or cabinets.

6. **Group B, Division 4 roof framing.** In Division 4 Occupancies, fire protection of the underside of roof framing may be omitted in all types of construction.

## Location on Property

**Sec. 703.** For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Exit Facilities

**Sec. 704.** Stairs, exits and smokeproof enclosures shall be provided as specified in Chapter 33. See also Section 702 (b) for exits from laboratories.



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## Light, Ventilation and Sanitation

**Sec. 705.** In Group B Occupancy buildings, all enclosed portions customarily occupied by human beings, other than rooms and areas for which requirements are specified elsewhere in this section, shall be provided with natural light by means of exterior glazed openings with an area equal to one tenth of the total floor area of such portions, and natural ventilation by means of exterior openings with an openable area not less than one twentieth of the total floor area of such portions; or shall be provided with artificial light and a mechanically operated ventilating system. The mechanically operated ventilation system shall be capable of supplying a minimum of 5 cubic feet per minute of outside air per occupant with a total circulated of not less than 15 cubic feet per minute per occupant in all occupied portions of the building.

In all buildings or portions thereof where Class I, II or III-A liquids are used, exhaust ventilation shall be provided sufficient to produce six air changes per hour. Such exhaust ventilation shall be taken from a point at or near the floor level.

In all parking garages, other than open parking garages as defined in Section 709 (b), used for storing or handling of automobiles operating under their own power and on all loading platforms in bus terminals, ventilation shall be provided capable of exhausting a minimum of 1.5 cfm per square foot of gross floor area. The building official may approve an alternate ventilation system designed to exhaust a minimum of 14,000 cfm for each operating vehicle. Such system shall be based upon the anticipated instantaneous movement rate of vehicles but not less than 2.5 percent (or one vehicle) of the garage capacity. Automatic CO sensing devices may be employed to modulate the ventilation system to maintain a maximum average concentration of CO of 50 ppm during any eight-hour period, with a maximum concentration not greater than 200 ppm for a period not exceeding one hour. Connecting offices, waiting rooms, ticket booths, etc., shall be supplied with conditioned air under positive pressure.

> **EXCEPTION:** In gasoline service stations without lubrication pits, storage garages and aircraft hangars the building official may authorize the omission of such ventilating equipment where, in his opinion, the building is supplied with unobstructed openings to the outer air which are sufficient to provide the necessary ventilation.

Every building or portion thereof where persons are employed shall be provided with at least one water closet. Separate facilities shall be provided for each sex when the number of employees exceeds four and both sexes are employed. Such toilet facilities shall be located either in such building or conveniently in a building adjacent thereto on the same property.

Such water closet rooms in connection with food establishments where food is prepared, stored or served shall have a nonabsorbent interior finish as specified in Section 510 (b), shall have hand-washing facilities therein or adjacent thereto, and shall be separated from food preparation or storage rooms as specified in Section 510 (a).

Toilet rooms shall be provided with a fully openable exterior window at least 3 square feet in area; or a vertical duct not less than 100 square inches in area for the



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first toilet facility, with 50 additional square inches for each additional facility; or a mechanically operated exhaust system capable of providing a complete change of air every 15 minutes. Such systems shall be connected directly to the outside, and the point of discharge shall be at least 5 feet from any openable window.

For other requirements on water closets, see Section 510.

## Shaft and Exit Enclosures

**Sec. 706.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts and other vertical openings shall be enclosed, and the enclosure shall be as specified in Section 1706.

**EXCEPTION:** In Group B, Division 4 Occupancies, exits shall be enclosed as specified in Chapter 33, but other vertical openings need not be enclosed.

## Sprinkler and Standpipe Systems

**Sec. 707.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

## Special Hazards

**Sec. 708.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

Storage of Class I liquids shall not be allowed in Group B, Divisions 1, 2 and 3 Occupancies and the handling and use of gasoline, fuel oil and other Class I, II, or III-A liquids shall not be permitted in any Group B Occupancy unless such use and handling comply with the Fire Code.

Devices generating a glow or flame capable of igniting gasoline vapor shall not be installed or used within 18 inches of the floor in any room in which Class I flammable liquids or gas are used or stored.

Every room containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

**EXCEPTION:** Boilers, central heating plants or hot-water supply boilers where the largest piece of fuel equipment does not exceed 400,000 Btu per hour input.

Buildings erected or converted to house high-piled combustible stock shall comply with the Fire Code.

## Open Parking Garages

**Sec. 709.** (a) **Scope.** Except where specific provisions are made in the following subsections, other requirements of this code shall apply.

(b) **Definitions.** 1. **General.** For the purpose of this section, certain terms are defined as follows:

**OPEN PARKING GARAGE** is a structure of Type I or Type II construction with the openings as described in Subsection 2 on two or more sides and which is used exclusively for the parking or storage of private or pleasure-type motor vehicles.



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**EXCEPTION:** The grade-level tier may contain an office, waiting and toilet rooms having a total area of not more than 1000 square feet, and such area need not be separated from the open parking garage.

**MECHANICAL-ACCESS OPEN PARKING GARAGES** are open parking garages employing parking machines, lifts, elevators or other mechanical devices for vehicles moving from and to street level and in which public occupancy is prohibited above the street level.

**RAMP-ACCESS OPEN PARKING GARAGES** are open parking garages employing a series of continuously rising floors or a series of interconnecting ramps between floors permitting the movement of vehicles under their own power from and to the street level.

2. **Openness.** For natural ventilation purposes, the exterior side of the structure shall have uniformly distributed openings on two or more sides. The area of such openings in exterior walls on a tier must be at least 20 percent of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40 percent of the perimeter of the tier. Interior wall lines and column lines shall be at least 20 percent open with uniformly distributed openings.

(c) **Construction.** Construction shall be of noncombustible materials. Open parking garages shall meet the design requirements of Chapter 23. Adequate curbs and guardrails shall be provided at every opening.

(d) **Area and Height.** Area and height of open parking garages shall be limited as set forth in Table No. 7-A except for increases allowed by Subsection (e).

In structures having a spiral or sloping floor, the horizontal projection of the structure at any cross section shall not exceed the allowable area per parking tier. In the case of a structure having a continuous spiral floor, each 9 feet 6 inches of height or portion thereof shall be considered as a tier.

The clear height of a parking tier shall be not less than 7 feet, except that a lesser clear height may be permitted in mechanical-access open parking garages when approved by the building official.

(e) **Area and Height Increases.** The area and height of structures with cross ventilation throughout may be increased in accordance with provisions of this subsection. Structures with sides open on three fourths of the building perimeter may be increased by 25 percent in area and one tier in height. Structures with sides open around the entire building perimeter may be increased 50 percent in area and one tier in height. For a side to be considered open under the above provisions, the total area of openings along the side shall be not less than 50 percent of the interior area of the side at each tier, and such openings shall be equally distributed along the length of the tier.

Open parking garages constructed to heights less than the maximums established by Table No. 7-A may have individual tier areas exceeding those otherwise permitted, provided the gross tier area of the structure does not exceed that permitted for the higher structure. At least three sides of each such larger tier shall have continuous horizontal openings not less than 30 inches in clear height extending for at least 80 percent of the length of the sides, and no part of such



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larger tier shall be more than 200 feet horizontally from such an opening. In addition, each such opening shall face a street or yard accessible to a street with a width of at least 30 feet for the full length of the opening, and standpipes shall be provided in each such tier.

Structures of Type II-F.R.; Type II One-hour or Type II-N construction; with all sides open, may be unlimited in area when the height does not exceed 75 feet. For a side to be considered open, the total area of openings along the side shall be not less than 50 percent of the exterior area of the side at each tier, and such openings shall be equally distributed along the length of the tier. All portions of tiers shall be within 200 feet horizontally from such openings.

(f) **Location on Property.** Exterior walls and openings in exterior walls shall comply with Table No. 7-B. The distance to adjacent property line shall be determined in accordance with Section 504.

(g) **Stairs and Exits.** Where persons other than parking attendants are permitted, stairs and exits shall meet the requirements of Chapter 33, based on an occupant load of 200 square feet per occupant. Where no persons other than parking attendants are permitted there shall be not less than two stairs 3 feet wide. Lifts may be installed for use of employees only, provided they are completely enclosed by noncombustible materials.

(h) **Standpipes.** Standpipes shall be installed when required by the provisions of Chapter 38.

(i) **Sprinkler Systems.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed in accordance with the provisions of Chapter 38.

(j) **Enclosure of Vertical Openings.** Enclosure shall not be required for vertical openings except as specified in Subsection (g) for lifts.

(k) **Ventilation.** Ventilation, other than the percentage of openings specified in Subsection (b), shall not be required.

(l) **Prohibitions.** The following uses and alterations are not permitted:

1. Automobile repair work.
2. Parking of busses, trucks and similar vehicles.
3. Partial or complete closing of required openings in exterior walls by tarpaulins or any other means.

## Helistops

**Sec. 710.** (a) **General.** Helistops may be erected on buildings or other locations if they are constructed in accordance with this section.

(b) **Size.** The touchdown or landing area for helicopters of less than 3500 pounds shall be a minimum of 20 feet by 20 feet in size. The touchdown area shall be surrounded on all sides by a clear area having a minimum average width at roof level of 15 feet but with no width less than 5 feet.

(c) **Design.** Helicopter landing areas and supports therefor on the roof of a building shall be of noncombustible construction. Landing areas shall be designed to confine any Class I, II or III-A liquid spillage to the landing area itself



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and provision shall be made to drain such spillage away from any exit or stairway serving the helicopter landing area or from a structure housing such exit or stairway.

(d) **Exits and Stairways.** Exits and stairways from helistops shall comply with the provisions of Chapter 33 of this code, except that all landing areas located on buildings or structures shall have two or more exits. For landing platforms or roof areas less than 60 feet in length, or less than 2000 square feet in area, the second exit may be a fire escape or ladder leading to the floor below.

(e) **Federal Aviation Approval.** Before operating helicopters from helistops, approval must be obtained from the Federal Aviation Administration.

**TABLE NO. 7-A—OPEN PARKING GARAGES AREA AND HEIGHT**

| TYPE OF CONSTRUCTION | AREA PER TIER (Square Feet) | HEIGHT | | |
|---|---|---|---|---|
| | | | MECHANICAL-ACCESS | |
| | | | Automatic Fire-extinguishing System | |
| | | RAMP-ACCESS | No | Yes |
| I | Unlimited | Unlimited | Unlimited | Unlimited |
| II-F.R. | 125,000 | 12 Tiers | 12 Tiers | 18 Tiers |
| II-1-hour | 50,000 | 10 Tiers | 10 Tiers | 15 Tiers |
| II-N | 30,000 | 8 tiers | 8 Tiers | 12 Tiers |

**TABLE NO. 7-B—OPEN PARKING GARAGES—EXTERIOR WALLS[1]**

| FIRE RESISTANCE OF EXTERIOR WALLS | OPENINGS IN EXTERIOR WALLS |
|---|---|
| One hour less than 10 feet | Not permitted less than 5 feet, protected less than 10 feet |

[1]See Section 709 (f).



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# Chapter 8
# REQUIREMENTS FOR GROUP E OCCUPANCIES

## Group E Occupancies Defined

**Sec. 801.** Group E Occupancies shall be:

**Division 1.** Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or four hours in any one day.

**Division 2.** Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or four hours in any one day.

**Division 3.** Any building used for day-care purposes for more than six children.

For occupancy separations, see Table No. 5-B.

## Construction, Height and Allowable Area

**Sec. 802.** (a) **General.** Buildings or parts of buildings classed in Group E because of the use or charaeter of the oecupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507, exeept that the area may be increased by 50 percent when the maximum travel distance specified in Section 3303 (d) is reduced by 50 percent.

(b) **Atmospheric Separation Requirements.** 1. **Definitions.** For the purpose of this chapter and Section 3319, the following definitions are applicable:

**COMMON ATMOSPHERE.** A common atmosphere exists between rooms, spaees or areas within a building which are not separated by an approved smoke and draft-stop barrier.

**SEPARATE ATMOSPHERE.** A separate atmosphere exists between rooms, spaees or areas that are separated by an approved smoke and draft-stop barrier.

**SMOKE AND DRAFT BARRIER.** A smoke and draft barrier consists of walls, partitions, floors and openings therein of such construction as will prevent the transmission of smoke or gases through the construction.

2. **General provisions.** The provisions of this subsection apply when a separate exit system is required in accordance with Section 3319.

Walls, partitions and floors forming all of, or part of, an atmospheric separation shall be of materials consistent with the requirements for the type of construction, but of construction not less effective than a smoke- or draft-stop barrier. Glass lights of approved wired glass set in steel frames may be installed in such walls or partitions.

Every door opening therein shall be protected with a fire assembly as required elsewhere in the code, but not less than a self-closing or automatic-closing, tight-fitting smoke barrier and fire assembly having a fire-protection rating of not less than 20 minutes when tested in accordance with U.B.C. Standard No. 43-2.



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Ducts penetrating atmospheric separation walls, partitions or floors shall be equipped with an approved automatic-closing smoke damper when having openings into more than one atmosphere.

All automatic-closing fire assemblies installed in the atmospheric separation shall be activated by approved smoke detectors.

The specific requirements of this section are not intended to prevent the design or use of other systems, equipment or techniques which will effectively prevent the products of combustion from breaching the atmospheric separation.

(c) **Special Provisions.** Rooms in Divisions 1 and 2 Occupancies used for kindergarten, first or second grade pupils and Division 3 Occupancies shall not be located above or below the first story, except for basements that have required exits at grade level.

> **EXCEPTION:** In buildings equipped with an automatic sprinkler system throughout, rooms used for kindergarten, first- and second-grade children or for day-care purposes may be located on the second story, provided there are at least two exits directly to the exterior for the exclusive use of such occupants.

Storage and janitor closets shall be of one-hour fire-resistive construction. Stages and platforms shall be constructed in accordanee with Chapter 39. For attic spaee partitions and draft stops, see Section 2516 (f).

(d) **Special Hazards.** Laboratories, vocational shops and similar areas containing hazardous materials shall be separated from each other and from other portions of the building by not less than a one-hour fire-resistive occupancy separation. When the quantities of hazardous materials in such uses do not exceed those listed in Table No. 9-A or No. 9-B, the requirements of Seetions 905 and 908 shall apply. When the quantities of hazardous materials in such uses exceed those allowed by Table No. 9-A or No. 9-B, the use shall be classified as the appropriate Group H Occupancy.

Oceupants in laboratories having an area in excess of 200 square feet shall have access to at least two exits from the room and all portions of the room shall be within 75 feet of an exit.

Equipment in rooms or groups of rooms sharing a common atmosphere where flammable liquids, combustible dust or hazardous materials are used, stored, developed or handled shall conform to the requirements of the Fire Code.

## Location on Property

**Sec. 803.** All buildings housing Group E Occupancies shall front directly upon or have access to a public street not less than 20 feet in width. The access to the public street shall be a minimum 20-foot-wide right-of-way, unobstructed and maintained only as access to the public street. At least one required exit shall be located on the public street or on the access way.

For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Exit Facilities

**Sec. 804.** Stairs, exits and smokeproof enclosures shall be provided as specified in Chapter 33. (See also Section 3319.)



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### Light, Ventilation and Sanitation

**Sec. 805.** All portions of Group E Occupancies shall be provided with light and ventilation, either natural or artificial, as specified in Section 605.

Water closets shall be provided on the basis of the following ratio of water closets to the number of students:

| | Boys | Girls |
|---|---|---|
| Elementary Schools | 1:100 | 1:35 |
| Secondary Schools | 1:100 | 1:45 |

In addition, urinals shall be provided for boys on the basis of 1:30 in elementary and secondary schools.

There shall be provided at least one lavatory for each two water closets or urinals, and at least one drinking fountain on each floor for elementary and secondary schools.

For other requirements on water closets, see Section 510.

### Shaft and Exit Enclosures

**Sec. 806.** Exits shall be enclosed as specified in Chapter 33. Elevator shafts, vent shafts and other vertical openings shall be enclosed; and the enclosure shall be as specified in Chapter 17.

### Sprinkler and Standpipe Systems

**Sec. 807.** Where required, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

### Special Hazards

**Sec. 808.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

Motion picture machine rooms shall conform to the requirements of Chapter 40.

All exterior openings in a boiler room or rooms containing central heating equipment, if located below openings in another story or if less than 10 feet from other doors or windows of the same building, shall be protected by a fire assembly having a three-fourths-hour fire-protection rating. Such fire assemblies shall be fixed, automatic- or self-closing. Every room containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

**EXCEPTION:** Boilers, central heating plants or hot-water supply boilers where the largest piece of fuel equipment does not exceed 400,000 Btu per hour input.

When the opening for a heater or equipment room is protected by a pair of fire doors, the inactive leaf shall be normally secured in the closed position and shall be openable only by the use of a tool. An astragal shall be provided and the active leaf shall be self-closing.

Class I, II or III-A liquids shall not be placed, stored or used in any Group E Occupancies, except in approved quantities as necessary in laboratories and



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approved utility rooms, and such liquids shall be kept in tight or sealed containers when not in actual use and shall be stored within a storage eabinet for Class I, II or III-A liquid approved by the fire department.

## Fire Alarms

**Sec. 809.** Approved fire alarms shall be provided for all Group E Occupancies with an occupant load of more than 50 persons. In every Group E Occupancy provided with an automatic sprinkler or detection system, the operation of such system shall automatically activate the school fire alarm system, which shall include an alarm mounted on the exterior of the building.



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# Chapter 9
# REQUIREMENTS FOR GROUP H OCCUPANCIES

## Group H Occupancies Defined

**Sec. 901.** (a) **General.** For definitions, identification and control of hazardous materials, see the Fire Code. For application and use of control areas, see Footnote 1 of Tables Nos. 9-A and 9-B. The primary use of a building shall be considered as a Group H, Division 1, 2 or 3 Occupancy when its primary use is for storage, and the aggregate quantity of hazardous materials in the building is in excess of Table No. 9-A. Group H Occupancies shall be:

**Division 1.** Occupancies with a quantity of material in the building in excess of those listed in Table No. 9-A which present a high explosion hazard, including but not limited to:

1. Explosives, blasting agents, fireworks and black powder.

   **EXCEPTION:** Storage and the use of pyrotechnic special effect materials in motion picture, television, theatrical and group entertainment production when under permit as required in the Fire Code. The time period for storage shall not exceed 90 days.

2. Unclassified detonatable organic peroxides.
3. Class 4 oxidizers.
4. Class 4 or Class 3 detonatable unstable (reactive) materials.

**Division 2.** Occupancies with a quantity of material in the building in excess of those listed in Table No. 9-A which present a moderate explosion hazard or a hazard from accelerated burning, including but not limited to:

1. Class I organic peroxides.
2. Class 3 nondetonatable unstable (reactive) materials.
3. Pyrophoric gases.
4. Flammable or oxidizing gases.
5. Class I, II or III-A flammable or combustible liquids which are used in normally open containers or systems or in closed containers pressurized at more than 15-pounds-per-square-inch gauge.
6. Combustible dusts in suspension or capable of being put into suspension in the atmosphere of the room or area.

   **EXCEPTIONS:** 1. Rooms or areas used for woodworking that do not exceed 500 square feet in area may be classified as Group B, Division 2 Occupancies, provided dust-producing machines are equipped with approved dust collectors and there are not more than two such machines.

   2. Lumberyards and similar retail stores utilizing only power saws may be classified as Group B, Division 2 Occupancies.

   The building official may revoke the use of these exceptions for due cause.

7. Class 3 oxidizers.

**Division 3.** Occupancies with a quantity of material in the building in excess of



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those listed in Table No. 9-A which present a high fire or physical hazard, including but not limited to:

1. Class II, III or IV organic peroxides.
2. Class 1 or 2 oxidizers.
3. Class I, II or III-A flammable liquids or combustible liquids which are utilized or stored in normally closed containers or systems and containers pressurized at 15-pounds-per-square-inch gauge or less.
4. Class III-B combustible liquids.
5. Pyrophoric liquids or solids.
6. Water reactives.
7. Flammable solids, including combustible fibers or dusts, except for dusts included in Division 2.
8. Flammable or oxidizing cryogenic fluids (other than inert).
9. Class 1 or 2 unstable (reactive) materials.

**Division 4:** Repair garages not classified as Group B, Division 1.

**Division 5.** Aircraft repair hangars and heliports not classified as Group B, Division 3.

**Division 6.** Semiconductor fabrication facilities and comparable research and development areas when the facilities in which hazardous production materials (HPM) are used and the aggregate quantity of materials are in excess of those listed in Table No. 9-A or 9-B. Such facilities and areas shall be designed and constructed in accordance with Section 911.

**Division 7.** Occupancies having quantities of materials in excess of those listed in Table No. 9-B that are health hazards; including but not limited to:

1. Corrosives.
2. Highly toxic materials.
3. Irritants.
4. Sensitizers.
5. Other health hazards.

(b) **Multiple Hazards.** When a hazardous material has multiple hazards, all hazards shall be addressed and controlled in accordance with the provisions of this chapter.

(c) **Liquid Use, Dispensing and Mixing Rooms.** Rooms in which Class I, Class II and Class III-A flammable or combustible liquids are used, dispensed or mixed in open containers shall be constructed in accordance with the requirements for a Group H, Division 2 Occupancy and the following:

1. Rooms in excess of 500 square feet shall have at least one exterior door approved for fire department access.
2. Rooms shall not exceed 1000 square feet in area.
3. Rooms shall be separated from other areas by an occupancy separation having a fire-resistive rating of not less than one hour for rooms up to 150



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square feet in area and not less than two hours where the room is more than 150 square feet in area. Separations from other occupancies shall not be less than required by Chapter 5, Table No. 5-B.

4. Shelving, racks and wainscoting in such areas shall be of noncombustible construction or wood not less than 1-inch nominal thickness.
5. Liquid use, dispensing and mixing rooms shall not be located in basements.

(d) **Liquid Storage Rooms.** Rooms in which Class I, Class II and Class III-A flammable or combustible liquids are stored in closed containers shall be constructed in accordance with the requirements for a Group H, Division 3 Occupancy and to the following:

1. Rooms in excess of 500 square feet shall have at least one exterior door approved for fire department access.
2. Rooms shall not exceed 1000 square feet in area.
3. Rooms shall be separated from other areas by an occupancy separation having a fire-resistive rating of not less than one hour for rooms up to 150 square feet in area and not less than two hours where the room is more than 150 square feet in area. Separations from other occupancies shall not be less than required by Chapter 5, Table No. 5-B.
4. Shelving, racks and wainscoting in such areas shall be of noncombustible construction or wood of not less than 1-inch nominal thickness.
5. Rooms used for the storage of Class I flammable liquids shall not be located in a basement.

(e) **Flammable or Combustible Liquid Storage Warehouses.** Liquid storage warehouses in which Class I, Class II and Class III-A flammable or combustible liquids are stored in closed containers shall be constructed in accordance with the requirements for a Group H, Division 3 Occupancy and the following:

1. Liquid storage warehouses shall be separated from all other uses by a four-hour area separation wall.
2. Shelving, racks and wainscoting in such warehouses shall be of noncombustible construction or wood not less than 1-inch nominal thickness.
3. Rooms used for the storage of Class I flammable liquids shall not be located in a basement.

(f) **Requirement for Report.** The building official may require a technical opinion and report to identify and develop methods of protection from the hazards presented by the hazardous material. The opinion and report shall be prepared by a qualified person, firm or corporation approved by the building official and shall be provided without charge to the enforcing agency.

The opinion and report may include, but is not limited to, the preparation of a hazardous material management plan (HMMP); chemical analysis; recommendations for methods of isolation, separation, containment or protection of hazardous materials or processes, including appropriate engineering controls to be applied; the extent of changes in the hazardous behavior to be anticipated under conditions of exposure to fire or from hazard control procedures; and the limitations or conditions of use necessary to achieve and maintain control of the hazardous



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materials or operations. The report shall be entered into the files of the code enforcement agencies. Proprietary and trade secret information shall be protected under the laws of the state or jurisdiction having authority.

## Construction, Height and Allowable Area

**Sec. 902.** (a) **General.** Buildings or parts of buildings classed in Group H because of the use or character of the occupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507.

(b) **Floors.** Except for surfacing, floors in areas containing hazardous materials and in areas where motor vehicles, boats, helicopters or airplanes are stored, repaired or operated shall be of noncombustible, liquid-tight construction.

> **EXCEPTION:** In Group H, Division 4 and 5 Occupancies, floors may be surfaced or waterproofed with asphaltic paving materials in that portion of the facility where no repair work is done.

(c) **Spill Control.** When required by the Fire Code, floors shall be recessed a minimum of 4 inches or shall be provided with a liquid-tight raised sill with a minimum height of 4 inches so as to prevent the flow of liquids to adjoining areas. When liquid-tight sills are provided, they may be omitted at door openings by the installation of an open-grate trench which connects to the room drainage system.

(d) **Drainage.** When required by the Fire Code, the room, building or area shall be provided with a drainage system to direct the flow of liquids to an approved location or the room, building or area shall be designed to provide secondary containment for the hazardous materials and fire-protection water.

Drains from the area shall be sized to carry the sprinkler system design flow rate over the sprinkler system design area. The slope of drains shall not be less than 1 percent. Materials of construction for the drainage system shall be compatible with the stored materials.

Incompatible materials shall be separated from each other in the drain systems. They may be combined when they have been rendered acceptable for discharge by an approved means into the public sewer. Drainage of spillage and fire-protection water directed to a neutralizer or treatment system shall comply with the following:

1. The system shall be designed to handle the maximum worst-case spill from the single largest container plus the volume of fire-protection water from the system over the minimum design area for a period of 20 minutes.
2. Overflow from the neutralizer or treatment system shall be provided to direct liquid leakage and fire-protection water to a safe location away from the building, any material or fire protection control valve, means of egress, adjoining property, or fire department access roadway.

(e) **Containment.** When required by the Fire Code, drains shall be directed to a containment system or other location designed as secondary containment for the hazardous material liquids and fire-protection water, or the building, room or area shall be designed to provide secondary containment of hazardous material liquids



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and fire-protection water through the use of recessed floors or liquid-tight raised sills.

Secondary containment shall be designed to retain the spill from the largest single container plus the design flow rate of the sprinkler system for the area of the room or area in which the storage is located or the sprinkler system design area, whichever is smaller. The containment capacity shall be capable of containing the flow for a period of 20 minutes.

Overflow from the secondary containment system shall be provided to direct liquid leakage and fire-protection water to a safe location away from the building, any material or fire protection control valve, means of egress, fire access roadway, adjoining property or storm drains.

If the storage area is open to rainfall, the secondary containment shall be designed to accommodate the volume of a 24-hour rainfall as determined by a 25-year storm.

When secondary containment is required, a monitoring method capable of detecting hazardous material leakage from the primary containment into the secondary containment shall be provided. When visual inspection of the primary containment is not practical, other approved means of monitoring may be provided. When secondary containment may be subject to the intrusion of water, a monitoring method for such water shall be provided. Whenever monitoring devices are provided, they shall be connected to distinct visual or audible alarms.

(f) **Smoke and Heat Vents.** Smoke and heat venting shall be provided in areas containing hazardous materials as set forth in the Fire Code in addition to the provisions of this code.

(g) **Standby Power.** Standby power shall be provided in Group H, Divisions 1 and 2 Occupancies and in Group H, Division 3 Occupancies in which Class I, II or III organic peroxides are stored. The standby power system shall be designed and installed in accordance with the Electrical Code to automatically supply power to all electrical equipment required by the Fire Code when the normal electrical supply system is interrupted.

(h) **Emergency Power.** An emergency power system shall be provided in Group H, Division 6 and Division 7 Occupancies. The emergency power system shall be designed and installed in accordance with the Electrical Code to automatically supply power to the exhaust ventilation system when the normal electrical supply system is interrupted.

The exhaust system may be designed to operate at not less than one-half the normal fan speed on the emergency power system when it is demonstrated that the level of exhaust will maintain a safe atmosphere.

(i) **Special Provisions for Group H, Division 1.** Group H, Division 1 Occupancies shall be in buildings used for no other purpose, without basements, crawl spaces or other under-floor spaces. Roofs shall be of lightweight construction with suitable thermal insulation to prevent sensitive material from reaching its decomposition temperature.

(j) **Special Provisions for Group H, Divisions 2 and 3.** Group H, Division 2 and Division 3 Occupancies containing quantities of hazardous materials in



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excess of those set forth in Table No. 9-E shall be in buildings used for no other purpose, shall not exceed one story in height and shall be without basements, crawl spaces or other under-floor spaces.

Group H, Division 3 Occupancies containing water-reactive materials shall be resistant to water penetration. Piping for conveying liquids shall not be over or through areas containing water reactives, unless isolated by approved liquid-tight construction.

**EXCEPTION:** Fire-protection piping may be installed over reactives without isolation.

(k) **Special Provisions for Group H, Division 4 and Division 5.** A Division 4 Occupancy having a floor area not exceeding 2,500 square feet may have exterior walls of not less than two-hour fire-resistive construction when less than 5 feet from a property line and not less than one-hour fire-resistive construction when more than 5 feet but less than 20 feet from a property line.

Group H, Division 5 Occupancies shall have exterior walls of not less than one-hour fire-resistive construction or shall be surrounded by public ways or yards not less than 60 feet in width.

**EXCEPTION:** Exterior walls of a nonrated building fronting on public ways or yards having a width of at least 40 feet may be of unprotected construction.

The area increases allowed by Section 506 (a) shall not exceed 500 percent for aircraft repair hangars, except as permitted in Section 506 (b).

(l) **Special Provisions for Group H, Division 6.** See Section 911.

## Location on Property

**Sec. 903.** Group H Occupancies shall be located on property in accordance with Section 504 and this chapter. In Group H, Division 2 or Division 3 Occupancies, not less than 25 percent of the perimeter wall of the occupancy shall be an exterior wall.

**EXCEPTIONS:** 1. Liquid use, dispensing and mixing rooms having a floor area of not more than 500 square feet need not be located on the outer perimeter of the building when they are in accordance with Section 901 (c).

2. Liquid storage rooms having a floor area of not more than 1000 square feet need not be located on the outer perimeter when they are in accordance with Section 901 (d).

3. Spray paint booths which comply with the Fire Code need not be located on the outer perimeter.

## Exit Facilities

**Sec. 904.** Stairs, exits and smokeproof enclosures shall be provided as specified in Chapter 33. (See also Section 3320.)

## Light, Ventilation and Sanitation

**Sec. 905.** (a) **General Ventilation.** In Group H Occupancy buildings, all enclosed portions customarily occupied by human beings, other than rooms and areas for which requirements are specified elsewhere in this section, shall be provided with natural light by means of exterior glazed openings with an area



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equal to one-tenth of the total floor area of such portions, and natural ventilation by means of exterior openings with an openable area not less than one twentieth of the total floor area of such portions, or shall be provided with artificial light and a mechanically operated ventilation system. The mechanically operated ventilation system shall be capable of supplying a minimum of 5 cubic feet per minute of outside air per occupant, with a total circulated of not less than 15 cubic feet per minute per occupant in all occupied portions of the building. When recirculation of air is not permitted, the ventilation system shall be capable of providing not less than 15 cubic feet per minute of outside air per occupant.

(b) **Ventilation in Rooms Containing Hazardous Material.** Rooms in which explosive, corrosive, combustible, flammable or highly toxic dusts, mists, fumes, vapors or gases are or may be emitted due to the processing, use, handling or storage of materials shall be mechanically ventilated as required by the Fire Code and the Mechanical Code.

Emissions generated at work stations shall be confined to the area in which they are generated as specified in the Fire and Mechanical Codes.

The location of supply and exhaust opening shall be in accordance with the Mechanical Code. Exhaust air contaminated by highly toxic material shall be treated in accordance with the Fire Code.

A manual shutoff control for ventilation equipment required by this subsection shall be provided outside the room adjacent to the principal access door to the room. The switch shall be of the break-glass type and shall be labeled "Ventilation System Emergency Shutoff."

(c) **Ventilation in Group H, Division 4.** In all buildings used for the repair or handling of motor vehicles operating under their own power, mechanical ventilation shall be provided capable of exhausting a minimum of 1 cubic foot per minute per square foot of floor area. Each engine repair stall shall be equipped with an exhaust pipe extension duct, extending to the outside of the building, which, if over 10 feet in length, shall mechanically exhaust 300 cubic feet per minute. Connecting offices and waiting rooms shall be supplied with conditioned air under positive pressure.

**EXCEPTION:** In repair garages, enclosed heliports and aircraft hangars, the building official may authorize the omission of such ventilating equipment when, in his opinion, the building is supplied with unobstructed openings to the outer air which are well distributed and sufficient in size to provide the necessary ventilation.

(d) **Sanitation.** Every building or portion thereof where persons are employed shall be provided with at least one water closet. Separate facilities shall be provided for each sex when the number of employees exceeds four and both sexes are employed. Such toilet facilities shall be located in such building or conveniently in a building adjacent thereto on the same property.

Toilet rooms shall be provided with a fully openable exterior window at least 3 square feet in area; or a vertical duct not less than 100 square inches in area for the first water closet, with 50 additional square inches for each additional fixture; or a mechanically operated exhaust system capable of providing a complete change of



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air every 15 minutes. Such systems shall be connected directly to the outside, and the point of discharge shall be at least 5 feet from any openable window.

For other requirements on water closets, see Sections 510 and 511.

## Shaft Enclosures

**Sec. 906.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts and other vertical openings shall be enclosed, and the enclosure shall be as specified in Section 1706.

Doors which are a part of an automobile ramp enclosure shall be equipped with automatic closing devices.

## Sprinkler and Standpipe Systems

**Sec. 907.** When required by other provisions of this code, automatic fire-extinguishing systems and standpipes shall be designed and installed as specified in Chapter 38.

## Special Hazards

**Sec. 908.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

Every boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a two-hour fire-resistive occupancy separation. In Divisions 1, 2 and 3, there shall be no openings in such occupancy separations except for necessary ducts and piping.

In Division 4 Occupancies, devices which generate a spark, flame or glow capable of igniting gasoline vapors shall not be installed or used within 18 inches of the floor.

Equipment or machinery which generates or emits combustible or explosive dust or fibers shall be provided with an adequate dust-collecting and exhaust system installed in conformance with the Mechanical Code. Equipment or systems that are used to collect, process or convey combustible dusts or fibers shall be provided with an approved explosion venting or containment system.

Combustible fiber storage rooms or vaults having a capacity of more than 100 cubic feet shall be separated from the remainder of the building by a two-hour fire-resistive occupancy separation.

Cellulose nitrate film storage and handling shall be in accordance with Chapter 48.

## Fire Alarms

**Sec. 909.** An approved fire alarm system shall be installed in Group H Occupancies used for the manufacturing of organic coatings as specified in the Fire Code.

## Explosion Venting

**Sec. 910.** Explosion venting shall be provided to vent the gases resulting from deflagrations of dusts, gases or mists in rooms, buildings or other enclosures as required by the Fire Code so as to minimize structural or mechanical damage. If



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detonation rather than deflagration is considered likely, protective devices or systems such as fully contained barricades shall be provided, except that explosion venting to minimize damage from less than 2.0 grams of TNT (equivalence) is permitted. Walls, floors and roofs separating a use from an explosion exposure shall be designed to resist a minimum internal pressure of 100 pounds per square foot in addition to the loads required by Chapter 23.

Explosion venting shall be provided in exterior walls or roof only. The venting shall be designed to prevent serious structural damage and production of lethal projectiles. The aggregate clear vent relief area shall be regulated by the pressure resistance of the nonrelieving portions of the building and be designed by persons competent in such design. The design shall recognize the nature of the material and its behavior in an explosion. Vents shall consist of any one or any combination of the following to relieve at a maximum internal pressure of 20 pounds per square foot, but not less than the loads required by Chapter 23.

1. Walls of lightweight material.
2. Lightly fastened hatch covers.
3. Lightly fastened, outward-opening swinging doors in exterior walls.
4. Lightly fastened walls or roof.

Venting devices shall discharge vertically or directly to an unoccupied yard not less than 50 feet in width on the same lot. Releasing devices shall be so located that the discharge end shall be not less than 10 feet vertically and 20 feet horizontally from window openings or exits in the same or adjoining buildings or structures. The exhaust shall always be in the direction of least exposure and never into the interior of the building unless a suitably designed shaft is provided which discharges to the exterior. See Footnote 7 of Table No. 9-A.

## Division 6 Occupancies

**Sec. 911.** (a) **General.** In addition to the requirements set forth elsewhere in this code, Group H, Division 6 Occupancies shall comply with the provisions of this section and the Fire Code.

(b) **Fabrication Area.** 1. **Separation.** Fabrication areas, whose size is limited by the quantity of HPM permitted by the Fire Code, shall be separated from each other, from exit corridors, and from other parts of the building by not less than one-hour fire-resistive occupancy separations.

**EXCEPTIONS:** 1. Doors within such occupancy separation, including doors to corridors, shall be only self-closing fire assemblies having a fire-protection rating of not less than three-fourths hour.

2. Windows between fabrication areas and exit corridors may be in accordance with Section 3305 (h) 2.

2. **Floors.** Except for surfacing, floors within fabrication areas shall be of noncombustible construction. Openings through floors of fabrication areas may be unprotected when the interconnected levels are used solely for mechanical equipment directly related to such fab area. See also Section 1706 (a), Exception 8. When forming a part of an occupancy separation, floors shall be liquid tight.



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3. **Ventilation.** Mechanical ventilation, which may include recirculated air, shall be provided throughout the fabrication area at the rate of not less than 1 cubic foot per minute per square foot of floor area. The exhaust air duct system of one fabrication area shall not connect to another duct system outside that fabrication area within the building.

Ventilation systems shall comply with the Mechanical Code except that the automatic shutoffs need not be installed on air-moving equipment. However, smoke detectors shall be installed in the circulating airstream and shall initiate a signal at the emergency control station.

Except for exhaust systems, at least one manually operated remote control switch that will shut down the fab area ventilation system shall be installed at an approved location outside the fab area.

4. **Transporting hazardous production materials.** Hazardous production materials shall be transported to fabrication areas through enclosed piping or tubing systems that comply with Section 911 (f), through service corridors or in exit corridors as permitted in the exception to Section 911 (c). The handling or transporting of hazardous production materials within service corridors shall comply with the Fire Code.

5. **Electrical.** Electrical equipment and devices within the fabrication area shall comply with the Electrical Code. The requirements for hazardous locations need not be applied when the average air change is at least four times that set forth in Section 911 (b) 3 and when the number of air changes at any location is not less than three times that required by Section 911 (b) 3 and the Fire Code.

(c) **Exit Corridors.** Exit corridors shall comply with Section 3305 and shall be separated from fabrication areas as specified in Section 911 (b) 1. Exit corridors shall not be used for transporting hazardous production materials except as provided in Section 911 (f) 2.

**EXCEPTION:** In existing Group H, Division 6 Occupancies when there are alterations or modifications to existing fabrication areas, the building official may permit the transportation of hazardous production materials in exit corridors subject to the requirements of the Fire Code and as follows:

1. Corridors adjacent to the fabrication area where the alteration work is to be done shall comply with Section 3305 for a length determined as follows:
   A. The length of the common wall of the corridor and the fabrication area, and
   B. For the distance along the exit corridor to the point of entry of HPM into the exit corridor serving that fabrication area.
2. There shall be an emergency telephone system or a local alarm manual pull station or approved signal device within exit corridors at not more than 150-foot intervals or fraction thereof and at each exit stair doorway. The signal shall be relayed to the emergency control station and a local signaling device shall be provided.
3. Sprinkler protection shall be designed in accordance with U.B.C. Standard No. 38-1 for Ordinary Hazard Group 3, except that when one row of sprinklers is used in the corridor protection, the maximum number of sprinklers that need be calculated is 13.



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(d) **Service Corridors.** Service corridors shall be classified as Group H, Division 6 Occupancies. Service corridors shall be separated from exit corridors as required by Section 911 (b) 1.

Service corridors shall be mechanically ventilated as required by Section 911 (b) 3 or at not less than six air changes per hour, whichever is greater.

The maximum distance of travel from any point in a service corridor to an exterior exit door, horizontal exit, exit passageway, enclosed stairway or door into a fabrication area shall not exceed 75 feet. Dead ends shall not exceed 4 feet in length. There shall be not less than two exits, and not more than one half of the required exits shall be into the fabrication area. Doors from service corridors shall swing in the direction of exit travel and shall be self-closing.

(e) **Storage of Hazardous Production Material.** 1. **Construction.** The storage of hazardous production materials in quantities greater than those listed in Table No. 9-A or 9-B shall be in inside rooms complying with Section 901 (d) or shall be in HPM storage rooms not exceeding 6000 square feet in area. Such HPM storage rooms shall be separated from all other areas by not less than a two-hour fire-resistive occupancy separation when the area is 300 square feet or more and not less than one-hour fire-resistive construction when the area is less than 300 square feet. The provisions of Section 503 (a) shall apply.

When an HPM storage room is also used for dispensing of Class I or II flammable liquids or flammable gases, the area of the room shall not exceed 1000 square feet. Except for surfacing, floors of storage rooms shall be of noncombustible liquid-tight construction. Raised grating over floors shall be of noncombustible materials. See Section 902 (c) for sill requirements for liquid storage rooms.

2. **Location within building.** When HPM storage rooms are provided, they shall have at least one exterior wall and such wall shall be not less than 30 feet from property lines, including property lines adjacent to public ways. Explosion venting shall be provided when required by Section 910.

3. **Exits.** When two exits are required from HPM storage rooms, one shall be directly to the outside of the building. See Section 911 (b) 1, Exception 1.

4. **Ventilation.** Mechanical exhaust ventilation shall be provided in storage rooms at the rate of not less than 1 cubic foot per minute per square foot of floor area or six air changes per hour, whichever is greater, for all categories of material.

F
F

5. **Emergency alarm.** An alarm pull station or approved signal device shall be installed outside of each interior exit door from HPM storage rooms. Operation of such alarm or signal device shall provide a local alarm and relay a signal to the emergency control station.

6. **Electrical.** HPM storage rooms containing flammable liquids or gases shall be classified as Class I, Division 1 hazardous locations. Electrical wiring and equipment within such rooms shall comply with the Electrical Code for such location.

(f) **Piping and Tubing.** 1. **General.** HPM piping and tubing shall comply with this subsection and shall be installed in accordance with nationally recognized standards. Piping and tubing systems shall be metallic unless the material being



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transported is incompatible with such system. Systems supplying gaseous HPM shall be welded throughout, except for connections, valves and fittings, to the systems which are within a ventilated enclosure. HPM supply piping or tubing in service corridors shall be exposed to view.

2. **Installations in exit corridors and above other occupancies.** Hazardous production materials shall not be located within exit corridors or above areas not classified as Group H, Division 6 Occupancies except as permitted by this subsection.

Hazardous production material piping and tubing may be installed within the space defined by the walls of exit corridors and the floor or roof above or in concealed spaces above other occupancies under the following conditions:

A. Automatic sprinklers shall be installed within the space unless the space is less than 6 inches in least dimension.

B. Ventilation at not less than six air changes per hour shall be provided. The space shall not be used to convey air from any other area.

C. When the piping or tubing is used to transport HPM liquids, a receptor shall be installed below such piping or tubing. The receptor shall be designed to collect any discharge or leakage and drain it to an approved location. The one-hour enclosure shall not be used as part of the receptor.

D. All HPM supply piping and tubing and HPM nonmetallic waste lines shall be separated from the exit corridor and from any occupancy other than Group H, Division 6 by construction as required for walls or partitions that have a fire-protection rating of not less than one hour. When gypsum wallboard is used, joints on the piping side of the enclosure need not be taped, provided the joints occur over framing members. Access openings into the enclosure shall be protected by approved fire assemblies.

E. Readily accessible manual or automatic remotely activated fail-safe emergency shutoff valves shall be installed on piping and tubing other than waste lines at the following locations:

(i) At branch connections into the fabrication area.

(ii) At entries into exit corridors.

Excess flow valves shall be installed as required by the Fire Code.

F. Electrical wiring and equipment located in the piping space shall be approved for Class I, Division 2 Hazardous Locations.

**EXCEPTION:** Occasional transverse crossings of the corridors by supply piping which is enclosed within a ferrous pipe or tube for the width of the corridor need not comply with Items A through F.

3. **Identification.** Piping, tubing and HPM waste lines shall be identified in accordance with nationally recognized standards to indicate the material being transported.

## Heliports

**Sec. 912.** Heliports may be erected on buildings or other locations if they are constructed in accordance with this chapter and with Section 710.



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# TABLE NO. 9-A—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS, LIQUIDS AND CHEMICALS PRESENTING A PHYSICAL HAZARD

## BASIC QUANTITIES PER CONTROL AREA[1]

**When two units are given, values within parantheaes are in cubic feet (Cu. Ft.) or pounds (Lbs.)**

| CONDITION | | STORAGE[2] | | | USE[2] — CLOSED SYSTEMS | | | USE[2] — OPEN SYSTEMS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MATERIAL | CLASS | Solid Lbs. (Cu. Ft.) | Liquid Gallons (Lbs.) | Gas Cu. Ft. | Solid Lbs. (Cu. Ft.) | Liquid Gallons (Lbs.) | Gas Cu. Ft. | Solid Lbs. (Cu. Ft.) | Liquid Gallons (Lbs.) | Gas Cu. Ft. |
| 1.1 Combustible liquid[3] | II | — | 120[4 5] | — | — | 120[4] | — | — | 30[4] | — |
| | III-A | — | 330[4 5] | — | — | 330[4] | — | — | 80[4] | — |
| | III-B | — | 13,200[5 6] | — | — | 13,200[6] | — | — | 3,300[6] | — |
| 1.2 Combustible dust lbs./1000 cu. ft. | | 1[7] | — | — | 1[7] | — | — | 1[7] | — | — |
| 1.3 Combustible fiber (loose) | | (100)[1] | — | — | (100) | — | — | (20) | — | — |
| (baled) | | (1,000) | — | — | (1,000) | — | — | (200) | — | — |
| 1.4 Cryogenic, flammable or oxidizing | | — | 45 | — | — | 45 | — | — | 10 | — |
| 2.1 Explosives | | 1[5 8 9] | (1)[5 8 9] | — | 1/4[8] | (1/4)[8] | — | 1/4[8] | (1/4)[8] | — |
| 3.1 Flammable solid | | 125[4 5] | — | — | 25[4] | — | — | 25[4] | — | — |
| 3.2 Flammable gas (gaseous) | | — | — | 750[4 5] | — | — | 750[4 5] | — | — | — |
| (liquefied) | | — | 15[4 5] | — | — | 15[4 5] | — | — | — | — |
| 3.3 Flammable liquid[3] | I-A | — | 30[4 5] | — | — | 30[4] | — | — | 10[4] | — |
| | I-B | — | 60[4 5] | — | — | 60[4] | — | — | 15[4] | — |
| | I-C | — | 90[4 5] | — | — | 90[4] | — | — | 20[4] | — |
| Combination I-A, I-B, I-C | | — | 120[4 5 10] | — | — | 120[4 10] | — | — | 30[4 10] | — |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 Organic peroxide, unclassified detonatable | | 1[5,8] | (1)[5,8] | — | 1/4[8] | (1/4)[8] | — | 1/4[8] | (1/4)[8] | — |
| 4.2 Organic peroxide | I | 5[4,5] | (5)[4,5] | — | (1)[4] | (1)[4] | — | 1[4] | 1[4] | — |
| | II | 50[4,5] | (50)[4,5] | — | 50[4] | (50)[4] | — | 10[4] | (10)[4] | |
| | III | 125[4,5] | (125)[4,5] | — | 125[4] | (125)[4] | — | 25[4] | (25)[4] | — |
| | IV | 500 | (500) | — | 500[4] | (500) | — | 100 | (100) | — |
| | V | N.L. | N.L. | — | N.L. | N.L. | — | N.L. | N.L. | — |
| 4.3 Oxidizer | 4 | 1[5,8] | (1)[5,8] | — | 1/4[8] | (1/4)[8] | — | 1/4[8] | (1/4)[8] | — |
| | 3 | 10[4,5] | (10)[4,5] | — | 2[4] | (2)[4] | — | 2[4] | (2)[4] | — |
| | 2 | 250[4,5] | (250)[4,5] | — | 250[4] | (250)[4] | — | 50[4] | (50)[4] | — |
| | 1 | 1,000[4,5] | (1,000)[4,5] | — | 1,000[4] | (1,000)[4] | — | 200[4] | (200)[4] | — |
| 4.4 Oxidizer—Gas | | | | | | | | | | |
| (gaseous) | | — | — | 1,500[4,5] | — | — | 1,500[4,5] | — | — | — |
| (liquefied) | | — | 15[4,5] | — | — | 15[4,5] | — | — | — | — |
| 5.1 Pyrophoric | | 4[5,8] | (4)[5,8] | 50[5,8] | 1[8] | (1)[8] | 10[5,8] | 0 | 0 | 0 |
| 6.1 Unstable (reactive) | 4 | 1[5,8] | (1)[5,8] | 10[5,8] | 1/4[8] | (1/4)[8] | 2[5,8] | 1/4[8] | (1/4)[8] | 0 |
| | 3 | 5[4,5] | (5)[4,5] | 50[4,5] | 1[4] | (1)[4] | 10[4,5] | 1[4] | (1)[4] | 0 |
| | 2 | 50[4,5] | (50)[4,5] | 250[4,5] | 50[4] | (50)[4] | 250[4,5] | 10[4] | (10)[4] | 0 |
| | 1 | 125[4,5] | (125)[4,5] | 750[4,5] | 125[4] | (125)[4] | 750[4,5] | 25[4] | (25)[4] | 0 |
| 7.1 Water (reactive) | 3 | 5[4,5] | (5)[4,5] | — | 5[4] | (5)[4] | — | 1[4] | (1)[4] | — |
| | 2 | 50[4,5] | (50)[4,5] | — | 50[4] | (50)[4] | — | 10[4] | (10)[4] | — |
| | 1 | 125[5,6] | (125)[5,6] | — | 125[6] | (125)[5,6] | — | 25[6] | (25)[6] | — |

N.L. = Not limited.

[1]Control area is a space bounded by not less than a one-hour fire-resistive occupancy separation within which the exempted amounts of hazardous materials may be stored dispensed, handled or used. The number of control areas within a building used for retail and wholesale stores shall not exceed two. The number of control areas in buildings with other uses shall not exceed four.

[2]The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

[3]The quantities of alcoholic beverages in retail sales uses are unlimited provided the liquids are packaged in individual containers not exceeding four liters.

The quantities of medicines, foodstuffs and cosmetics containing not more than 50 percent of volume of water-miscible liquids and with the

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remainder of the solutions not being flammable in retail sales or storage occupancies are unlimited when packaged in individual containers not exceeding four liters.

[4]Quantities may be increased 100 percent in sprinklered buildings. When Footnote 5 also applies, the increase for both footnotes may be applied.

[5]Quantities may be increased 100 percent when stored in approved storage cabinets or safety cans as specified in the Fire Code. When Footnote 4 also applies, the increase for both footnotes may be applied.

[6]The quantities permitted in a sprinklered building are not limited.

[7]A dust explosion potential is considered to exist if 1 pound or more of combustible dust per 1,000 cubic feet of volume is normally in suspension or could be put into suspension in all or a portion of an enclosure or inside pieces of equipment. This also includes combustible dust which accumulates on horizontal surfaces inside buildings or equipment and which could be put into suspension by an accident, sudden force or small explosion.

[8]Permitted in sprinklered buildings only. None is allowed in unsprinklered buildings.

[9]One pound of black sporting powder and 20 pounds of smokeless powder are permitted in sprinklered or unsprinklered buildings.

[10]Containing not more than the exempt amounts of Class I-A, Class I-B or Class I-C flammable liquids.



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## TABLE NO. 9-B—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS, LIQUIDS AND CHEMICALS PRESENTING A HEALTH HAZARD

### MAXIMUM QUANTITIES PER CONTROL AREA[1] [2]

**When two units are given, values within parentheses are in pounds (Lbs.)**

| MATERIAL[4] | STORAGE[3] | | | USE[3]—CLOSED SYSTEMS | | | USE[3]—OPEN SYSTEMS | | |
|---|---|---|---|---|---|---|---|---|---|
| | Solid Lbs.[5] [6] | Liquid Gallons[5] [6] (Lbs.) | Gas Cu. Ft.[5] | Solid Lbs.[5] | Liquid Gallons[5] (Lbs.) | Gas Cu. Ft. | Solid Lbs.[5] | Liquid Gallons[5] (Lbs.) | Gas Cu. Ft. |
| 1. Corrosives | 5,000 | 500 | 650[6] | 5,000 | 500 | 650[5] | 1,000 | 100 | — |
| 2. Highly Toxics[8] | 1 | (1) | 20[7] | 1 | (1) | 20[7] | 1/4 | (1/4) | — |
| 3. Irritants | 5,000 | 500 | 650[6] | 5,000 | 500 | 650[5] | 1,000 | 100 | — |
| 4. Sensitizers | 5,000 | 500 | 650[6] | 5,000 | 500 | 650[5] | 1,000 | 100 | — |
| 5. Other Health Hazards | 5,000 | 500 | 650[6] | 5,000 | 500 | 650[5] | 1,000 | 100 | — |

[1]Control area is a space bounded by not less than one-hour fire-resistive occupancy separation within which the exempted amounts of hazardous materials may be stored, dispensed, handled or used. The number of control areas within retail and wholesale stores shall not exceed two and the number of control areas in other uses shall not exceed four.

[2]The quantities of medicines, foodstuffs and cosmetics, containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solutions not being flammable, in retail sales uses are unlimited when packaged in individual containers not exceeding 4 liters.

[3]The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

[4]For carcinogenic and radioactive materials, see the Fire Code.

[5]Quantities may be increased 100 percent in sprinklered buildings. When Footnote 6 also applies, the increase for both footnotes may be applied.

[6]Quantities may be increased 100 percent when stored in approved storage cabinets or safety cans as specified in the fire code. When Footnote 5 also applies, the increase for both footnotes may be applied.

[7]Permitted only when stored in approved exhausted gas cabinets, exhausted enclosures or fume hoods.

[8]For special provisions, see the Fire Code.





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## TABLE NO. 9-C—DISTANCE FROM PROPERTY LINES, WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY

| OCCUPANCY GROUP | MINIMUM DISTANCE FROM PROPERTY LINE[1] | FIRE RESISTANCE OF EXTERIOR WALLS | OPENINGS IN EXTERIOR WALLS[2] |
|---|---|---|---|
| H-1 Detached building required | 75 feet<br>See Table No. 9-D | No requirement based on location | No requirement based on location |
| H-2-3 Not in a detached building | 30 feet when the area exceeds 1,500 sq. ft.[3] | 4 hours less than 5 feet,<br>2 hours less than 10 feet,<br>1 hour less than 20 feet | Not permitted less than 5 feet, protected less than 20 feet |
| H-2-3 When detached building is required[4] | 50 feet<br>See Table No. 9-D | No requirement based on location | No requirement based on location |
| H-4[5]—6-7. | No requirement | 4 hours less than 5 feet,<br>2 hours less than<br>10 ft., 1 hour less than 20 feet. | Not permitted less than 5 feet, protected less than 20 feet. |
| H-5 | No requirement | 1 hour less than 60 feet | Protected less than 60 feet |

[1]The distance specified is the distance from the walls enclosing the occupancy to all property lines including those on a public way.

[2]When protected openings are specified, the protection shall be by a fire assembly having a fire-protection rating of not less than three-fourths hour.

[3]Walls or portions of walls used for explosion venting shall be located not less than 50 feet from any property line including those on a public way.

[4]Detached buildings are required for storage of quantities of materials which exceed the amounts specified in Table No. 9-E.

[5]A Group H, Division 4 Occupancy having a floor area not exceeding 2,500 square feet may have exterior walls of not less than two-hour fire-resistive construction when less than 5 feet from a property line and of not less than one-hour fire-resistive construction when more than 5 feet but less than 20 feet from a property line.



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## TABLE NO. 9-D—MINIMUM DISTANCES FOR STORAGE OF EXPLOSIVE MATERIALS

| QUANTITY OF EXPLOSIVE MATERIAL[1] | | MINIMUM DISTANCE (Feet) | |
|---|---|---|---|
| Pounds Over | Pounds Not Over | Property lines[2 3] and Inhabited Buildings[4] | Separation of Magazines[3 4 5] |
| 2 | 5 | 140 | 12 |
| 5 | 10 | 180 | 16 |
| 10 | 20 | 220 | 20 |
| 20 | 30 | 250 | 22 |
| 30 | 40 | 280 | 24 |
| 40 | 50 | 300 | 28 |
| 50 | 75 | 340 | 30 |
| 75 | 100 | 380 | 32 |
| 100 | 125 | 400 | 36 |
| 125 | 150 | 430 | 38 |
| 150 | 200 | 470 | 42 |
| 200 | 250 | 510 | 46 |
| 250 | 300 | 540 | 48 |
| 300 | 400 | 590 | 54 |
| 400 | 500 | 640 | 58 |
| 500 | 600 | 680 | 62 |
| 600 | 700 | 710 | 64 |
| 700 | 800 | 750 | 66 |
| 800 | 900 | 780 | 70 |
| 900 | 1,000 | 800 | 72 |
| 1,000 | 1,200 | 850 | 78 |
| 1,200 | 1,400 | 900 | 82 |
| 1,400 | 1,600 | 940 | 86 |
| 1,600 | 1,800 | 980 | 88 |
| 1,800 | 2,000 | 1,010 | 90 |
| 2,000 | 2,500 | 1,090 | 98 |
| 2,500 | 3,000 | 1,160 | 104 |
| 3,000 | 4,000 | 1,270 | 116 |
| 4,000 | 5,000 | 1,370 | 122 |
| 5,000 | 6,000 | 1,460 | 130 |
| 6,000 | 7,000 | 1,540 | 136 |
| 7,000 | 8,000 | 1,600 | 144 |
| 8,000 | 9,000 | 1,670 | 150 |
| 9,000 | 10,000 | 1,730 | 156 |
| 10,000 | 12,000 | 1,750 | 164 |
| 12,000 | 14,000 | 1,770 | 174 |
| 14,000 | 16,000 | 1,800 | 180 |
| 16,000 | 18,000 | 1,880 | 188 |
| 18,000 | 20,000 | 1,950 | 196 |
| 20,000 | 25,000 | 2,000 | 210 |
| 25,000 | 30,000 | 2,000 | 224 |
| 30,000 | 35,000 | 2,000 | 238 |
| 35,000 | 40,000 | 2,000 | 248 |
| 40,000 | 45,000 | 2,000 | 258 |
| 45,000 | 50,000 | 2,000 | 270 |

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## TABLE NO. 9-D—MINIMUM DISTANCES FOR STORAGE OF EXPLOSIVE MATERIALS—(Continued)

| QUANTITY OF EXPLOSIVE MATERIAL[1] | | MINIMUM DISTANCE (Feet) | |
|---|---|---|---|
| Pounds Over | Pounds Not Over | Property lines[2 3] and Inhabited Buildings[4] | Separation of Magazines[3 4 5] |
| 50,000 | 55,000 | 2,000 | 280 |
| 55,000 | 60,000 | 2,000 | 290 |
| 60,000 | 65,000 | 2,000 | 300 |
| 65,000 | 70,000 | 2,000 | 310 |
| 70,000 | 75,000 | 2,000 | 320 |
| 75,000 | 80,000 | 2,000 | 330 |
| 80,000 | 85,000 | 2,000 | 340 |
| 85,000 | 90,000 | 2,000 | 350 |
| 90,000 | 95,000 | 2,000 | 360 |
| 95,000 | 100,000 | 2,000 | 370 |
| 100,000 | 110,000 | 2,000 | 390 |
| 110,000 | 120,000 | 2,000 | 410 |
| 120,000 | 130,000 | 2,000 | 430 |
| 130,000 | 140,000 | 2,000 | 450 |
| 140,000 | 150,000 | 2,000 | 470 |
| 150,000 | 160,000 | 2,000 | 490 |
| 160,000 | 170,000 | 2,000 | 510 |
| 170,000 | 180,000 | 2,000 | 530 |
| 180,000 | 190,000 | 2,010 | 550 |
| 190,000 | 200,000 | 2,030 | 570 |
| 200,000 | 210,000 | 2,055 | 590 |
| 210,000 | 230,000 | 2,100 | 630 |
| 230,000 | 250,000 | 2,155 | 670 |
| 250,000 | 275,000 | 2,215 | 720 |
| 275,000 | 300,000 | 2,275 | 770 |

[1]The number of pounds of explosives listed is the number of pounds of trinitrotoluene (TNT) or the equivalent pounds of other explosive.

[2]The distanee listed is the distance to property line including property lines at public ways.

[3]The distance listed may be redueed by 50 percent when approved natural or artificial barriers are provided. Barriers shall effectively screen the building containing explosives from other buildings, public ways or magazines. When mounds or rivetted walls of earth are used for barriers, they shall not be less than 3 feet in thickness. A straight line from the top of any sidewall of the building containing explosive materials to the eave line of any other building, magazine or a point 12 feet above the centerline of a public way shall pass through the barrier.

[4]Inhabited building is any building on the same property which is regularly occupied by human beings. When two or more buildings containing explosives or magazines are located on the same property, each building or magazine shall comply with the minimum distances specified from inhabited buildings, and, in addition, they should be separated from each other by not less than the distances shown for "Separation of Magazines," except that the quantity of explosive materials contained in detonator buildings or magazines shall govern in regard to the spacing of said detonator buildings or magazines from buildings or magazines containing other explosive materials. If any two or more buildings or magazines are separated from each other by less than the specified "Separation of Magazines" distances, then such two or more buildings or magazines, as a group shall be considered as one building or magazine, and the total quantity of explosive materials stored in such group shall be treated as if the explosive was in a single building or

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magazine located on the site of any building or magazine of the group, and shall comply with the minimum of distances specified from other magazines or inhabited buildings.

[5]Magazine is a building or structure approved for storage of explosive material. In addition to the requirements of this code, magazines shall comply with the Fire Code.

## TABLE NO. 9-E—REQUIRED DETACHED STORAGE

| DETACHED STORAGE IS REQUIRED WHEN THE QUANTITY OF MATERIAL EXCEEDS THAT LISTED | | | |
|---|---|---|---|
| Material | | Solids and Liquids (Tons)[1] [2] | Gases (Cubic Feet)[1] [2] |
| 1. Explosives, blasting agents, black powder, fireworks, detonatable organic peroxides,<br>2. Class 4 oxidizers,<br>3. Class 4 or Class 3 detonatable unstable (reactives) | | Over exempt amounts | Over exempt amounts |
| 4. Oxidizers, liquids and solids | Class 3 | 25 | — |
| | Class 2 | 50 | — |
| 5. Organic peroxides | Class I | Over exempt amounts | — |
| | Class II | 25 | — |
| | Class III | 50 | — |
| 6. Unstable (reactives) | Class 4 | 1/1,000 | 20 |
| | Class 3 | 1 | 2,000 |
| | Class 2 | 25 | 10,000 |
| 7. Water reactives | Class 3 | 1 | 2,000 |
| | Class 2 | 25 | 10,000 |
| 8. Pyrophoric gases | | — | 2,000 |

[1]Distance to other buildings or property lines shall be as specified in Table No. 9-D based on TNT equivalence of the material.

[2]Over exempt amounts mean over the quantities listed in Table No. 9-A.



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# Chapter 10
# REQUIREMENTS FOR GROUP I OCCUPANCIES

## Group I Occupancies Defined

**Sec. 1001.** Group I Occupancies shall be:

**Division 1.** Nurseries for the full-time care of children under the age of six (each accommodating more than five persons).

Hospitals, sanitariums, nursing homes with nonambulatory patients and similar buildings (each accommodating more than five persons).

**Division 2.** Nursing homes for ambulatory patients, homes for children six years of age or over (each accommodating more than five persons).

**Division 3.** Mental hospitals, mental sanitariums, jails, prisons, reformatories and buildings where personal liberties of inmates are similarly restrained.

For occupancy separations, see Table No. 5-B.

**EXCEPTION:** Group I Occupancies shall not include buildings used only for private residential purposes for a family group.

## Construction, Height and Allowable Area

**Sec. 1002.** (a) **General.** Buildings or parts of buildings classed in Group I because of the use or character of the occupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507.

**EXCEPTIONS:** 1. Hospitals and nursing homes classified as Group I, Division 1 Occupancies that are equipped with an automatic sprinkler system throughout shall not exceed one story in height when in Type III One-hour, Type IV or Type V One-hour construction.

2. Hospitals and nursing homes classified as Group I, Division 1 Occupancies that are equipped with automatic sprinkler systems throughout may be five stories when of Type II-F.R. construction and three stories when of Type II One-hour construction. The allowable area increase specified in Section 506 (c) applies only when the number of stories in the building is one less than set forth above.

3. Hospitals and nursing homes classified as Group I, Division 1 Occupancies that are equipped with automatic sprinkler systems throughout may be housed within one-story buildings of Type II-N construction. The area of such building shall not exceed 13,500 square feet plus the allowable area increase for separation by public space or yards as set forth in Section 506 (a).

(b) **Special Provisions.** Division 3 Occupancies shall be housed in buildings of Type I or Type II-F.R. construction.

**EXCEPTION:** One-story buildings of Type II One-hour, Type III One-hour, or V One-hour construction may be permitted, provided the floor area does not exceed 3900 square feet between separation walls of two-hour fire-resistive construction with openings protected by fire assemblies having one and one-half-hour fire-protection rating.

Floor levels of Group I, Division 1 Occupancies used by inpatients for sleeping or treatment, or having an occupant load of 50 or more, shall be divided into at



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least two compartments by smoke barriers. The area within a smoke compartment shall not exceed 22,500 square feet nor shall its width or length exceed 150 feet. The area of a smoke compartment shall not be less than that required to accommodate the occupants of the compartment plus the occupants from the adjoining compartments, assuming not less than 30 square feet net clear floor area for bed and litter patients and 6 square feet for other occupants.

Smoke barriers shall have a fire-resistance rating of not less than one hour. Such barriers shall form an effective membrane continuous from outside wall to outside wall, from a smoke barrier to a smoke barrier, from floor to floor or roof above, or a combination thereof, including continuity through all concealed spaces, such as above suspended ceilings, interstitial structural and mechanical spaces. Transfer grilles, louvers and similar openings shall not be used in these partitions.

Doors in smoke barriers shall be tight-fitting smoke- and draft-control assemblies having a fire-protection rating of not less than 20 minutes and shall comply with Section 3321 (b). When doors are installed across corridors a pair of opposite swinging doors without a center mullion shall be installed. Smoke barrier doors shall:

1. When installed across corridors, have vision panels of not less than 1/4-inch-thick approved wired glass in steel frames. The area of the vision panels shall not exceed that tested.
2. Be close fitting with only the clearance necessary for proper operation and shall be without undercuts, louvers or grilles.
3. Doors shall have stops at the head and jambs. Opposite swinging corridor doors shall have rabbets or astragals at the meeting edges.
4. Have positive latching devices except on doors installed across corridors.
5. Be self-closing or automatic closing. An approved sign shall be on or adjacent to self-closing doors specifying that they are to be maintained in a closed position. Doors installed across corridors shall comply with Section 4306 (f) 1, Item C, and doors on the floor or in the affeeted zone shall automatically close if the fire alarm or sprinkler system is activated.

An approved damper designed to resist the passage of smoke shall be provided at each point a duct penetrates a smoke barrier. The damper shall close upon detection of smoke by an approved smoke detector located within the duct.

**EXCEPTIONS:** 1. In lieu of an approved smoke detector located within the duct, ducts which penetrate smoke barriers above required smoke-barrier doors are permitted to have the approved damper arranged to close upon detection of smoke by the local device designed to detect smoke on either side of the smoke-barrier door opening.

2. Dampers are not required where the openings in ducts are limited to a single smoke compartment and the ducts are of steel construction.

At least two exits shall be provided from each smoke compartment. Exits may be through adjaeent compartments, provided at least one exit does not return through the compartment from which exiting originated.

Rooms occupied by inmates or patients whose personal liberties are restrained shall have noncombustible floor surfaces.



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Medical gas systems shall be installed and maintained in accordance with the Fire Code. When nonflammable supply cylinders for such systems are located inside buildings they shall be in a separate room or enclosure separated from the rest of the building by not less than one-hour fire-resistive construction. Doors to the room or enclosure shall be self-closing smoke- and draft-control assemblies having a fire-protection rating of not less than one-hour. Rooms shall have at least one exterior wall in which there are not less than two vents of not less than 36 square inches in area. One vent shall be within 6 inches of the floor and one shall be within 6 inches of the ceiling.

**EXCEPTION:** When an exterior wall cannot be provided, the room shall be vented to the exterior through ducting contained within a one-hour-rated shaft enclosure. Approved mechanical ventilation shall provide six air changes per hour for the room.

## Location on Property

**Sec. 1003.** For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Exit Facilities

**Sec. 1004.** Stairs, exits and smokeproof enclosures shall be provided as specified in Chapter 33. (See also Section 3321.)

## Light, Ventilation and Sanitation

**Sec. 1005.** All portions of Group I Occupancies customarily used by human beings shall be provided with natural light by means of exterior glazed openings with an area equal to one tenth of the total floor area, and natural ventilation by means of exterior openings with an area not less than one twentieth of the total floor area, or shall be provided with artificial light and a mechanically operated ventilating system as specified in Section 605.

For other requirements on water closets, see Section 510.

## Shaft and Exit Enclosures

**Sec. 1006.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts and other vertical openings shall be enclosed, and the enclosure shall be as specified in Section 1706.

## Sprinkler and Standpipe Systems

**Sec. 1007.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

## Special Hazards

**Sec. 1008.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

Motion picture projection rooms shall conform to the requirements of Chapter 40.



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Specific use areas shall be separated from Group I, Division 1 Occupancies used for hospitals or nursing homes in accordance with Table No. 10-A. Doors shall be maintained self-closing or shall be automatic-closing by actuation of a smoke detector.

Storage and the handling of flammable and combustible liquids shall be in accordance with the Fire Code.

All exterior openings in a boiler room or room containing central heating equipment if located below openings in another story, or if less than 10 feet from the other doors or windows of the same building, shall be protected by a fire assembly having a three-fourths-hour fire-protection rating. Such fire assemblies shall be fixed, automatic- or self-closing. Every room containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

## Fire Alarms

**Sec. 1009.** An approved fire alarm system shall be provided for all Group I Occupancies. Audible alarm devices shall be used in all nonpatient areas. Visible alarm devices may be used in lieu of audible devices in patient-occupied areas.

## Smoke Detectors

**Sec. 1010.** Smoke detectors which receive their primary power from the building wiring shall be installed in patient sleeping rooms of hospital and nursing homes. Actuation of such detectors shall cause a visual display on the corridor side of the room in which the detector is located and shall cause an audible and visual alarm at the respective nurses' station. If such detectors and related devices are combined with the nursing call system, the total system need not be electrically supervised.

**EXCEPTION:** In rooms equipped with automatic door closers having integral smoke detectors on the room side, the integral detector may substitute for the room smoke detector, provided it performs the required alerting functions.



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## TABLE NO. 10-A—REQUIRED SEPARATION OF SPECIFIC USE AREAS

| DESCRIPTION | OCCUPANCY SEPARATION |
|---|---|
| 1. Employee locker rooms | none |
| 2. Gift/retail shops | none |
| 3. Handicraft shops | none |
| 4. Kitchens | none |
| 5. Laboratories which employ hazardous materials in quantities less than that which would cause classification as a Group H Occupancy | One hour |
| 6. Laundries greater than 100 sq. ft. | One hour |
| 7. Paint shops employing hazardous substances and materials in quantities less than that which would cause classification as a Group H Occupancy | One hour |
| 8. Physical plant maintenance shop | One hour |
| 9. Soiled linen room | One hour |
| 10. Storage rooms 100 sq. ft. or less in area storing combustible material | none |
| 11. Storage rooms more than 100 sq. ft. storing combustible material | One hour |
| 12. Trash-collection rooms | One hour |



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# Chapter 11

# REQUIREMENTS FOR GROUP M OCCUPANCIES

## Group M Occupancies Defined

**Sec. 1101.** Group M Occupancies shall be:

**Division 1.** Private garages, carports, sheds and agricultural buildings.

**EXCEPTION:** Where applicable (see Section 103) for agricultural buildings, see Appendix Chapter 11.

**Division 2.** Fences over 6 feet high, tanks and towers.

For occupancy separations, see Table No. 5-B.

## Construction, Height and Allowable Area

**Sec. 1102.** (a) **General.** Buildings or parts of buildings classed as Group M, Division 1 Occupancies because of the use or character of the occupancy shall not exceed 1000 square feet in area or one story in height except as provided in Subsection (b). Any building or portion thereof that exceeds the limitations specified in this chapter shall be classed in the occupancy group other than Group M, Division 1 that it most nearly resembles.

(b) **Special Area Provisions.** The total area of a private garage used only as a parking garage for private or pleasure-type motor vehicles where no repair work is done nor fuel dispensed may be 3000 square feet, provided the provisions set forth in Items 1 or 2 below are satisfied. More than one 3000-square-foot Group M, Division 1 Occupancy may be within the same building, provided each 3000-square-foot area is separated by area separation walls complying with Section 505 (e).

1. For a mixed-occupancy building, the exterior wall and opening protection for the Group M, Division 1 portion of the building shall be as required for the major occupancy of the building. For such mixed-occupancy building, the allowable floor area of the building shall be as permitted for the major occupancy contained therein.
2. For a building containing only a Group M, Division 1 Occupancy, the exterior wall and opening protection shall be as required for a building classified as a Group R, Division 1 Occupancy.

(c) **Headroom Clearance.** Garages in connection with Group R, Division 1 Occupancies shall have an unobstructed headroom clearance of not less than 7 feet above the finish floor to any ceiling, beam, pipe or similar construction except for wall-mounted shelves, storage surfaces, racks or cabinets.

## Location on Property

**Sec. 1103.** For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Special Hazards

**Sec. 1104.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 and the Mechanical Code.



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Under no circumstances shall a private garage have any opening into a room used for sleeping purposes.

Class I, II or III-A liquids shall not be stored, handled or used in Group M Occupancies unless such storage or handling shall comply with the Fire Code.

### Garage Floor Surfaces

**Sec. 1105.** In areas where motor vehicles are stored or operated, floor surfaces shall be of noncombustible materials or asphaltic paving materials.

### Agricultural Buildings

**Sec. 1106.** Where applicable (see Section 103) for agricultural buildings, see Appendix Chapter 11.



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# Chapter 12
# REQUIREMENTS FOR GROUP R OCCUPANCIES

## Group R Occupancies Defined

**Sec. 1201.** Group R Occupancies shall be:

**Division 1.** Hotels and apartment houses.

Convents and monasteries (each accommodating more than 10 persons).

**Division 2.** Not used.

**Division 3.** Dwellings and lodging houses.

For occupancy separations, see Table No. 5-B.

A complete code for construction of detached one- and two-family dwellings is in Appendix Chapter 12 of this code. When adopted, as set forth in Section 103, it will take precedence over the requirements set forth in Parts I through X and Chapter 60 of this code.

## Construction, Height and Allowable Area

**Sec. 1202.** (a) **General.** Buildings or parts of buildings classed in Group R because of the use or character of the occupancy shall be limited to the types of construction set forth in Tables No. 5-C and No. 5-D and shall not exceed, in area or height, the limits specified in Sections 505, 506 and 507.

(b) **Special Provisions.** Walls and floors separating dwelling units in the same building shall be of not less than one-hour fire-resistive construction.

Group R, Division 1 Occupancies more than two stories in height or having more than 3000 square feet of floor area above the first story shall be of not less than one-hour fire-resistive construction throughout except as provided in Section 1705 (b) 2.

Storage or laundry rooms that are within Group R, Division 1 Occupancies that are used in common by tenants shall be separated from the rest of the building by not less than one-hour fire-resistive occupancy separation.

For Group R, Division 1 Occupancies with a Group B, Division 1 parking garage in the basement or first floor, see Section 702 (a).

For attic space partitions and draft stops, see Section 2516 (f).

## Location on Property

**Sec. 1203.** For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

## Exits and Emergency Escapes

**Sec. 1204.** Stairs, exits and smokeproof enclosures shall be as specified in Chapter 33.

Basements in dwelling units and every sleeping room below the fourth story shall have at least one operable window or door approved for emergency escape or rescue which shall open directly into a public street, public alley, yard or exit court. The units shall be operable from the inside to provide a full clear opening without the use of separate tools.



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All escape or rescue windows shall have a minimum net clear openable area of 5.7 square feet. The minimum net clear openable height dimension shall be 24 inches. The minimum net clear openable width dimension shall be 20 inches. When windows are provided as a means of escape or rescue they shall have a finished sill height not more than 44 inches above the floor.

Bars, grilles, grates or similar devices may be installed on an emergency escape or rescue windows or doors, provided:

1. Such devices are equipped with approved release mechanisms which are openable from the inside without the use of a key or special knowledge or effort; and
2. The building is equipped with smoke detectors installed in accordance with Section 1210.

## Light, Ventilation and Sanitation

**Sec. 1205.** (a) **General.** For the purpose of determining the light or ventilation required by this section, any room may be considered as a portion of an adjoining room when one half of the area of the common wall is open and unobstructed and provides an opening of not less than one tenth of the floor area of the interior room or 25 square feet, whichever is greater.

Exterior openings for natural light or ventilation required by this section shall open directly onto a public way or a yard or court located on the same lot as the building.

**EXCEPTION:** Required windows may open into a roofed porch where the porch:

1. Abuts a public way, yard or court; and
2. Has a ceiling height of not less than 7 feet; and
3. Has the longer side at least 65 percent open and unobstructed.

(b) **Light.** All guest rooms, dormitories and habitable rooms within a dwelling unit shall be provided with natural light by means of exterior glazed openings with an area not less than one tenth of the floor area of such rooms with a minimum of 10 square feet.

(c) **Ventilation.** All guest rooms, dormitories and habitable rooms within a dwelling unit shall be provided with natural ventilation by means of openable exterior openings with an area of not less than one twentieth of the floor area of such rooms with a minimum of 5 square feet.

In lieu of required exterior openings for natural ventilation, a mechanical ventilating system may be provided. Such system shall be capable of providing two air changes per hour in all guest rooms, dormitories, habitable rooms and in public corridors. One fifth of the air supply shall be taken from the outside.

All bathrooms, water closet compartments, laundry rooms and similar rooms shall be provided with natural ventilation by means of openable exterior openings with an area not less than one twentieth of the floor area of such rooms with a minimum of 1 1/2 square feet.

In lieu of required exterior openings for natural ventilation in bathrooms containing a bathtub or shower or combination thereof, laundry rooms, and



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similar rooms, a mechanical ventilation system connected directly to the outside capable of providing five air changes per hour shall be provided. The point of discharge of exhaust air shall be at least 5 feet from any mechanical ventilating intake. Bathrooms which contain only a water closet or lavatory or combination thereof, and similar rooms may be ventilated with an approved mechanical recirculating fan or similar device designed to remove odors from the air.

(d) **Sanitation.** Every building shall be provided with at least one water closet. Every hotel or subdivision thereof where both sexes are accommodated shall contain at least two separate toilet facilities which are conspicuously identified for male or female use, each of which contains at least one water closet.

**EXCEPTION:** Hotel guest rooms may have one unidentified toilet facility.

Additional water closets shall be provided on each floor for each sex at the rate of one for every additional 10 guests, or fractional part thereof, in excess of 10.

Every dwelling unit shall be provided with a kitchen equipped with a kitchen sink. Every dwelling unit and every lodging house shall be provided with a bathroom equipped with facilities consisting of a water closet, lavatory and either a bathtub or shower. Each sink, lavatory and either a bathtub or shower shall be equipped with hot and cold running water necessary for its normal operation.

For other requirements on water closets, see Section 511.

## Yards and Courts

**Sec. 1206.** (a) **Scope.** This section shall apply to yards and courts having required windows opening therein.

(b) **Yards.** Every yard shall be not less than 3 feet in width for one-story and two-story buildings. For buildings more than two stories in height, the minimum width of the yard shall be increased at the rate of 1 foot for each additional story. For buildings exceeding 14 stories in height, the required width of yard shall be computed on the basis of 14 stories.

(c) **Courts.** Every court shall be not less than 3 feet in width. Courts having windows opening on opposite sides shall be not less than 6 feet in width. Courts bounded on three or more sides by the walls of the building shall be not less than 10 feet in length unless bounded on one end by a public way or yard. For buildings more than two stories in height, the court shall be increased 1 foot in width and 2 feet in length for each additional story. For buildings exceeding 14 stories in height, the required dimensions shall be computed on the basis of 14 stories.

Adequate access shall be provided to the bottom of all courts for cleaning purposes. Every court more than two stories in height shall be provided with a horizontal air intake at the bottom not less than 10 square feet in area and leading to the exterior of the building unless abutting a yard or public way. The construction of the air intake shall be as required for the court walls of the building, but in no case shall be less than one-hour fire resistive.

## Room Dimensions

**Sec. 1207.** (a) **Ceiling Heights.** Habitable space shall have a ceiling height of not less than 7 feet 6 inches except as otherwise permitted in this section.



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Kitchens, halls, bathrooms and toilet compartments may have a ceiling height of not less than 7 feet measured to the lowest projection from the ceiling. Where exposed beam ceiling members are spaced at less than 48 inches on center, ceiling height shall be measured to the bottom of these members. Where exposed beam ceiling members are spaced at 48 inches or more on center, ceiling height shall be measured to the bottom of the deck supported by these members, provided that the bottom of the members is not less than 7 feet above the floor.

If any room in a building has a sloping ceiling, the prescribed ceiling height for the room is required in only one-half the area thereof. No portion of the room measuring less than 5 feet from the finished floor to the finished ceiling shall be included in any computation of the minimum area thereof.

If any room has a furred ceiling, the prescribed ceiling height is required in two thirds the area thereof, but in no case shall the height of the furred ceiling be less than 7 feet.

(b) **Floor Area.** Every dwelling unit shall have at least one room which shall have not less than 120 square feet of floor area. Other habitable rooms except kitchens shall have an area of not less than 70 square feet. Efficiency dwelling units shall comply with the requirements of Section 1208.

(c) **Width.** Habitable rooms other than a kitchen shall be not less than 7 feet in any dimension.

## Efficiency Dwelling Units

**Sec. 1208.** An efficiency dwelling unit shall conform to the requirements of the code except as herein provided:

1. The unit shall have a living room of not less than 220 square feet of superficial floor area. An additional 100 square feet of superficial floor area shall be provided for each occupant of such unit in excess of two.

2. The unit shall be provided with a separate closet.

3. The unit shall be provided with a kitchen sink, cooking appliance and refrigeration facilities, each having a clear working space of not less than 30 inches in front. Light and ventilation conforming to this code shall be provided.

4. The unit shall be provided with a separate bathroom containing a water closet, lavatory and bathtub or shower.

## Shaft and Exit Enclosures

**Sec. 1209.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts, dumbwaiter shafts, clothes chutes and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 1706.

In nonsprinklered Group R, Division 1 Occupancies, corridors serving an occupant load of 10 or more shall be separated from corridors and other areas on adjacent floors by not less than approved fixed wired glass set in steel frames or by 20-minute smoke- and draft-control assemblies which are automatic-closing by smoke detection.



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## Smoke Detectors and Sprinkler Systems

**Sec. 1210.** (a) **Smoke Detectors.** 1. **General.** Dwelling units and hotel or lodging house guest rooms that are used for sleeping purposes shall be provided with smoke detectors. Detectors shall be installed in accordance with the approved manufacturer's instructions.

2. **Additions, alterations or repairs to Group R Occupancies.** When the valuation of an addition, alteration or repair to a Group R Occupancy exceeds $1000.00 and a permit is required, or when one or more sleeping rooms are added or created in existing Group R Occupancies, smoke detectors shall be installed in accordance with Subsections 3, 4 and 5 of this section.

3. **Power source.** In new construction, required smoke detectors shall receive their primary power from the building wiring when such wiring is served from a commercial source. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection. Smoke detectors may be battery operated when installed in existing buildings, or in buildings without commercial power, or in buildings which undergo alterations, repairs or additions regulated by Subsection 2 of this section.

4. **Location within dwelling units.** In dwelling units, detectors shall be mounted on the ceiling or wall at a point centrally located in the corridor or area giving access to each separate sleeping area. When the dwelling unit has more than one story and in dwellings with basements, a detector shall be installed on each story and in the basement. In dwelling units where a story or basement is split into two or more levels, the smoke detector shall be installed on the upper level, except that when the lower level contains a sleeping area, a detector shall be installed on each level. When sleeping rooms are on an upper level, the detector shall be placed at the ceiling of the upper level in close proximity to the stairway. In dwelling units where the ceiling height of a room open to the hallway serving the bedrooms exceeds that of the hallway by 24 inches or more, smoke detectors shall be installed in the hallway and in the adjacent room. Detectors shall sound an alarm audible in all sleeping areas of the dwelling unit in which they are located.

5. **Location in efficiency dwelling units and hotels.** In efficiency dwelling units, hotel suites and in hotel sleeping rooms, detectors shall be located on the ceiling or wall of the main room or hotel sleeping room. When sleeping rooms within an efficiency dwelling unit or hotel suite are on an upper level, the detector shall be placed at the ceiling of the upper level in close proximity to the stairway. When actuated, the detector shall sound an alarm audible within the sleeping area of the dwelling unit, hotel suite or sleeping room in which it is located.

(b) **Sprinkler and Standpipe Systems.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

## Fire Alarm Systems

**Sec. 1211.** A manual and automatic approved fire alarm system shall be installed in apartment houses that are three or more stories in height or contain



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more than 15 dwelling units and in hotels three or more stories in height or containing 20 or more guest rooms, in accordance with the Fire Code.

**EXCEPTIONS:** 1. A fire alarm system need not be installed in buildings not over two stories in height when all individual dwelling units and contiguous attic and crawl spaces are separated from each other and from public or common areas by at least one-hour fire-resistive occupancy separations and each individual dwelling unit or guest room has an exit direct to a public way, exit court or yard, exterior stairway or exterior exit balcony.

2. A separate fire alarm system need not be installed in buildings which are protected throughout by an approved supervised fire sprinkler system installed in accordance with U.B.C. Standard No. 38-1 and having a local alarm to notify all occupants.

For the purposes of this section, area separation walls shall not define separate buildings.

## Heating

**Sec. 1212.** Every dwelling unit and guest room shall be provided with heating facilities capable of maintaining a room temperature of 70°F. at a point 3 feet above the floor in all habitable rooms.

## Special Hazards

**Sec. 1213.** Chimneys and heating apparatus shall conform to the requirements of Chapter 37 and the Mechanical Code.

The storage and handling of gasoline, fuel oil or other flammable liquids in Division 1 Occupancies shall be in accordance with the Fire Code.

In Division 1 Occupancies, doors leading into rooms in which Class I flammable liquids are stored or used shall be protected by a fire assembly having a one-hour fire-protection rating. Such fire assembly shall be self-closing and shall be posted with a sign on each side of the door in 1-inch block letters stating: FIRE DOOR—KEEP CLOSED.

Every room containing a boiler, central heating plant or hot-water supply boiler in Division 1 Occupancies shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

**EXCEPTION:** A separation shall not be required for such rooms with equipment serving only one dwelling unit.

## Access to Buildings and Facilities

**Sec. 1214.** Buildings containing more than 20 dwelling units or 20 guest rooms shall be accessible to the physically handicapped by a level entry, ramp or elevator. The number of dwelling units or guest rooms accessible to the physically handicapped shall be not less than the following:

| | |
|---|---|
| 21 through 99 | — one unit |
| 100 and over | — one, plus one for each additional 100 units or fraction thereof |



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To determine the total number of accessible units, more than one structure on a building site shall be considered as one building. Habitable rooms, bathrooms, toilet compartments, halls and utility rooms in units that are required to be accessible to the physically handicapped shall be accessible by level floors, ramps or elevators, and doorways to such rooms shall have a clear unobstructed width of not less than 32 inches.

Toilet facilities in accessible units shall comply with Section 511.

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# Chapters 13-16
# NO REQUIREMENTS



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# *Part IV*

# REQUIREMENTS BASED ON TYPES OF CONSTRUCTION

## Chapter 17

## CLASSIFICATION OF ALL BUILDINGS BY TYPES OF CONSTRUCTION AND GENERAL REQUIREMENTS

### General

**Sec. 1701.** The requirements of Part IV are for the various types of construction and represent varying degrees of public safety and resistance to fire. Every building shall be classified by the building official into one of the types of construction set forth in Table No. 17-A. Any building which does not entirely conform to a type of construction set forth in Table No. 17-A shall be classified by the building official into a type having an equal or lesser degree of fire resistance.

A building or portion thereof shall not be required to conform to the details of a type of construction higher than that type which meets the minimum requirements based on occupancy (Part III) even though certain features of such building actually conform to a higher type of construction.

Where specific materials, types of construction or fire-resistive protection are required, such requirements shall be the minimum requirements, and any materials, types of construction or fire-resistive protection which will afford equal or greater public safety or resistance to fire, as specified in this code, may be used.

Portions of buildings separated as specified in Section 505 (e) may be considered a separate building for classification of types of construction. When there is no such separation, the area of the entire building shall not exceed the least area permitted for the types of construction involved.

### Structural Frame

**Sec. 1702.** The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and all other members which are essential to the stability of the building as a whole. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

### Usable Space Under Floors

**Sec. 1703.** Usable space under the first story shall be enclosed except in Groups R, Division 3 and M Occupancies, and such enclosure when constructed of metal or wood shall be protected on the side of the usable space as required for one-hour fire-resistive construction. Doors shall be self-closing, of noncombustible construction or solid wood core, not less than 1¾ inches in thickness.



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## Roofs

**Sec. 1704.** Roof coverings shall be as specified in Table No. 32-A.

## Exceptions to Table No. 17-A

**Sec. 1705.** (a) **General.** The provisions of this section are exceptions to the construction requirements of Table No. 17-A, Chapters 5 through 12 and 18 through 22.

(b) **Fixed Partitions.** 1. **Stores and offices.** Interior nonload-bearing partitions dividing portions of stores, offices or similar places occupied by one tenant only and which do not establish a corridor serving an occupant load that would require it to be of fire-resistive construction under the provisions of Section 3305 (g) may be constructed of:

A. Noncombustible materials.

B. Fire-retardant treated wood.

C. One-hour fire-resistive construction.

D. Wood panels or similar light construction up to three fourths the height of the room in which placed; when more than three fourths the height of the room, such partitions shall have not less than the upper one fourth of the partition constructed of glass.

2. **Hotels and apartments.** Interior nonload-bearing partitions within individual dwelling units in apartment houses and guest rooms or suites in hotels when such dwelling units, guest rooms or suites are separated from each other and from corridors by not less than one-hour fire-resistive construction may be constructed of:

A. Noncombustible materials or fire-retardant-treated wood in buildings of any type of construction; or

B. Combustible framing with noncombustible materials applied to the framing in buildings of Type III or V construction.

Openings to such corridors shall be equipped with doors conforming to Section 3305 (h) regardless of the occupant load served.

For use of plastics in partitions, see Section 5210.

(c) **Folding, Portable or Movable Partitions.** Approved folding, portable or movable partitions need not have a fire-resistive rating, provided:

1. They do not block required exits (without providing alternative conforming exits) and they do not establish an exit corridor.

2. Their location is restricted by means of permanent tracks, guides or other approved methods.

3. Flammability shall be limited to materials having a flame-spread classification as set forth in Table No. 42-B for rooms or areas.

(d) **Walls Fronting on Streets or Yards.** Regardless of fire-resistive requirements for exterior walls, certain elements of the walls fronting on streets or yards having a width of 40 feet may be constructed as follows:

1. Bulkheads below show windows, show-window frames, aprons and show-



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cases may be of combustible materials, provided the height of such construction does not exceed 15 feet above grade.

2. Wood veneer of boards not less than 1-inch nominal thickness or exterior-type panels not less than 3/8-inch nominal thickness may be applied to walls, provided the veneer does not exceed 15 feet above grade, and further provided such veneer shall be placed either directly against noncombustible surfaces or furred out from such surfaces not to exceed 1 5/8 inches with all concealed spaces fire-stopped as provided in Section 2516 (f). Where boards, panels and furring as described above comply with Section 407 as fire-retardant treated wood suitable for exterior exposure, the height above grade may be increased to 35 feet.

(e) **Trim.** Trim, picture molds, chair rails, baseboard, handrails and show-window backing may be of wood. Unprotected wood doors and windows may be used except where openings are required to be fire protected.

Foam plastic trim covering not more than 10 percent of the wall or ceiling area may be used, provided such trim (1) has a density of no less than 20 pounds per cubic foot, (2) has a maximum thickness of 1/2 inch and a maximum width of 4 inches and (3) has a flame-spread rating no greater than 75.

Materials used for interior finish of walls and ceilings, including wainscoting, shall be as specified in Chapter 42.

(f) **Loading Platforms.** Exterior loading platforms may be of noncombustible construction or heavy timber construction with wood floors not less than 2-inch nominal thickness. Such wood construction shall not be carried through the exterior walls.

(g) **Insulating Boards.** Combustible insulating boards may be used under finished flooring.

## Shaft Enclosures

**Sec. 1706.** (a) **General.** Openings extending vertically through floors shall be enclosed in a shaft of fire-resistive construction having the time period set forth in Table No. 17-A for "Shaft Enclosures." Protection for stairways shall be as specified in Sections 3309 and 3310. See Section 706 for exception in Group B, Division 4 Occupancies and Section 709 (j) for open parking garages.

**EXCEPTIONS:** 1. In other than Group I Occupancies, an enclosure will not be required for openings which serve only one adjacent floor and are not connected with openings serving other floors and which are not concealed within the building construction.

2. In buildings housing Group B Occupancies equipped with automatic sprinkler systems throughout, enclosures shall not be required for escalators where the top of the escalator opening at each story is provided with a draft curtain and automatic fire sprinklers are installed around the perimeter of the opening within 2 feet of the draft curtain. The draft curtain shall enclose the perimeter of the unenclosed opening and extend from the ceiling downward at least 12 inches on all sides. The spacing between sprinklers shall not exceed 6 feet.

3. In Type V buildings, chutes and dumbwaiter shafts with a cross-sectional area of not more than 9 square feet may be unenclosed if lined on the inside with lath and



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plaster or gypsum wallboard, with such lining covered with not less than No. 26 galvanized sheet metal gauge with all joints in such sheet metal locklapped. All openings into any such enclosure shall be protected by metal or metal-clad doors with either metal or metal-elad jambs, casings or frames.

4. Exit enclosures shall conform to the applicable provisions of Sections 3309 and 3310.

5. In one- and two-story buildings of other than Group I Occupancies, shafts for gas vents, factory-built chimneys or piping which extend through not more than two floors need not comply with Table No. 17-A. In Group R, Division 3 Occupancies less than three stories in height, shafts for gas vents and for ducts and piping which extend through not more than two floors need not comply with Table No. 17-A.

6. Gas vents and noncombustible piping installed in walls of buildings passing through three floors or less need not comply with Table No. 17-A. Such shafts shall be effectively draft-stopped at each floor or ceiling.

7. Noncombustible pipe and conduit may be installed and maintained within the cavity of fire-resistive walls, provided both the floor and wall penetrations are tightly sealed with a noncombustible material impervious to the passage of smoke.

8. In buildings with Group H, Division 6 Occupancies, a fabrication area may have mechanical, duct and piping penetrations which extend through not more than two floors within that fabrication area. Penetrations for tubing, piping, conduit or duct shall be effectively draft-stopped at the floor level. The fabrication area, including the areas through which the ductwork and piping extend, shall be considered a single conditioned environment.

(b) **Protection of Openings.** Every opening into a shaft enclosure shall be protected by a self-closing fire assembly conforming to Section 4306 and having a fire-protection rating of one hour for openings through one-hour walls and one and one-half hours for openings through two-hour walls.

**EXCEPTIONS:** 1. Openings to the exterior may be unprotected when so permitted by Table No. 5-A.

2. Openings produced by air ducts piercing shaft enclosure walls may be protected by fire dampers conforming to U.B.C. Standard No. 43-7.

(c) **Rubbish and Linen Chutes.** In other than Group R, Division 3 Occupancies, rubbish and linen chutes shall terminate in rooms separated from the remainder of the building by a one-hour fire-resistive occupancy separation. Openings into the chutes and termination rooms shall not be located in exit corridors or stairways.

## Weather Protection

**Sec. 1707.** (a) **Weather-resistive Barriers.** All weather-exposed surfaces shall have a weather-resistive barrier to protect the interior wall covering. Such barrier shall be equal to that provided for in U.B.C. Standard No. 17-1 for kraft waterproof building paper or U.B.C. Standard No. 32-1 for asphalt-saturated rag felt. Building paper and felt shall be free from holes and breaks other than those created by fasteners and construction system due to attaching of the building paper, and shall be applied over studs or sheathing of all exterior walls. Such felt or paper shall be applied weatherboard fashion, lapped not less than 2 inches at horizontal joints and not less than 6 inches at vertical joints.



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Weather-protected barrier may be omitted in the following cases:

1. When exterior covering is of approved weatherproof panels.
2. In back-plastered construction.
3. When there is no human occupancy.
4. Over water-repellent panel sheathing.
5. Under approved paperbacked metal or wire fabric lath.
6. Behind lath and portland cement plaster applied to the underside of roof and eave projections.

(b) **Flashing and Counterflashing.** Exterior openings exposed to the weather shall be flashed in such a manner as to make them weatherproof.

All parapets shall be provided with coping of approved materials. All flashing, counterflashing and coping, when of metal, shall be of not less than No. 26 U.S. gauge corrosion-resistant metal.

(c) **Waterproofing Weather-exposed Areas.** Balconies, landings, exterior stairways and similar surfaces exposed to the weather and sealed underneath shall be waterproofed.

(d) **Dampproofing Foundation Walls.** Unless otherwise approved by the building official, foundation walls enclosing a basement below finished grade shall be dampproofed outside by approved methods and materials.

## Members Carrying Masonry or Concrete

**Sec. 1708.** All members carrying masonry or concrete walls in buildings over one story in height shall be fire protected with one-hour fire protection or the fire-resistive requirement of the wall, whichever is greater.

**EXCEPTION:** Fire protection may be omitted from the bottom flange of lintels spanning not over 6 feet, shelf angles, or plates that are not a part of the structural frame.

## Parapets

**Sec. 1709.** (a) **General.** Parapets shall be provided on all exterior walls of buildings.

**EXCEPTIONS:** 1. Walls which are not required to be of fire-resistive construction.

2. Walls which terminate at roofs of not less than two-hour fire-resistive construction or roofs constructed entirely of noncombustible materials.

3. Walls where, due to location on property, unprotected openings are permitted.

4. Walls on all buildings having a floor area of not more than 1000 square feet per floor.

(b) **Construction.** Parapets shall have the same degree of fire resistance required for the wall upon which they are erected and on any side adjacent to a roof surface shall have noncombustible faces for the uppermost 18 inches, including counterflashing and coping materials. The height of the parapet shall be not less than 30 inches above the point where the roof surface and the wall interseet. Where the roof slopes toward a parapet at slopes greater than 2:12, the parapet



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shall extend to the same height as any portion of the roof that is within the distance where protection of wall openings would be required, but in no case shall the height be less than 30 inches.

## Projections

**Sec. 1710.** Cornices, eave overhangs, exterior balconies and similar architectural appendages extending beyond the floor area as defined in Section 407 shall conform to the requirements of this section. (See Sections 3305 and 3306 for additional requirements applicable to exterior exit balconies and stairways.)

Projections from walls of Type I or II construction shall be of noncombustible materials.

Projections from walls of Type III, IV or V construction may be of noncombustible or combustible materials.

Combustible projections located where openings are not permitted or where protection of openings is required shall be of one-hour fire-resistive or heavy-timber construction conforming to Section 2106.

Projections shall not extend more than 12 inches into the areas where openings are prohibited.

For projections extending over public property, see Chapter 45.

For combustible ornamentation, see Section 1705 (d).

## Guardrails

**Sec. 1711.** All unenclosed floor and roof openings, open and glazed sides of stairways, landings and ramps, balconies or porches, which are more than 30 inches above grade or floor below, and roofs used for other than service of the building shall be protected by a guardrail.

**EXCEPTION:** Guardrails need not be provided at the following locations:

1. On the loading side of loading docks.
2. On the auditorium side of a stage or enclosed platform.

The top of guardrails shall be not less than 42 inches in height.

**EXCEPTIONS:** 1. The top of guardrails for Group R, Division 3 and Group M, Division 1 Occupancies and interior guardrails within individual dwelling units and guest rooms of Group R, Division 1 Occupancies may be 36 inches in height.

2. The top of guardrails on a balcony immediately in front of the first row of fixed seats and which are not at the end of an aisle may be 26 inches in height.

3. The top of guardrails for stairways, exclusive of their landings, may have a height as specified in Section 3306 (j) for handrails.

Open guardrails shall have intermediate rails or an ornamental pattern such that a sphere 6 inches in diameter cannot pass through.

**EXCEPTION:** The open space between the intermediate rails or ornamental pattern of guardrails in areas of commercial and industrial-type occupancies which are not accessible to the public may be such that a sphere 12 inches in diameter cannot pass through.



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## Foam Plastic Insulation

**Sec. 1712.** (a) **General.** The provisions of this section shall govern the requirements and uses of foam plastic insulation in buildings and structures. For trim, see Section 1705 (e).

Except where otherwise noted in this section, all foam plastic insulation used in building construction shall have a flame-spread rating of not more than 75 and shall have a smoke-developed rating of not more than 450 when tested in the maximum thickness intended for use in accordance with U.B.C. Standard No. 42-1. All packages and containers of foam plastic insulation and foam plastic insulation ingredients shall bear the label of an approved agency showing either the flame-spread rating and smoke-developed rating of the product at the thickness tested or the use for which the product has been listed. The interior of the building shall be separated from the foam plastic insulation by an approved thermal barrier having an index of 15 when tested in accordance with U.B.C. Standard No. 17-3. The thermal barrier shall be installed in such a manner that it will remain in place for the time of its index classification based upon approved diversified tests.

(b) **Specific Requirements.** Unless otherwise specifically approved as provided by Section 1712 (c) or by other sections of this code, foam plastic insulation may be used as follows:

1. **Masonry or concrete construction.** Foam plastic insulation may be used without the thermal barrier described above, regardless of the type of construction, when the foam plastic insulation is covered by a minimum of 1-inch thickness of masonry or concrete in a wall, floor or roof system.

2. **Attics and crawl spaces.** Within an attic or crawl space where entry is made only for service of utilities, foam plastic insulation shall be protected against ignition by 1½-inch-thick mineral fiber insulation, ¼-inch-thick plywood, hardboard or gypsum wallboard, corrosion-resistant sheet metal having a base metal thickness not less than 0.0160 inch at any point, or other approved material installed in such a manner that the foam plastic is not exposed.

3. **Cold storage construction.** Foam plastic insulation installed and meeting the requirements of (a) above when tested in a thickness of 4 inches may be used in a greater thickness in cold storage buildings, ice plants, food-processing rooms and similar areas. For rooms within a building, the foam plastic insulation shall be protected by a thermal barrier on both sides having an index of 15.

Foam plastic insulation may be used in freestanding cooler and freezer walls without the thermal barrier when the foam plastic insulation has a flame-spread rating of 25 or less when tested in a 4-inch thickness, has a minimum allowable flash and self-ignition temperatures of 600°F. and 800°F., respectively, when tested in accordance with U.B.C. Standard No. 52-3, is covered by not less than 0.032 inch of aluminum or corrosion-resistant steel having a base metal thickness not less than 0.0160 inch at any point and is protected by an automatic sprinkler system. When such a cooler or freezer is within a building, both the cooler or freezer and that part of the building in which the room is located shall be sprinklered.



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**EXCEPTION:** Freestanding walk-in coolers and freezer units having an aggregate floor area less than 400 square feet need meet only the flame-spread and smoke requirements of Section 1712 (a) above, when tested at the thickness intended for use.

4. **Noncombustible exterior walls.** Except as provided in Items Nos. 1 and 3, assemblies employing foam plastic insulation in or on exterior walls in buildings requiring noncombustible exterior walls shall comply with the following:

A. **One-story buildings.** When the building is protected with automatic sprinklers throughout, foam plastic insulation having a flame spread of 25 or less and a maximum smoke-developed value of 450 may be used without thermal barriers in or on walls in a thickness of not more than 4 inches when the foam plastic insulation is covered by a thickness of not less than 0.032-inch aluminum or corrosion-resistive sheet steel having a base metal thickness of 0.0160 inch, and when the wall is required to have a fire-resistive rating, data, based on tests conducted in accordance with U.B.C. Standard No. 43-1, shall be provided to substantiate that the fire-resistive rating is maintained.

B. **Buildings of any height.**

(i) When the wall is required to have a fire-resistive rating, data, based on tests conducted in accordance with U.B.C. Standard No. 43-1, shall be provided to substantiate that the fire resistive rating is maintained.

(ii) The foam plastic insulation shall be separated from the interior of the building by a thermal barrier having an index of 15 unless a specific approval is obtained on the basis of the criteria of Section 1712 (c).

(iii) The amount of foam plastic insulation in any portion of the wall or panel shall not exceed 6000 Btu per square foot of wall area as determined by tests conducted in accordance with U.B.C. Standard No. 17-2.

(iv) Foam plastic insulation tested in the maximum thickness intended for use and exterior coatings and facings each, when tested separately, shall have a flame-spread rating of 25 or less and a smoke-developed rating of 450 or less as determined by tests conducted in accordance with U.B.C. Standard No. 42-1.

(v) The wall assembly shall be tested in accordance with U.B.C. Standard No. 17-6 and shall comply with the conditions of acceptance contained therein.

(vi) Foam plastic insulation shall be listed and the edge or face of each piece shall be labeled giving the following information:

a. Inspection agency name.
b. Product for which the insulation is listed.
c. Identification of insulation manufacturer.
d. Flame-spread and smoke-development rating.

5. **Roofing.** Foam plastic insulation meeting the requirements of Section 1712 (a) may be used as part of a roof covering assembly, provided the assembly with the foam plastic insulation is a Class A, B or C roof covering when tested in



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accordance with U.B.C. Standard No. 32-7. Foam plastic insulation which is a part of a Class A, B or C roof covering assembly need not meet the requirements of Section 1712 (a), provided the assembly with the foam plastic insulation also meets the requirements of U.B.C. Standard No. 17-4.

Any roof covering installed in accordance with this code and the manufacturer's instructions may be applied over foam plastic insulation when the foam is separated from the interior of the building by plywood sheathing not less than 1/2 inch in thickness bonded with exterior glue, with edges supported by blocking, tongue-and-groove joints or other approved type of edge support, or an equivalent material. The thermal barrier requirement is waived.

For all roof applications, the smoke-developed rating shall not be limited.

6. **Doors.** Where doors are permitted without a fire-resistive rating, foam plastic insulation having a flame-spread rating of 75 or less may be used as a core material when the door facing is metal having a minimum thickness of 0.032-inch aluminum or steel having a base metal thickness not less than 0.0160 inch at any point. The thermal barrier requirement is waived.

7. **Siding backer board.** Foam plastic insulation of not more than 2000 Btu per square foot as determined by U.B.C. Standard No. 17-2 may be used as siding backer board with a maximum thickness of 1/2 inch, provided it is separated from the interior of the building by not less than 2 inches of mineral fiber insulation or equivalent in lieu of the thermal barrier, or when it is applied as residing over existing wall construction.

(c) **Specific Approval.** Plastic foam or assemblies using foam plastic insulation may be specifically approved based on approved tests such as, but not limited to, tunnel tests conducted in accordance with U.B.C. Standard No. 42-1; fire tests related to actual end use such as set forth in U.B.C. Standard No. 17-5 and an ignition temperature test establishing a minimum self-ignition temperature of 650°F. under U.B.C. Standard No. 52-3. The specific approval may be based on the end use, quantity, location and similar considerations where such tests would not be applicable or practical.

## Insulation

**Sec. 1713.** (a) **General.** Thermal and acoustical insulation located on or within floor-ceiling and roof-ceiling assemblies, crawl spaces, walls, partitions and insulation on pipes and tubing shall comply with this section. Duct insulation and insulation in plenums shall conform to the requirements of the Uniform Mechanical Code.

**EXCEPTION:** Roof insulation shall comply with Section 3208 (d).

(b) **Insulation and Covering on Pipe and Tubing.** Insulation and covering on pipe and tubing shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with U.B.C. Standard No. 42-1.

**EXCEPTION:** Foam plastic insulation shall comply with Section 1712.

(c) **Insulation.** All insulation materials including facings, such as vapor barriers or breather papers installed within floor-ceiling assemblies, roof-ceiling



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assemblies, walls, crawl spaces or attics, shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with U.B.C. Standard No. 42-1.

**EXCEPTIONS:** 1. Foam plastic insulation shall comply with Section 1712.

2. When such materials are installed in concealed spaces of Types III, IV and V construction, the flame-spread and smoke-developed limitations do not apply to facings, provided that the facing is installed in substantial contact with the unexposed surface of the ceiling, floor or wall finish.

## Solar Energy Collectors

**Sec. 1714.** Collectors which function as building components shall comply with the applicable provisions of the code.

Collectors located above or upon a roof and not functioning as building components shall not reduce the required fire resistance nor fire-retardancy classification of the roof covering materials.

**EXCEPTIONS:** 1. Collectors installed on one- and two-family dwellings.

2. Noncombustible collectors located on buildings not over three stories in height or 9000 square feet in total floor area.

3. Collectors that comply with the provisions of Section 5214.

## Atria

**Sec. 1715.** (a) **General.** Buildings, of other than Group H Occupancy, with automatic sprinkler protection throughout may have atria complying with the provisions of this section. Such atria shall have a minimum opening area and dimension as set forth in Table No. 17-B.

(b) **Smoke-control System.** A mechanically operated air-handling system shall be installed that will exhaust smoke either entering or developed within the atrium. Exhaust openings shall be located in the ceiling or in a smoke trap area immediately adjacent to the ceiling of the atrium. The lowest level of the exhaust openings shall be located above the top of the highest portion of door openings into the atrium. Supply openings sized to provide a minimum of 50 percent of the exhaust volume shall be located at the lowest level of the atrium.

When the height of the atrium is 55 feet or less, supply air may be introduced by gravity, provided smoke control is accomplished. When the height of the atrium is more than 55 feet, supply air shall be introduced mechanically from the floor of the atrium and be directed vertically toward the exhaust outlets. In atria over six stories in height or where tenant spaces above the second story are open to the atrium, supplemental supply air may be introduced at upper levels. The smoke-control system for the atrium shall operate automatically upon the actuation of the automatic sprinkler system within the atrium or areas open to the atrium. The smoke-control system for the atrium shall also operate automatically upon the activation of two or more smoke detectors required by this section. Actuation of the smoke control system shall follow immediately after the actuation of the second smoke detector. The smoke-control system shall also be manually operable by controls designed for fire department use. The smoke-control system may



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be separate or integrated with other air-handling systems. When the smoke-control mode is actuated, air-handling systems which would interfere with the smoke-control system shall be automatically shut down.

Tenant spaces that are adjacent to but separated from the atrium by walls or glazing as specified in Section 1715 (c) shall be provided with a smoke-control system complying with the requirements of a sprinklered building in Section 1807 (g).

The atrium smoke-control system shall exhaust not less than the following quantities of air:

1. For atria having a volume of not more than 600,000 cubic feet, including the volume of any levels not physically separated from the atrium, not less than six air changes per hour nor less than 40,000 cfm. A lesser cfm is acceptable if it can be shown by test that smoke will not migrate beyond the perimeter of the atrium.
2. For atria having a volume of more than 600,000 cubic feet, including the volume of any levels not physically separated from the atrium, not less than four air changes per hour.

Smoke detectors which will automatically operate the atrium smoke-control system shall be installed in the following locations:

1. At the atrium ceiling, spaced in accordance with their listing.
2. On the underside of projections into the atrium, spaced in accordance with their listing.
3. Around the perimeter of the atrium opening on all floors open to the atrium. These detectors shall be spaced no more than 30 feet on center and be located within 15 feet of the atrium opening.

(c) **Enclosure of Atria.** Atria shall be separated from adjacent spaces by not less than one-hour fire-resistive construction.

**EXCEPTIONS:** 1. The separation between atria and tenant spaces that are not guest rooms or dwelling units may be omitted at three floor levels.

2. Open exit balconies are permitted within the atrium.

Openings in the atrium enclosure other than fixed glazing shall be protected by smoke- and draft-control assemblies conforming to Section 3305 (h).

**EXCEPTION:** Other tight-fitting doors which are maintained automatic-closing, in accordance with Section 4306 (b), by actuation of a smoke detector, or self-closing may be used when protected as required for glazed openings in Exception 2 below.

Fixed glazed openings in the atrium enclosure shall be equipped with fire windows having a fire-resistive rating of not less than three-fourths hour, and the total area of such openings shall not exceed 25 percent of the area of the common wall between the atrium and the room into which the opening is provided.

**EXCEPTIONS:** 1. In Group R, Division 1 Occupancies, openings may be unprotected when the floor area of each guest room or dwelling unit does not exceed 1000 square feet and each room or unit has an approved exit not entering the atrium.

2. Guest rooms, dwelling units and tenant spaces may be separated from the



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atrium by approved fixed wired glass set in steel frames. In lieu thereof, tempered or laminated glass may be used, subject to the following:

A. The glass shall be protected by a sprinkler system equipped with listed quick-response sprinklers. The sprinkler system shall completely wet the entire surface of the glass wall when actuated. Where there are walking surfaces on both sides of the glass, both sides of the glass shall be so protected.

B. The glass shall be in a gasketed frame so installed that the glazing system may deflect without breaking (loading) the glass before the sprinkler system operates.

C. Obstructions such as curtain rods, drapery traverse rods, curtains, drapes or similar materials, shall not be installed between the sprinkler and the glass.

(d) **Travel Distance.** When a required exit enters the atrium space, the travel distance from the doorway of the tenant space to an enclosed stairway, horizontal exit, exterior door or exit passageway shall not exceed 100 feet.

(e) **Group I Occupancy Exits.** In Group I Occupancies, other than jails, prisons and reformatories, sleeping rooms shall not be permitted to have required exits through the atrium.

(f) **Occupancy Separation Exceptions.** The vertical portion of the occupancy separation which is adjacent to the atrium may be omitted between a Group B, Division 2 Occupancy office or sales area or Group A, Division 3 Occupancy and Group R, Division 1 apartment or guest room located on another level.

(g) **Standby Power.** The smoke-control system for the atrium and the smoke-control system for the tenant space are to be provided with standby power as required in Section 1807 (i).

(h) **Interior Finish.** The interior finish of walls and ceilings of the atrium and all unseparated tenant spaces allowed under Exception 1 of the first paragraph of Subsection (c) above shall be Class I with no reduction in class for sprinkler protection.

(i) **Acceptance of the Smoke-control System.** Before the Certificate of Occupancy is issued, the smoke-control systems shall be tested in an approved manner and shall show compliance with the requirements of this section.

(j) **Combustible Furnishings in Atria.** The quantity of combustible furnishings in atria shall not exceed that specified in the Fire Code.

## Mezzanines

**Sec. 1716.** Rooms may contain mezzanine floors when constructed in accordance with the following:

1. The construction of a mezzanine shall be consistent with the requirements for the type of construction in which the mezzanine is located, but the fire-resistive time period need not exceed one hour for unenclosed mezzanines constructed in accordance with Item No. 4 below. The clear height above and below the mezzanine floor construction shall be not less than 7 feet.

2. There shall be not more than two levels of mezzanines in a room. However, there is no limitation on the number of mezzanines within a room.

3. The aggregate area of mezzanines within a room shall not exceed one third



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the area of the room in which they are located. Intermediate floor levels that are 6 or more feet above grade shall be considered a story when the area of such level exceeds one third the area of the room in which it is located.

4. All portions of a mezzanine shall be open to the room in which it is located. The side of the mezzanine which is open to the room shall be unobstructed except for columns and posts and protective walls or railings not more than 42 inches in height.

**EXCEPTIONS:** 1. Partitioning may be installed, provided the aggregate floor area of the enclosed space does not exceed 10 percent of the area of the mezzanine or an occupant load not exceeding 10, whichever is greater.

2. Mezzanines having two or more exits need not open into the story in which they are located, provided at least one of the exits gives direct access to a protected exit corridor, an exit court, enclosed exit stairway, exterior exit, exterior exit balcony or exit passageway.

3. In industry facilities, mezzanines used for control equipment may be glazed on all sides.

5. Two exits shall be provided from a mezzanine when two exits are required by Table No. 33-A or when the area of the mezzanine exceeds 2000 square feet, whichever is the more restrictive.

6. The occupant load of the mezzanine shall be added to the occupant load of the story or room into which it exits.



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## TABLE NO. 17-A—TYPES OF CONSTRUCTION—FIRE-RESISTIVE REQUIREMENTS
(In Hours)

**For details see chapters under Occupancy and Types of Construction and for exceptions see Section 1705.**

| | TYPE I | TYPE II | | | TYPE III | | TYPE IV | TYPE V | |
|---|---|---|---|---|---|---|---|---|---|
| | | NONCOMBUSTIBLE | | | COMBUSTIBLE | | | | |
| BUILDING ELEMENT | Fire-resistive | Fire-resistive | 1-Hr. | N | 1-Hr. | N | H.T. | 1-Hr. | N |
| Exterior Bearing Walls | 4 Sec. 1803 (a) | 4 1903 (a) | 1 | N | 4 2003 (a) | 4 2003 (a) | 4 2103 (a) | 1 | N |
| Interior Bearing Walls | 3 | 2 | 1 | N | 1 | N | 1 | 1 | N |
| Exterior Nonbearing Walls | 4 Sec. 1803 (a) | 4 1903 (a) | 1 1903 (a) | N | 4 2003 (a) | 4 2003 (a) | 4 2103 (a) | 1 | N |
| Structural Frame[1] | 3 | 2 | 1 | N | 1 | N | 1 or H.T. | 1 | N |
| Partitions—Permanent | 1[2] | 1[2] | 1[2] | N | 1 | N | 1 or H.T. | 1 | N |
| Shaft Enclosures | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 1706 | 1 1706 |
| Floors-Ceilings/Floors | 2 | 2 | 1 | N | 1 | N | H.T. | 1 | N |
| Roofs-Ceilings/Roofs | 2 Sec. 1806 | 1 1906 | 1 1906 | N | 1 | N | H.T. | 1 | N |
| Exterior Doors and Windows | Sec. 1803 (b) | 1903 (b) | 1903 (b) | 1903 (b) | 2003 (b) | 2003 (b) | 2103 (b) | 2203 | 2203 |

N—No general requirements for fire resistance. H.T.—Heavy Timber.

[1] Structural frame elements in the exterior wall shall be protected against external fire exposure as required for exterior bearing walls or the structural frame, whichever is greater.

[2] Fire-retardant treated wood (see Section 407) may be used in the assembly, provided fire-resistance requirements are maintained. See Sections 1801 and 1901, respectively.





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## TABLE NO. 17-B—ATRIUM OPENING AND AREA

| HEIGHT IN STORIES | MINIMUM CLEAR OPENING[1] (Ft.) | MINIMUM AREA (Sq. Ft.) |
|---|---|---|
| 3-4 | 20 | 400 |
| 5-7 | 30 | 900 |
| 8 or more | 40 | 1600 |

[1]The specified dimensions are the diameters of inscribed circles whose centers fall on a common axis for the full height of the atrium.



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# Chapter 18

# TYPE I FIRE-RESISTIVE BUILDINGS

## Definition

**Sec. 1801.** The structural elements in Type I fire-resistive buildings shall be of steel, iron, concrete or masonry.

Walls and permanent partitions shall be of noncombustible fire-resistive construction except that permanent nonbearing partitions of one-hour or two-hour fire-resistive construction, which are not part of a shaft enclosure, may have fire-retardant treated wood (see Section 407) within the assembly.

Materials of construction and fire-resistive requirements shall be as specified in Chapter 17.

## Structural Framework

**Sec. 1802.** Structural framework shall be of structural steel or iron as specified in Chapter 27, reinforced concrete as in Chapter 26, or reinforced masonry as in Chapter 24.

For additional requirements for Group H Occupancies, see Section 902.

## Exterior Walls and Openings

**Sec. 1803.** (a) **Exterior Walls.** Exterior walls and all structural members shall comply with the requirements specified in Section 504 and the fire-resistive provisions set forth in Table No. 17-A. For Group H Occupancies, see also Chapter 9.

**EXCEPTIONS:** 1. Nonbearing walls fronting on public ways or yards having a width of at least 40 feet may be of unprotected noncombustible construction.

2. In Groups R, Division 1, and B Occupancies, exterior bearing walls may be of two-hour fire-resistive noncombustible construction where openings are permitted.

3. In other than Group H Occupancies, exterior nonbearing walls may be of one-hour fire-resistive noncombustible construction where unprotected openings are permitted and two-hour fire-resistive noncombustible construction where fire protection of openings is required.

(b) **Openings in Walls.** All openings in exterior walls shall conform to the requirements of Section 504 (b) and shall be protected by a fire assembly having a three-fourths-hour fire-protection rating when they are less than 20 feet from an adjacent property line or the center line of a public way.

No openings shall be permitted in exterior walls of Groups A, E, I and B, Divisions 1, 2 and 3 Occupancies less than 5 feet from the property line, and no openings in Groups B, Division 4, R and M Occupancies less than 3 feet from the property line.

For Group H Occupancies, see Chapter 9.

## Floors

**Sec. 1804.** Where wood sleepers are used for laying wood flooring on masonry or concrete fire-resistive floors, the space between the floor slab and the under-



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side of the wood flooring shall be filled with noncombustible material or fire-stopped in such a manner that there will be no open spaces under the flooring which will exceed 100 square feet in area and such space shall be filled solidly under all permanent partitions so that there is no communication under the flooring between adjoining rooms.

**EXCEPTIONS:** 1. Firestopping need not be provided in such floors when at or below grade level in gymnasiums.

2. Firestopping need be provided only at the juncture of each alternate lane and at the ends of each lane in a bowling facility.

## Stairway Construction

**Sec. 1805.** Stairways shall be constructed of reinforced concrete, iron or steel with treads and risers of concrete, iron or steel. Brick, marble, tile or other hard noncombustible materials may be used for the finish of such treads and risers.

Stairways shall comply with the requirements of Chapter 33.

## Roofs

**Sec. 1806.** Roofs and their members other than the structural frame more than 25 feet above any floor, balcony or gallery may be of unprotected noncombustible materials. Heavy-timber members in accordance with Section 2106 may be used for such unprotected members in one-story buildings.

When every part of the structural framework of the roof of a Group A or E Occupancy or of an atrium is not less than 25 feet above any floor, balcony or gallery, fire protection of all members of the roof construction including those of the structural frame may be omitted. Heavy-timber members in accordance with Section 2106 may be used for such unprotected members in one-story buildings.

Roofs of unprotected noncombustible or heavy timber construction conforming to Section 2106 (b) may be less than 25 feet above any floor, balcony or gallery of a Group A, Division 2.1 Occupancy having an occupant load of 10,000 or more when all of the following conditions are met:

1. The building is not more than one story in height, except for multilevel areas located under the roof and used for locker rooms, exiting, concession stands, mechanical rooms and others accessory to the assembly room.
2. The area in which the roof clearance is less than 25 feet does not exceed 35 percent of the area encompassed by the exterior walls.
3. An approved supervised automatic sprinkler system shall be installed throughout.

Where every part of the structural steel framework of the roof of a Group A or E Occupancy is more than 18 feet and less than 25 feet above any floor, balcony or gallery, the roof construction shall be protected by a ceiling of not less than one-hour fire-resistive construction.

Roof coverings shall be as specified in Chapter 32.



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## Special Provisions for Group B, Division 2 Office Buildings and Group R, Division 1 Occupancies

**Sec. 1807.** (a) **Scope.** This section applies to all Group B, Division 2 office and Group R, Division 1 Occupancies, each having floors used for human occupancy located more than 75 feet above the lowest level of fire department access. Such buildings shall be provided with an approved automatic sprinkler system in accordance with Section 1807 (c).

(b) **Certificate of Occupancy.** All mechanical and electrical equipment and other required life safety systems shall be approved and installed in accordance with approved plans and specifications pursuant to this section and shall be tested and proved to be in proper working condition to the satisfaction of the building official before issuance of the Certificate of Occupancy. Such system shall be maintained in accordance with the Fire Code.

(c) **Automatic Sprinkler System.** 1. **System Design.** The automatic sprinkler system shall be provided throughout the building. The sprinkler system shall be designed using the parameters set forth in U.B.C. Standard No. 38-1 and the following:

A. Shutoff valves and a water-flow device shall be provided for each floor. The sprinkler riser may be combined with the standpipe riser.

B. In Seismic Zones No. 2, No. 3 and No. 4, in addition to the main water supply, a secondary on-site supply of water equal to the hydraulically calculated sprinkler design demand plus 100 gallons per minute additional for the total standpipe system shall be provided. This supply shall be automatically available if the principal supply fails and shall have a duration of 30 minutes.

2. **Modifications.** The following modifications of code requirements are permitted:

A. The fire-resistive time periods set forth in Table No. 17-A may be reduced by one hour for interior bearing walls, exterior bearing and nonbearing walls, roofs and the beams supporting roofs, provided they do not frame into columns. Vertical shafts other than stairway enclosures and elevator shafts may be reduced to one hour when sprinklers are installed within the shafts at alternate floors. The fire-resistive time period reduction as specified herein shall not apply to exterior bearing and nonbearing walls whose fire-resistive rating has already been reduced under the exceptions contained within Section 1803 (a) or 1903 (a).

B. Except for corridors in Group B, Division 2 and Group R, Division 1 Occupancies and partitions separating dwelling units or guest rooms, all interior nonbearing partitions required to be one-hour fire-resistive construction by Table No. 17-A may be of noncombustible construction without a fire-resistive time period.

C. Fixed tempered glass may be used in lieu of openable panels for smoke-control purposes.

D. Travel distance from the most remote point in the floor area to a horizontal exit or to an enclosed stairway may be 300 feet.



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E. Fire dampers, other than those needed to protect floor-ceiling assemblies to maintain the fire resistance of the assembly, are not required.

F. Emergency windows required by Section 1204 are not required.

(d) **Smoke Detection Systems.** At least one approved smoke detector suitable for the intended use shall be installed:

1. In every mechanical equipment, electrical, transformer, telephone equipment, elevator machine or similar room.
2. In the main return and exhaust air plenum of each air-conditioning system and located in a serviceable area downstream of the last duct inlet.
3. At each connection to a vertical duct or riser serving two or more stories from a return-air duct or plenum of an air-conditioning system. In Group R, Division 1 Occupancies, an approved smoke detector may be used in each return-air riser carrying not more than 5000 cfm and serving not more than 10 air inlet openings.

The actuation of any detector required by this section shall operate the voice alarm system and shall place into operation all equipment necessary to prevent the recirculation of smoke.

(e) **Alarm and Communication Systems.** The alarm and communication systems shall be designed and installed so that damage to any terminal unit or speaker will not render more than one zone of the system inoperative.

The voice alarm and public address system may be a combined system. When approved the fire department communications system may be combined with the voice alarm system and the public address system.

Three communication systems which may be combined as set forth above shall be provided as follows:

1. **Voice alarm system.** The operation of any smoke detector, sprinkler, water flow device or manual fire alarm station shall automatically sound an alert signal to the desired areas followed by voice instructions giving appropriate information and direction to the occupants.

The central control station shall contain controls for the voice alarm system so that a selective or general voice alarm may be manually initiated.

The system shall be supervised to cause the activation of an audible trouble signal in the central control station upon interruption or failure of the audiopath including amplifiers, speaker wiring, switches and electrical contacts and shall detect opens, shorts and grounds which might impair the function of the system.

The alarm shall be designed to be heard clearly by all occupants within the building or designated portions thereof as is required for the public address system.

2. **Public address system.** A public address communication system designed to be clearly heard by all occupants of the building shall operate from the central control station. It shall be established on a selective or general basis to the following terminal areas:

A. Elevators.



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B. Elevator lobbies.

C. Corridors.

D. Exit stairways.

E. Rooms and tenant spaces exceeding 1000 square feet in area.

F. Dwelling units in apartment houses.

G. Hotel guest rooms or suites.

3. **Fire department communication system.** A two-way fire department communication system shall be provided for fire department use. It shall operate between the central control station and every elevator, elevator lobby and entry to every enclosed exit stairway.

(f) **Central Control Station.** A central control station for fire department operations shall be provided in a location approved by the fire department. It shall contain:

1. The voice alarm and public address system panels.
2. The fire department communications panel.
3. Fire detection and alarm system annunciator panels.
4. Annunciator visually indicating the location of the elevators and whether they are operational.
5. Status indicators and controls for air-handling systems.
6. Controls for unlocking all stairway doors simultaneously.
7. Sprinkler valve and water-flow detector display panels.
8. Standby power controls and status indicators.
9. A telephone for fire department use with controlled access to the public telephone system.

(g) **Smoke Control.** Natural or mechanical ventilation for the removal of products of combustion shall be provided in every story and shall consist of one of the following:

1. Easily identifiable windows or panels which are manually openable or approved fixed tempered glass shall be provided in the exterior walls. They shall be distributed around the perimeter of the building at not more than 50-foot intervals at the rate of 20 square feet per 50 lineal feet.

**EXCEPTION:** In Group R, Division 1 Occupancies each guest room or suite having an exterior wall may be provided with a minimum of 2 square feet of venting area.

2. When a complete and approved automatic sprinkler system is installed, the mechanical air-handling equipment may be designed to accomplish smoke removal. Under fire conditions, the return and exhaust air shall be moved directly to the outside without recirculation to other sections of the building. The air-handling system shall provide a minimum of one exhaust air change each 10 minutes for the area involved.

3. Any other approved design which will produce equivalent results.



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(h) **Elevators.** Elevators and elevator lobbies shall comply with the provisions of Chapter 51 and the following:

**NOTE:** A bank of elevators is a group of elevators or a single elevator controlled by a common operating system: that is, all those elevators which respond to a single call button constitute a bank of elevators. There is no limit on the number of cars which may be in a bank or group but there may be not more than four cars within a common hoistway.

1. Elevators on all floors shall open into elevator lobbies which are separated from the remainder of the building, including corridors and other exits, by walls extending from the floor to the underside of the fire-resistive floor or roof above. Such walls shall be of not less than one-hour fire-resistive construction. Openings through such walls shall conform to Section 3305 (h).

**EXCEPTIONS:** 1. The main entrance level elevator lobby in office buildings.

2. Elevator lobbies located within an atrium complying with the provisions of Section 1715.

3. In fully-sprinklered office buildings, corridors may lead through enclosed elevator lobbies if all areas of the building have access to at least one required exit without passing through the elevator lobby.

2. Each elevator lobby shall be provided with an approved smoke detector located on the lobby ceiling. When the detector is activated, elevator doors shall not open and all cars serving that lobby are to return to the main floor and be under manual control only. If the main floor detector or a transfer floor detector is activated, all cars serving the main floor or transfer floor shall return to a location approved by the fire department and building official and be under manual control only. The smoke detector is to operate before the optical density reaches 0.03 per foot. The detector may serve to close the lobby doors.

3. Elevator hoistways shall not be vented through an elevator machine room. Cable slots entering the machine room shall be sleeved beneath the machine room floor and extend to not less than 12 inches below the shaft vent to inhibit the passage of smoke into the machine room.

(i) **Standby Power, Light and Emergency Systems.** 1. **Standby power.** Standby power generating system conforming to U.B.C. Standard No. 18-1 shall be provided. The system shall be equipped with suitable means for automatically starting the generator set upon failure of the normal electrical supply systems and for automatic transfer of all functions required by this section at full power within 60 seconds of such normal service failure. Systems supervisions with manual start and transfer features shall be provided at the central control station.

An on-premise fuel supply sufficient for not less than two hours full demand operation of the system shall be provided.

The standby system shall have a capacity and rating that would supply all equipment required to be operational at the same time. The generating capacity need not be sized to operate all the connected electrical equipment simultaneously.

All power, lighting, signal and communication facilities specified in (d), (e), (f), (g), (h), (i) and (j) as applicable; fire pumps required to maintain pressure,



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standby lighting and normal circuits supplying exit signs and exit illumination shall be transferable to the standby source.

2. **Standby lighting.** Standby lighting shall be provided as follows:

A. Separate lighting circuits and fixtures sufficient to provide light with an intensity of not less than one footcandle measured at floor level in all exit corridors, stairways, smokeproof enclosures, elevator cars and lobbies and other areas which are clearly a part of the escape route.

B. All circuits supply lighting for the central control station and mechanical equipment room.

3. **Emergency systems.** The following are classified as emergency systems and shall operate within 10 seconds of failure of the normal power supply:

A. Exit sign and exit illumination is required by Sections 3313 and 3314.

B Elevator car lighting.

(j) **Exits.** Exits shall comply with other requirements of this code and the following:

1. All stairway doors which are locked from the stairway side shall have the capability of being unlocked simultaneously without unlatching upon a signal from the central control station.

2. A telephone or other two-way communications system connected to an approved emergency service which operates continuously shall be provided at not less than every fifth floor in each required stairway where other provisions of this code permit the doors to be locked.

(k) **Seismic Considerations.** In Seismic Zones No. 2, No. 3 and No. 4, the anchorage of mechanical and electrical equipment required for life safety systems, including fire pumps and elevator drive and suspension systems, shall be designed in accordance with the requirements of Section 2312.



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# Chapter 19
# TYPE II BUILDINGS

## Definition

**Sec. 1901.** The structural elements in Type II fire-resistive buildings shall be of steel, iron, concrete or masonry.

The structural elements of Type II One-hour or II-N buildings shall be of noncombustible materials.

Walls and permanent partitions of Type II-F.R. buildings shall be of noncombustible fire-resistive construction, except that permanent nonbearing partitions of one-hour or two-hour fire-resistive construction, which are not part of a shaft enclosure may have fire-retardant treated wood (see Section 407) within the assembly.

Type II One-hour buildings shall be of noncombustible construction and one-hour fire resistive throughout except that permanent nonbearing partitions may use fire-retardant treated wood (see Section 407) within the assembly, provided fire-resistive requirements are maintained.

Walls and permanent partitions of Type II-N buildings shall be of noncombustible materials.

Materials of construction and fire-resistive requirements shall be as specified in Chapter 17.

For requirements due to occupancy, see Chapters 6 to 12, inclusive.

## Structural Framework

**Sec. 1902.** Structural framework shall be as specified in Chapter 27 for iron and steel, Chapter 26 for concrete and Chapter 24 for masonry.

## Exterior Walls and Openings

**Sec. 1903.** (a) **Exterior Walls.** Exterior walls and all structural members shall comply with the requirements specified in Section 504 and the fire-resistive provisions set forth in Table No. 17-A. In Type II-N and Type II One-hour buildings, exterior walls shall comply with the fire-resistive requirements set forth in Section 504 and Table No. 5-A and Table No. 9-C for Group H Occupancies.

**EXCEPTIONS:** 1. Nonbearing walls fronting on public ways or yards having a width of at least 40 feet may be of unprotected noncombustible construction.

2. In Groups R, Division 1, and B Occupancies, exterior bearing walls of Type II-F.R. buildings may be of two-hour fire-resistive noncombustible construction where openings are permitted.

3. In other than Group H Occupancies, exterior nonbearing walls of Type II-F.R. buildings may be of one-hour fire-resistive noncombustible construction where unprotected openings are permitted and two-hour fire-resistive noncombustible construction where fire protection of openings is required.

4. In a Group B Occupancy a fire-resistive time period will not be required for an exterior wall of a one-story Type II-N building, provided the floor area of the



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building does not exceed 1000 square feet and such wall is located not less than 5 feet from a property line.

(b) **Openings in Walls.** All openings in exterior walls of Type II-F.R. buildings shall conform to the requirements of Section 504 (b) and shall be protected by a fire assembly having a three-fourths-hour fire-protection rating when they are less than 20 feet from an adjacent property line or the center line of a public way.

No openings shall be permitted in exterior walls of Type II-F.R. buildings housing Groups A, E, I and B, Divisions 1, 2 and 3 Occupancies less than 5 feet from the property line, and no openings in Groups B, Division 4, R, and M Occupancies less than 3 feet from the property line.

Openings in exterior walls located where protected openings are required by Table No. 5-A shall be protected by fixed fire windows or automatic-closing fire windows or self-closing doors having a fire protection rating of at least three-fourths hour and shall comply with Section 504.

For Group H Occupancies, see Chapter 9.

## Floors

**Sec. 1904.** Where wood sleepers are used for laying wood flooring on masonry or concrete fire-resistive floors, the space between the floor slab and the underside of the wood flooring shall be filled with noncombustible material or fire-stopped in such a manner that there will be no open spaces under the flooring which will exceed 100 square feet in area and such space shall be filled solidly under all permanent partitions so that there is no communication under the flooring between adjoining rooms.

**EXCEPTIONS:** 1. Firestopping need not be provided in such floors when at or below grade level in gymnasiums.

2. Firestopping need be provided only at the juncture of each alternate lane and at the ends of each lane in a bowling facility.

Floor construction of Type II One-hour and Type II-N buildings shall be of noncombustible material, provided, however, that a wood surface or finish may be applied over such noncombustible material.

## Stairway Construction

**Sec. 1905.** Stairways of Type II-F.R. buildings shall be constructed of reinforced concrete, iron or steel with treads and risers of concrete, iron or steel. Brick, marble, tile or other hard noncombustible materials may be used for the finish of such treads and risers. Stairways of Type II One-hour and Type II-N buildings shall be of noncombustible construction.

Stairways shall comply with the requirements of Chapter 33.

## Roofs

**Sec. 1906.** Roofs shall be of noncombustible construction, except that in Type II-F.R. and Type II One-hour buildings, roofs may be as specified in Section 1806.

Roof coverings shall be not less than a Class B as specified in Table No. 32-A.



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## Special Provisions for Group B, Division 2 Office Buildings and Group R, Division 1 Occupancies

**Sec. 1907.** Group B, Division 2 office buildings and Group R, Division 1 Occupancies of Type II-F.R. construction, having floors used for human occupancy located more than 75 feet above the lowest level of fire department vehicle access, shall comply with the special provisions on high-rise buildings in Section 1807.

**EXCEPTION:** The reduction provisions for roofs in Section 1807 (c), Item No. 2A, are not permitted.



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# Chapter 20
# TYPE III BUILDINGS

## Definition

**Sec. 2001.** Structural elements in Type III buildings may be of any materials permitted by this code.

Type III One-hour buildings shall be of one-hour fire-resistive construction throughout.

## Structural Framework

**Sec. 2002.** Structural framework shall be of steel or iron as specified in Chapter 27, concrete as in Chapter 26, masonry as in Chapter 24, or wood as in Chapter 25 and this chapter.

## Exterior Walls, Openings and Partitions

**Sec. 2003.** (a) **Exterior Walls.** Exterior walls shall be constructed of noncombustible materials and shall comply with the fire-resistive requirements set forth in Section 504 and Table No. 17-A. For Group H Occupancies, see also Chapter 9.

**EXCEPTIONS:** 1. Nonbearing walls fronting on public ways, or yards having a width of at least 40 feet may be unprotected when entirely of noncombustible material.

2. In other than Groups H and I Occupancies, exterior nonbearing walls may be noncombustible one-hour fire resistive where unprotected openings are permitted and noncombustible two-hour fire resistive where protection of openings is required.

3. In Groups R, Division 1, and B Occupancies exterior noncombustible bearing walls may be two-hour fire resistive where openings are permitted.

4. Approved fire-retardant treated wood framing may be used within the assembly of exterior walls as permitted by Exceptions 1, 2 and 3, provided the required fire resistance is maintained and the exposed outer and inner faces of such walls are noncombustible.

5. Wood columns and arches conforming to heavy-timber sizes may be used externally where exterior walls are permitted to be unprotected, noncombustible construction or where one-hour fire-resistive noncombustible exterior walls are permitted.

(b) **Openings in Walls.** Openings in exterior walls shall conform to the requirements of Section 504 (b) and shall be protected by a fire assembly having a three-fourths-hour fire-resistive rating when they are less than 20 feet from an adjacent property line or the center line of a public way.

No openings shall be permitted in exterior walls of Groups A, E, I and B, Divisions 1, 2 and 3 Occupancies less than 5 feet from the property line, and no openings in Groups B, Division 4, R and M Occupancies less than 3 feet from the property line.

For Group H Occupancies, see also Chapter 9.

(c) **Partitions.** Bearing partitions, when constructed of wood, shall comply with Section 2516 (d).



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## Stairway Construction

**Sec. 2004.** (a) **General.** Stairways shall comply with the requirements of Chapter 33.

(b) **Interior.** Interior stairways serving buildings not exceeding three stories in height may be constructed of any material permitted by this code.

In buildings more than three stories in height, interior stairways shall be constructed as required for Type I buildings.

(c) **Exterior.** Exterior stairways shall be of noncombustible material except that on buildings not exceeding two stories in height, they may be of wood not less than 2 inches in nominal thickness.

## Roofs

**Sec. 2005.** Roof coverings shall be as specified in Chapter 32.



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# Chapter 21
# TYPE IV BUILDINGS

## Definition

**Sec. 2101.** Structural elements of Type IV buildings may be of any materials permitted by this code.

Type IV construction shall conform to Section 2106 except that permanent partitions and members of the structural frame may be of other materials, provided they have a fire resistance of not less than one hour.

## Structural Framework

**Sec. 2102.** Structural framework shall be of steel or iron as specified in Chapter 27, concrete as in Chapter 26, masonry as in Chapter 24, or wood as in Chapter 25 and this chapter.

## Exterior Walls, Openings and Partitions

**Sec. 2103.** (a) **Exterior Walls.** Exterior walls shall be constructed of noncombustible materials and shall comply with the fire-resistive requirements set forth in Section 504 and Table No. 17-A. For Group H Occupancies, see also Chapter 9.

**EXCEPTIONS:** 1. Nonbearing walls fronting on public ways, or yards having a width of at least 40 feet may be unprotected when entirely of noncombustible material.

2. In other than Groups H and I Occupancies, exterior nonbearing walls may be noncombustible one-hour fire resistive where unprotected openings are permitted and noncombustible two-hour fire resistive where protection of openings is required.

3. In Groups R, Division 1, and B Occupancies exterior noncombustible bearing walls may be two-hour fire resistive where openings are permitted.

4. Approved fire-retardant treated wood framing may be used within the assembly of exterior walls as permitted by Exceptions 1, 2 and 3, provided the required fire resistance is maintained and the exposed outer and inner faces of such walls are noncombustible.

5. Wood columns and arches conforming to heavy-timber sizes may be used externally where exterior walls are permitted to be unprotected, noncombustible construction or where one-hour fire-resistive noncombustible exterior walls are permitted.

(b) **Openings in Walls.** Openings in exterior walls shall conform to the requirements of Section 504 (b) and shall be protected by a fire assembly having a three-fourths-hour fire-resistive rating when they are less than 20 feet from an adjacent property line or the center line of a public way.

No openings shall be permitted in exterior walls of Groups A, E, I and B, Divisions 1, 2 and 3 Occupancies less than 5 feet from the property line and no openings in Groups B, Division 4, R and M Occupancies less than 3 feet from the property line.

For Group H Occupancies, see Chapter 9.



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(c) **Partitions.** Bearing partitions, when constructed of wood, shall comply with Section 2516 (d).

## Stairway Construction

**Sec. 2104.** (a) **General.** Stairways shall comply with the requirements of Chapter 33.

(b) **Interior.** Interior stairways serving buildings not exceeding three stories in height may be constructed of wood or as required for Type I buildings. If constructed of wood, treads and risers shall be not less than 2 inches in thickness, except where built on laminated or plank inclines as required for floors, where they may be of 1-inch thickness. Wood stair stringers shall be a minimum of 3 inches in thickness and not less than 10 inches in depth.

In buildings more than three stories in height, interior stairways shall be constructed as required for Type I buildings.

(c) **Exterior.** Exterior stairways shall be of noncombustible material except that on buildings not exceeding two stories in height, they may be of wood not less than 2 inches in nominal thickness.

## Roofs

**Sec. 2105.** Roof coverings shall be as specified in Chapter 32.

## Heavy-timber Construction

**Sec. 2106.** (a) **General.** Details of heavy-timber construction shall be in accordance with the provisions of this section. Unless otherwise specified, all dimensions are nominal as defined in Section 2502.

(b) **Columns.** Wood columns may be of sawn timber or structural glued-laminated timber not less than 8 inches in any dimension when supporting roof or floor loads except as specified in Section 2106 (d).

Columns shall be continuous or superimposed and connected in an approved manner.

(c) **Floor Framing.** Beams and girders may be of sawn timber or structural glued-laminated timber and shall be not less than 6 inches in width and not less than 10 inches in depth.

Framed sawn timber or structural glued-laminated timber arches, which spring from the floor line and support floor loads, shall be not less than 8 inches in any dimension.

Framed lumber or structural glued-laminated timber trusses supporting floor loads shall have members of not less than 8 inches in any dimension.

(d) **Roof Framing.** Framed sawn timber arches or structural glued-laminated timber arches for roof construction, which spring from the floor line and do not support floor loads, shall have members not less than 6 inches in width and not less than 8 inches in depth for the lower half of the height and not less than 6 inches in depth for the upper half.

Framed sawn timber or structural glued-laminated timber arches for roof construction which spring from the top of walls or wall abutments; framed lumber



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or structural glued-laminated timber trusses, and other roof framing which does not support floor loads, shall have members not less than 4 inches in width and not less than 6 inches in depth. Spaced members may be composed of two or more pieces not less than 3 inches in thickness, when blocked solidly throughout their intervening spaces, or when such spaces are tightly closed by a continuous wood cover plate of not less than 2 inches in thickness, secured to the underside of the members. Splice plates shall be not less than 3 inches in thickness. When protected by an approved automatic sprinkler system under the roof deck, framing members shall be not less than 3 inches in thickness.

(e) **Floors.** Floors shall be without concealed spaces. Floors shall be of planks, splined or tongue and groove, of not less than 3 inches in thickness covered with 1-inch tongue-and-groove flooring laid crosswide or diagonally, or 15/32-inch plywood, or of plank not less than 4 inches in width set on edge close together and well spiked, and covered with 1-inch flooring or 15/32-inch plywood. The lumber shall be laid so that no continuous line of joints will occur except at points of support. Floors shall not extend closer than 1/2 inch to walls. Such 1/2-inch space shall be covered by a molding fastened to the wall and so arranged that it will not obstruct the swelling or shrinkage movements of the floor. Corbeling of masonry walls under floors may be used in place of such molding.

(f) **Roof Decks.** Roofs shall be without concealed spaces and roof decks shall be of planks, splined or tongue and groove, of not less than 2-inch thickness, or 1 1/8-inch tongue-and-groove plywood with exterior glue, or of a double thickness of 1-inch boards with tongue-and-groove joints, or with staggered joints, of lumber not less than 3 inches nominal in width, set on edge close together and laid as required for floors.

(g) **Construction Details.** Approved wall plate boxes or hangers shall be provided where wood beams, girders or trusses rest on masonry or concrete walls.

Girders and beams shall be closely fitted around columns, and adjoining ends shall be cross tied to each other, or intertied by caps or ties, to transfer horizontal loads across the joints. Wood bolsters may be placed on top of columns which support roof loads only.

Where intermediate beams are used to support a floor, they shall rest on top of the girders, or shall be supported by ledgers or blocks securely fastened to the sides of the girders, or they may be supported by approved metal hangers into which the ends of the beams shall be closely fitted.

In heavy-timber roof construction, every roof girder and at least every alternate roof beam shall be anchored to its supporting member; roof decks, where supported by a wall, shall be anchored to such wall at intervals not exceeding 20 feet; every monitor and every sawtooth construction shall be anchored to the main roof construction. Such anchors shall consist of steel or iron bolts of sufficient strength to resist vertical uplift of the roof.

(h) **Mechanically Laminated Floors and Roof Decks.** Mechanically laminated floors and roof decks conforming to Section 2516 (l) may be used as heavy-timber floors or roof decks, provided the minimum thickness and other applicable requirements of the section are followed.



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(i) **Partitions.** Partitions shall be of solid wood construction formed by not less than two layers of 1-inch matched boards or laminated construction of 4-inch thickness, or of one-hour fire-resistive construction.



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# Chapter 22
# TYPE V BUILDINGS

## Definition

**Sec. 2201.** Type V buildings may be of any materials allowed by this code.

Type V One-hour buildings shall be of one-hour fire-resistive construction throughout.

Materials of construction and fire-resistive requirements shall be as specified in Chapter 17

For requirements due to occupancy, see Chapters 6 to 12 inclusive.

## Structural Framework

**Sec. 2202.** Structural framework shall be of steel or iron as specified in Chapter 27, concrete as in Chapter 26, masonry as in Chapter 24, or wood as in Chapter 25 and this chapter.

## Exterior Walls and Openings

**Sec. 2203.** Exterior walls shall comply with fire-resistive requirements set forth in Section 504 and Table No. 5-A. Openings in exterior walls located where protected openings are required by Table No. 5-A shall be protected by fixed fire windows or automatic-closing fire windows or self-closing doors having a fire-protection rating of at least three-fourths hour and shall comply with Section 504.

For Group H Occupancies, see Chapter 9.

## Stairway Construction

**Sec. 2204.** (a) **General.** Stairways shall comply with the requirements of Chapter 33.

(b) **Interior.** Interior stairways may be constructed of any materials permitted by this code.

(c) **Exterior.** Exterior stairways shall be constructed of wood not less than 2 inches in nominal thickness, or may be of noncombustible materials.

## Roofs

**Sec. 2205.** Roof coverings shall be as specified in Chapter 32.



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# *Part V*

# ENGINEERING REGULATIONS—QUALITY AND DESIGN OF THE MATERIALS OF CONSTRUCTION

## Chapter 23

## GENERAL DESIGN REQUIREMENTS

### Scope

**Sec. 2301.** This chapter preseribes general design requirements applicable to all structures regulated by this code.

### Definitions

**Sec. 2302.** The following definitions give the meaning of certain terms used in this chapter:

**DEAD LOAD** is the vertieal load due to the weight of all permanent structural and nonstructural components of a building, such as walls, floors, roofs and fixed service equipment.

**LIVE LOAD** is the load superimposed by the use and occupancy of the building not ineluding the wind load, earthquake load or dead load.

**LOAD DURATION** is the period of continuous application of a given load, or the aggregate of periods of intermittent application of the same load.

### Design Methods

**Sec. 2303.** (a) **General.** All buildings and portions thereof shall be designed and eonstructed to sustain, within the stress limitations speeified in this code, all dead loads and all other loads speeified in this chapter or elsewhere in this code. Impaet loads shall be considered in the design of any structure where impact loads occur.

> **EXCEPTION:** Unless otherwise required by the building official, buildings or portions thereof which are constructed in accordance with the eonventional framing requirements specified in Chapter 25 of this code shall be deemed to meet the requirements of this section.

(b) **Rationality.** Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system which provides a complete load path capable of transferring all loads and forces from their point of origin to the load-resisting elements. The analysis shall include, but not be limited to, the following:

1. **Distribution of horizontal shear.** The total lateral force shall be distributed to the various vertical elements of the lateral force-resisting system in proportion to their rigidities considering the rigidity of the horizontal bracing system or diaphragm. Rigid elements that are assumed not to be part of the lateral force-resisting system may be incorporated into buildings, provided that their effect on the action of the system is considered and provided for in the design.



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2. **Horizontal torsional moments.** Provision shall be made for the increased forces induced on resisting elements of the structural system resulting from torsion due to eccentricity between the center of application of the lateral forces and the center of rigidity of the lateral force-resisting system. Forces shall not be decreased due to torsional effects. For accidental torsion requirements for seismic design, see Section 2312 (e) 6.

3. **Stability against overturning.** Every building or structure shall be designed to resist the overturning effects caused by the lateral forces specified in this chapter. See Section 2311 (e) for wind and Section 2312 (f) for seismic.

4. **Anchorage.** Anchorage of the roof to walls and columns, and of walls and columns to foundations, shall be provided to resist the uplift and sliding forces which result from the application of the prescribed forces. For additional requirements for masonry or concrete walls, see Section 2310.

(c) **Critical Distribution of Live Loads.** Where structural members are arranged so as to create continuity, the loading conditions which would cause maximum shear and bending moments along the member shall be investigated.

(d) **Stress Increases.** All allowable stresses and soil-bearing values specified in this code for working stress design may be increased one-third when considering wind or earthquake forces either acting alone or when combined with vertical loads. No increase will be allowed for vertical loads acting alone.

(e) **Load Factors.** Load factors for ultimate strength design of concrete and plastic design of steel shall be as indicated in the appropriate chapters on the materials.

(f) **Load Combinations.** Every building component shall be provided with strength adequate to resist the most critical effect resulting from the following combination of loads (floor live load shall not be included where its inclusion results in lower stresses in the member under investigation):[1]

1. Dead plus floor live plus roof live (or snow).[2]
2. Dead plus floor live plus wind[2] (or seismic).
3. Dead plus floor live plus wind plus snow/2.[2]
4. Dead plus floor live plus snow plus wind/2.[2]
5. Dead plus floor live plus snow[3] plus seismic.

## Floor Design

**Sec. 2304.** (a) **General.** Floors shall be designed for the unit loads set forth in Table No. 23-A. These loads shall be taken as the minimum live loads in pounds per square foot of horizontal projection to be used in the design of buildings for the

[1]Lateral earth pressure shall be included in the design where it will result in a more critical combination.

[2]Crane hook loads need not be combined with roof live load nor with more than three fourths of the snow load or one-half wind load.

[3]Snow loads over 30 psf may be reduced 75 percent upon approval of the building official, and snow loads 30 psf or less need not be combined with seismic.



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occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but which create or accommodate similar loadings.

When it can be determined in designing floors that the actual live load will be greater than the value shown in Table No. 23-A, the actual live load shall be used in the design of such buildings or part thereof and special provisions shall be made for machine or apparatus loads.

(b) **Distribution of Uniform Floor Loads.** Where uniform floor loads are involved, consideration may be limited to full dead load on all spans in combination with full live load on adjacent spans and on alternate spans.

(c) **Concentrated Loads.** Provision shall be made in designing floors for a concentrated load as set forth in Table No. 23-A placed upon any space 2½ feet square, wherever this load upon an otherwise unloaded floor would produce stresses greater than those caused by the uniform load required therefor.

Provision shall be made in areas where vehicles are used or stored for concentrated loads consisting of two or more loads spaced 5 feet nominally on center without uniform live loads. Each load shall be 40 percent of the gross weight of the maximum size vehicle to be accommodated. The condition of concentrated or uniform live load producing the greater stresses shall govern. Parking garages for the storage of private or pleasure-type motor vehicles with no repair or fueling shall have a floor system designed for a concentrated wheel load of not less than 2000 pounds without uniform live loads. The condition of concentrated or uniform live load producing the greater stresses shall govern.

Provision shall be made for special vertical and lateral loads as set forth in Table No. 23-B.

(d) **Partition Loads.** Floors in office buildings and in other buildings where partition locations are subject to change shall be designed to support, in addition to all other loads, a uniformly distributed dead load equal to 20 pounds per square foot. Access floor systems may be designed to support, in addition to all other loads, a uniformly distributed dead load equal to 10 pounds per square foot.

(e) **Live Loads Posted.** The live loads for which each floor or part thereof of a commercial or industrial building is or has been designed shall have such designed live loads conspicuously posted by the owner in that part of each story in which they apply, using durable metal signs, and it shall be unlawful to remove or deface such notices. The occupant of the building shall be responsible for keeping the actual load below the allowable limits.

## Roof Design

**Sec. 2305.** (a) **General.** Roofs shall sustain, within the stress limitations of this code, all "dead loads" plus unit "live loads" as set forth in Table No. 23-C. The live loads shall be assumed to act vertically upon the area projected upon a horizontal plane.

(b) **Distribution of Loads.** Where uniform roof loads are involved in the design of structural members arranged so as to create continuity, consideration may be limited to full dead loads on all spans in combination with full live loads on adjacent spans and on alternate spans.



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**EXCEPTION:** Alternate span loading need not be considered where the uniform roof live load is 20 pounds per square foot or more or the provisions of Section 2305 (d) are met.

(c) **Unbalanced Loading.** Unbalanced loads shall be used where such loading will result in larger members or connections. Trusses and arches shall be designed to resist the stresses caused by unit live loads on one half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load upon the entire span. For roofs whose structure is composed of a stressed shell, framed or solid, wherein stresses caused by any point loading are distributed throughout the area of the shell, the requirements for unbalanced unit live load design may be reduced 50 percent.

(d) **Snow Loads.** Snow loads full or unbalanced shall be considered in place of loads set forth in Table No. 23-C, where such loading will result in larger members or connections.

Potential accumulation of snow at valleys, parapets, roof structures and offsets in roofs of uneven configuration shall be considered. Where snow loads occur, the snow loads shall be determined by the building official.

Snow loads in excess of 20 pounds per square foot may be reduced for each degree of pitch over 20 degrees by $R_s$ as determined by the following formula:

$$R_s = \frac{S}{40} - \frac{1}{2}$$

**WHERE:**

$R_s$ = Snow load reduction in pounds per square foot per degree of pitch over 20 degrees.

$S$ = Total snow load in pounds per square foot.

For alternate design procedure see Appendix Chapter 23, Division 1.

(e) **Special Roof Loadings.** Roofs to be used for special purposes shall be designed for appropriate loads as approved by the building official.

Greenhouse roof bars, purlins and rafters shall be designed to carry a 100-pound-minimum concentrated load in addition to the live load.

(f) **Water Accumulation.** All roofs shall be designed with sufficient slope or camber to assure adequate drainage after the long-time deflection from dead load or shall be designed to support maximum loads, including possible ponding of water from any source, including snow, due to deflection. See Section 2307 for deflection criteria.

## Reduction of Live Loads

**Sec. 2306.** The design live load determined using the unit live loads as set forth in Table No. 23-A for floors and Table No. 23-C, Method 2, for roofs may be reduced on any member supporting more than 150 square feet, including flat slabs, except for floors in places of public assembly and for live loads greater than 100 pounds per square foot, in accordance with the following formula:

$$R = r\,(A - 150) \qquad (6\text{-}1)$$



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The reduction shall not exceed 40 percent for members receiving load from one level only, 60 percent for other members, nor $R$ as determined by the following formula:

$$R = 23.1 (1 + D/L) \quad \text{.....(6-2)}$$

**WHERE:**

$R$ = Reduction in percent.

$r$ = Rate of reduction equal to .08 percent for floors. See Table No. 23-C for roofs.

$A$ = Area of floor or roof supported by the member.

$D$ = Dead load per square foot of area supported by the member.

$L$ = Unit live load per square foot of area supported by the member.

For storage live loads exceeding 100 pounds per square foot, no reduction shall be made, except that design live loads on columns may be reduced 20 percent.

The live load reduction shall not exceed 40 percent in garages for the storage of private pleasure cars having a capacity of not more than nine passengers per vehicle.

## Deflection

**Sec. 2307.** The deflection of any structural members shall not exceed the values set forth in Table No. 23-D, based upon the factors set forth in Table No. 23-E. The deflection criteria representing the most restrictive condition shall apply. Deflection criteria for materials not specified shall be developed in a manner consistent with the provisions of this section. See Section 2305 (f) for camber requirements. Span tables for light wood frame construction as specified in Sections 2517 (d) and 2517 (h) 2 shall conform to the design criteria contained therein, except that where the dead load exceeds 50 percent of the live load, Table No. 23-D shall govern. (For aluminum, see Section 2803.)

## Special Design

**Sec. 2308.** (a) **General.** In addition to the design loads specified in this chapter, the design of all structures shall consider the special loads set forth in Table No. 23-B and in this section.

(b) **Retaining Walls.** Retaining walls shall be designed to resist the lateral pressure of the retained material in accordance with accepted engineering practice. Walls retaining drained earth may be designed for pressure equivalent to that exerted by a fluid weighing not less than 30 pounds per cubic foot and having a depth equal to that of the retained earth. Any surcharge shall be in addition to the equivalent fluid pressure.

Retaining walls shall be designed to resist sliding or overturning by at least 1.5 times the lateral force or overturning moment.



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(c) **Heliport and Helistop Landing Areas.** In addition to other design requirements of this chapter, heliport and helistop landing or touchdown areas shall be designed for the maximum stress induced by the following:

1. Dead load plus actual weight of the helicopter.
2. Dead load plus a single concentrated impact load covering 1 square foot of 0.75 times the fully loaded weight of the helicopter if it is equipped with hydraulic-type shock absorbers, or 1.5 times the fully loaded weight of the helicopter if it is equipped with a rigid or skid-type landing gear.
3. The dead load plus a uniform live load of 100 pounds per square foot. The required live load may be reduced in accordance with the formula in Section 2306.

(d) **Hydrostatic Uplift.** All foundations, slabs and other footings subject to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure.

## Walls and Structural Framing

**Sec. 2309.** (a) **General.** Walls and structural framing shall be erected true and plumb in accordance with the design.

(b) **Interior Walls.** Interior walls, permanent partitions and temporary partitions which exceed 6 feet in height shall be designed to resist all loads to which they are subjected but not less than a force of 5 pounds per square foot applied perpendicular to the walls. The deflection of such walls under a load of 5 pounds per square foot shall not exceed $^{1}/_{240}$ of the span for walls with brittle finishes and $^{1}/_{120}$ of the span for walls with flexible finishes. See Table No. 23-P for earthquake design requirements where such requirements are more restrictive.

**EXCEPTION:** Flexible, folding or portable partitions are not required to meet the load and deflection criteria but must be anchored to the supporting structure to meet the provisions of this code.

## Anchorage of Concrete or Masonry Walls

**Sec. 2310.** Concrete or masonry walls shall be anchored to all floors and roofs which provide lateral support for the wall. Such anchorage shall provide a positive direct connection capable of resisting the horizontal forces specified in this chapter or a minimum force of 200 pounds per lineal foot of wall, whichever is greater. Walls shall be designed to resist bending between anchors where the anchor spacing exceeds 4 feet. Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall. See Sections 2312 (g), 2312 (h) 2 H and 2312 (h) 2 I.

## Wind Design

**Sec. 2311.** (a) **General.** Every building or structure and every portion thereof shall be designed and constructed to resist the wind effects determined in accordance with the requirements of this section. Wind shall be assumed to come from



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any horizontal direction. No reduction in wind pressure shall be taken for the shielding effect of adjacent structures.

Structures sensitive to dynamic effects, such as buildings with a height-width ratio greater than five, structures sensitive to wind-excited oscillations, such as vortex shedding or icing, and buildings over 400 feet in height, shall be, and any structure may be, designed in accordance with approved national standards.

(b) **Basic Wind Speed.** The minimum basic wind speed for determining design wind pressure shall be taken from Figure No. 1. Where terrain features and local records indicate that 50-year wind speeds at standard height are higher than those shown in Figure No. 1, these higher values shall be the minimum basic wind speeds.

(c) **Exposure.** An exposure shall be assigned at each site for which a building or structure is to be designed. Exposure C represents the most severe exposure and has terrain which is flat and generally open, extending one-half mile or more from the site in any full quadrant. Exposure B has terrain which has buildings, forest or surface irregularities 20 feet or more in height covering at least 20 percent of the area extending one mile or more from the site.

(d) **Design Wind Pressures.** Design wind pressures for structures or elements of structures shall be determined for any height in accordance with the following formula:

$$p = C_e C_q q_s I \quad \text{(11-1)}$$

**WHERE:**

$p$ = Design wind pressure.

$C_e$ = Combined height, exposure and gust factor coefficient as given in Table No. 23-G.

$C_q$ = Pressure coefficient for the structure or portion of structure under consideration as given in Table No. 23-H.

$q_s$ = Wind stagnation pressure at the standard height of 30 feet as set forth in Table No. 23-F.

$I$ = Importance factor as set forth in Section 2311 (i).

(e) **Primary Frames and Systems.** The primary frames or load-resisting system of every structure shall be designed for the pressures calculated using Formula (11-1) and the pressure coefficients, $C_q$, of either Method 1 or Method 2. In addition, design of the overall structure and its primary load-resisting system shall conform to Section 2303.

The base overturning moment for the entire structure, or for any one of its individual primary lateral resisting elements, shall not exceed two thirds of the dead-load-resisting moment. For an entire structure with a height-to-width ratio of 0.5 or less in the wind direction and a maximum height of 60 feet, the combination of the effects of uplift and overturning may be reduced by one-third. The weight of earth superimposed over footings may be used to calculate the dead-load-resisting moment.



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1. **Method 1 (Normal Force Method).** Method 1 shall be used for the design of gabled rigid frames and may be used for any structure. In the Normal Force Method, the wind pressures shall be assumed to act simultaneously normal to all exterior surfaces. For pressures on roofs and leeward walls, $C_e$ shall be evaluated at the mean roof height.

2. **Method 2 (Projected Area Method).** Method 2 may be used for any structure less than 200 feet in height except those using gabled rigid frames. This method may be used in stability determinations for any structure less than 200 feet high. In the Projected Area Method, horizontal pressures shall be assumed to act upon the full vertical projected area of the structure, and the vertical pressures shall be assumed to act simultaneously upon the full horizontal projected area.

(f) **Elements and Components of Structures.** Design wind pressures for each element or component of a structure shall be determined from Formula (11-1) and $C_q$ values from Table No. 23-H, and shall be applied perpendicular to the surface. For outward acting forces the value of $C_e$ shall be obtained from Table No. 23-G based on the mean roof height and applied for the entire height of the structure. Each element or component shall be designed for the more severe of the following loadings:

1. The pressures determined using $C_q$ values for elements and components acting over the entire tributary area of the element.

2. The pressures determined using $C_q$ values for local areas at discontinuities such as corners, ridges and eaves. These local pressures shall be applied over a distance from a discontinuity of 10 feet or 0.1 times the least width of the structure, whichever is less.

The wind pressures from Subsections (e) and (f) need not be combined.

(g) **Open-frame Towers.** Radio towers and other towers of trussed construction shall be designed and constructed to withstand wind pressures specified in this section, multiplied by the shape factors set forth in Table No. 23-H.

(h) **Miscellaneous Structures.** Greenhouses, lath houses, agricultural buildings or fences 12 feet or less in height shall be designed in accordance with Section 2311. However, three fourths of $q_s$, but not less than 10 pounds per square foot, may be substituted for $q_s$ in Formula (11-1). Pressures on local areas at discontinuities need not be considered.

(i) **Importance Factor.** A factor of 1.15 shall be used for essential facilities which must be safe and usable for emergency purposes after a windstorm in order to preserve the health and safety of the general public. Such facilities shall include:

1. Hospitals and other medical facilities having surgery or emergency treatment areas.
2. Fire and police stations.
3. Municipal government disaster operation and communication centers deemed to be vital in emergencies.
4. Buildings where the primary occupancy is for assembly use for more than 300 people.

A factor of 1.0 shall be used for all other buildings.



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(j) **Open Buildings, Structure or Story.** A building structure or story shall be considered open when 15 percent or more of the area of the exterior wall on any one side is open. All windows and doors or other openings in exterior walls shall be considered as openings unless specifically detailed and designed to resist the loads of elements and components in accordance with the provisions of this section.

## Earthquake Regulations

**Sec. 2312** (a) **General.** 1. **Minimum seismic design.** Structures and portions thereof shall, as a minimum, be designed and constructed to resist the effects of seismic ground motions as provided in this section.

2. **Seismic and wind.** When the code-prescribed wind design produces greater effects, the wind design shall govern, but detailing requirements and limitations prescribed in this and referenced sections shall be followed.

(b) **Definitions.** For the purposes of this section certain terms are defined as follows:

**BASE** is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported.

**BASE SHEAR,** $V$, is the total design lateral force or shear at the base of a structure.

**BEARING WALL SYSTEM** is a structural system without a complete vertical load-carrying space frame. See Section 2312 (d) 6 B.

**BOUNDARY ELEMENT** is an element at edges of openings or at perimeters of shear walls or diaphragms.

**BRACED FRAME** is an essentially vertical truss system of the concentric or eccentric type which is provided to resist lateral forces.

**BUILDING FRAME SYSTEM** is an essentially complete space frame which provides support for gravity loads. See Section 2312 (d) 6 C.

**COLLECTOR** is a member or element provided to transfer lateral forces from a portion of a structure to vertical elements of the lateral force-resisting system.

**CONCENTRICALLY BRACED FRAME** is a braced frame in which the members are subjected primarily to axial forces.

**DIAPHRAGM** is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. The term "diaphragm" includes horizontal bracing systems.

**DIAPHRAGM CHORD** is the boundary element of a diaphragm or shear wall which is assumed to take axial stresses analogous to the flanges of a beam.

**DIAPHRAGM STRUT** (drag strut, tie, collector) is the element of a diaphragm parallel to the applied load which collects and transfers diaphragm shear to vertical resisting elements or distributes loads within the diaphragm. Such members may take axial tension or compression.

**DRIFT** see STORY DRIFT.



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**DUAL SYSTEM** is a combination of a special or intermediate moment-resisting space frame and shear walls or braced frames designed in accordance with the criteria of Section 2312 (d) 6 E.

**ECCENTRICALLY BRACED FRAME (EBF)** is a steel-braced frame designed in conformance with Section 2722 (h).

**ESSENTIAL FACILITIES** are those structures which are necessary for emergency postearthquake operations.

**FLEXIBLE ELEMENT** or system is one whose deformation under lateral load is significantly larger than adjoining parts of the system. Limiting ratios for defining specific flexible elements are set forth in Sections 2312 (e) 3 B (ii), 2312 (e) 6 or 2312 (g) 2.

**HORIZONTAL BRACING SYSTEM** is a horizontal truss system that serves the same function as a diaphragm.

**LATERAL FORCE-RESISTING SYSTEM** is that part of the structural system assigned to resist lateral forces.

**ORTHOGONAL EFFECTS** are the effects on structural elements common to the resisting systems along two orthogonal axes due to earthquake forces acting in a direction other than those axes.

**P-DELTA EFFECT** is the secondary effect on shears, axial forces and moments of frame members induced by the vertical loads acting on the laterally displaced building frame.

**SHEAR WALL** is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as a vertical diaphragm).

**SOFT STORY** is one in which the lateral stiffness is less than 70 percent of the stiffness of the story above. See Table No. 23-M.

**SPACE FRAME** is a three-dimensional structural system, without bearing walls, composed of members interconnected so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.

**Intermediate moment-resisting space frame (IMRSF)** is a concrete space frame designed in conformance with Section 2625 (k).

**Moment-resisting space frame** is a space frame in which the members and joints are capable of resisting forces primarily by flexure.

**Ordinary moment-resisting space frame (OMRSF)** is a moment-resisting space frame not meeting special detailing requirements for ductile behavior.

**Special moment-resisting space frame (SMRSF)** is a moment-resisting space frame specially detailed to provide ductile behavior and comply with the requirements given in Chapter 26 or 27.

**Vertical load-carrying space frame** is a space frame designed to carry all vertical gravity loads.

**STORY** is the space between levels. Story $x$ is the story below Level $x$.

**STORY DRIFT** is the displacement of one level relative to the level above or below.



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**STORY DRIFT RATIO** is the story drift divided by the story height.

**STORY SHEAR, $V_x$,** is the summation of design lateral forces above the story under consideration.

**STRENGTH** is the useable capacity of a structure or its members to resist load within the deformation limits prescribed in this section and referenced sections.

**STRUCTURE** is an assemblage of framing members designed to support gravity loads and resist lateral forces. Structures may be categorized as building structures or nonbuilding structures.

**WEAK STORY** is one in which the story strength is less than 80 percent of that of the story above. See Table No. 23-M.

(c) **Symbols and Notations.** The following symbols and notations apply to the provisions of this section:

$A_c$ = The combined effective area, in square feet, of the shear walls in the first story of the structure.

$A_e$ = The minimum cross-sectional shear area in any horizontal plane in the first story, in square feet, of a shear wall.

$A_x$ = The torsional amplification factor at Level $x$.

$C$ = Numerical coefficient specified in Section 2312 (e) 2 A.

$C_p$ = Numerical coefficient specified in Section 2312 (g) and given in Table No. 23-P.

$C_t$ = Numerical coefficient given in Section 2312 (e) 2 B.

$D_e$ = The length, in feet, of a shear wall in the first story in the direction parallel to the applied forces.

$\delta i$ = Horizontal displacement at Level $i$ relative to the base due to applied lateral forces, $f$, for use in Formula (12-5).

$f_i$ = Lateral force at Level $i$ for use in Formula (12-5).

$F_i$, $F_n$, $F_x$ = Lateral force applied to Level $i$, $n$, or $x$, respectively.

$F_p$ = Lateral forces on a part of the structure.

$F_t$ = That portion of the base shear, $V$, considered concentrated at the top of the structure in addition to $F_n$.

$g$ = Acceleration due to gravity.

$h_i$, $h_n$, $h_x$ = Height in feet above the base to Level $i$, $n$, or $x$, respectively.

$I$ = Importance factor given in Table No. 23-L.

Level $i$ = Level of the structure referred to by the subscript i. "$i$ = 1" designates the first level above the base.

Level $n$ = That level which is uppermost in the main portion of the structure.

Level $x$ = That level which is under design consideration. "$x$ = 1" designates the first level above the base.

$R_w$ = Numerical coefficient given in Tables Nos. 23-O and 23-Q.

$S$ = Site coefficient for soil characteristics given in Table No. 23-J.



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$T$ = Fundamental period of vibration, in seconds, of the structure in the direction under consideration.

$V$ = The total design lateral force or shear at the base.

$V_x$ = The design story shear in Story $x$.

$W$ = The total seismic dead load defined in Section 2312 (e) 1.

$w_i$, $w_x$ = That portion of $W$ which is located at or is assigned to Level $i$ or $x$, respectively.

$w_{px}$ = The weight of the diaphragm and the elements tributary thereto at Level $x$, including applicable portions of other loads defined in Section 2312 (e) 1.

$W_p$ = The weight of an element or component.

$Z$ = Seismic zone factor given in Table No. 23-I.

(d) **Criteria Selection.** 1. **Basis for design.** The procedures and limitations for the design of structures shall be determined considering zoning, site characteristics, occupancy, configuration, structural system and height in accordance with this section. The minimum design seismic forces shall be those determined in accordance with the static lateral force procedure of Section 2312 (e) except as modified by 2312 (f) 5 C. One- and two-family dwellings in Seismic Zone 1 need not conform to the provisions of this section.

2. **Seismic zones.** Each site shall be assigned to a seismic zone in accordance with Figure No. 2. Each structure shall be assigned a zone factor, $Z$, in accordance with Table No. 23-I.

3. **Site geology and soil characteristics.** Soil profile type and site coefficient, $S$, shall be established in accordance with Table No. 23-J.

4. **Occupancy categories.** For purposes of earthquake-resistant design, each structure shall be placed in one of the occupancy categories listed in Table No. 23-K. Table No. 23-L lists importance factors, $I$, and review requirements for each category.

5. **Configuration requirements.** A. **General.** Each structure shall be designated as being structurally regular or irregular.

B. **Regular structures.** Regular structures have no significant physical discontinuities in plan or vertical configuration or in their lateral force-resisting systems such as the irregular features described below.

C. **Irregular structures.**

(i) Irregular structures have significant physical discontinuities in configuration or in their lateral force-resisting systems. Irregular features include, but are not limited to, those described in Tables Nos. 23-M and 23-N. Structures in Seismic Zone No. 1 and in Occupancy Category IV in Seismic Zone No. 2 need be evaluated only for vertical irregularities of Type E (Table No. 23-M) and horizontal irregularities of Type A (Table No. 23-N).

(ii) Structures having one or more of the features listed in Table No. 23-M shall be designated as of having a vertical irregularity.



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**EXCEPTION:** Where no story drift ratio under design lateral load is greater than 1.3 times the story drift ratio of the story above the structure may be deemed to not have the structural irregularities of Types A or B in Table No. 23-M. The drift ratio relationship for the top two stories need not be considered. The story drifts for this determination may be calculated neglecting torsional effects.

(iii) Structures having one or more of the features listed in Table No. 23-N shall be designated as having a plan irregularity.

6. **Structural systems.** A. **General.** Structural systems shall be classified as one of the types listed in Table No. 23-0 and defined in this subsection.

B. **Bearing wall system.** A structural system without a complete vertical load-carrying space frame. Bearing walls or bracing systems provide support for all or most gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

C. **Building frame system.** A structural system with an essentially complete space frame providing support for gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

D. **Moment-resisting frame system.** A structural system with an essentially complete space frame provides support for gravity loads. Moment-resisting space frames provide resistance to lateral load primarily by flexural action of members.

E. **Dual system.** A structural system with the following features:

(i) An essentially complete space frame which provides support for gravity loads.

(ii) Resistance to lateral load is provided by a specially detailed moment-resisting space frame (concrete or steel) which is capable of resisting at least 25 percent of the base shear and shear walls or braced frames.

(iii) The two systems shall be designed to resist the total lateral load in proportion to their relative rigidities.

F. **Undefined structural system.** A structural system not listed in Table No. 23-O.

G. **Nonbuilding structural system.** A structural system conforming to Section 2312 (i).

7. **Height limits.** Height limits for the various structural systems in Seismic Zones 3 and 4 are given in Table No. 23-0.

**EXCEPTION:** Regular structures may exceed these limits by not more than 50 percent for unoccupied structures which are not accessible to the general public.

8. **Selection of lateral force procedure.** A. **General.** Any structure may be, and certain structures defined below shall be, designed using the dynamic lateral force procedures of Section 2312 (f).

B. **Static.** The static lateral force procedure of Section 2312 (e) may be used for the following structures:

(i) All structures, regular or irregular, in Seismic Zone No. 1 and in Occupancy Category IV in Seismic Zone No. 2.

(ii) Regular structures under 240 feet in height with lateral force resistance provided by systems listed in Table No. 23-O.



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(iii) Irregular structures not more than five stories nor 65 feet in height.

(iv) Structures having a flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average story stiffness of the lower portion is at least ten times the average story stiffness of the upper portion and the period of the entire structure is not greater than 1.1 times the period of the upper portion considered as a separate structured fixed at the base.

C. **Dynamic.** The dynamic lateral force procedure of Section 2312 (f) shall be used for all other structures, including the following:

(i) Structures 240 feet or more in height except as permitted by Section 2312 (d) 8, Item B (i).

(ii) Structures having a stiffness, weight or geometric vertical irregularity of Type A, B or C as defined in Table No. 23-M or struetures having irregular features not described in Table No. 23-M or 23-N except as permitted by Section 2312 (e) 3 B.

(iii) Structures over five stories or 65 feet in height in Seismic Zones Nos. 3 and 4 not having the same structural system throughout their height except as permitted by Section 2312 (e) 3 B.

9. **System limitations.** A. **Discontinuity.** Structures with a discontinuity in capacity, vertical irregularity Type E as defined in Table No. 23-M, shall not be over two stories or 30 feet in height where the weak story has a calculated strength of less than 65 percent of the story above.

**EXCEPTION:** Where the weak story is capable of resisting a total lateral seismic force of 3 ($R_w$/8) times the design force prescribed in Section 2312 (e).

B. **Undefined structural systems.** Undefined structural systems shall be shown by technical and test data which establish the dynamic characteristics and demonstrate the lateral force resistance and energy absorption capacity to be equivalent to systems listed in Table No. 23-O for equivalent $R_w$ values.

C. **Irregular features.** All structures having irregular features described in Table No. 23-M or 23-N shall be designed to meet the additional requirements of those sections referenced in the tables.

10. **Alternative procedures.** Alternative lateral force procedures using rational analyses based on well established principles of mechanics may be used in lieu of those prescribed in these provisions.

(e) **Minimum Design Lateral Forces and Related Effects.** 1. **General.** Structures shall be designed for seismic forces coming from any horizontal direction.

The design seismic forces may be assumed to act noncurrently in the direction of each principal axis of the structure, except as required by Section 2312 (h) 1.

Seismic dead load, $W$, is the total dead load and applicable portions of other loads listed below.

A. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.



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B. Where a partition load is used in the floor design, a load of not less than 10 psf shall be included.

C. Where the snow load is greater than 30 psf, the snow load shall be included. Where considerations of siting, configuration and load duration warrant, the snow load may be reduced up to 75 percent when approved by the building official.

D. Total weight of permanent equipment shall be included.

2. **Static force procedure.** A. **Design base shear.** The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{Z\,I\,C}{R_W}\,W \qquad (12\text{-}1)$$

$$C = \frac{1.25\,S}{T^{2/3}} \qquad (12\text{-}2)$$

The value of $C$ need not exceed 2.75 and may be used for any structure without regard to soil type or structure period.

Except for those provisions where code prescribed forces are scaled up by 3 $(R_w/8)$ the minimum value of the ratio $C/R_w$ shall be 0.075.

B. **Structure period.** The value of $T$ shall be determined from one of the following methods:

(i) **METHOD A:** For all buildings, the value $T$ may be approximated from the following formula:

$$T = C_t(h_n)^{3/4} \qquad (12\text{-}3)$$

**WHERE:**

$C_t$ = 0.035 for steel moment-resisting frames.

$C_t$ = 0.030 for reinforced concrete moment-resisting frames and eccentrically braced frames.

$C_t$ = 0.020 for all other buildings.

Alternatively, the value of $C_t$ for structures with concrete or masonry shear walls may be taken as $0.1/\sqrt{A_c}$.

The value of $A_c$ shall be determined from the following formula:

$$A_c = \Sigma A_e\,[0.2 + (D_e/h_n)^2] \qquad (12\text{-}4)$$

The value of $D_e/h_n$ used in formula (12-4) shall not exceed 0.9.

(ii) **METHOD B:** The fundamental period $T$ may be calculated using the structural properties, and deformational characteristics of the resisting elements in a properly substantiated analysis. This requirement may be satisfied by using the following formula:

$$T = 2\pi\sqrt{\left(\sum_{i=1}^{n} w_i\delta_i^2\right) \div \left(g\sum_{i=1}^{n} f_i\delta_i\right)} \qquad (12\text{-}5)$$



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The values of $f_i$ represent any lateral force distributed approximately in accordance with the principles of Formulas (12-6), (12-7) and (12-8) or any other rational distribution. The elastic deflections, $\delta_i$, shall be calculated using the applied lateral forces, $f_i$. The value of $C$ shall be not less than 80 percent of the value obtained by using $T$ from Method A.

3. **Combinations of structural systems.** A. **General.** Where combinations of structural systems are incorporated into the same structure, the requirements of this subsection shall be satisfied.

B. **Vertical combinations.** The value of $R_w$ used in the design of any story shall be less than or equal to the value of $R_w$ used in the given direction for the story above.

**EXCEPTION:** This requirement need not be applied to a story where the dead weight above that story is less than 10 percent of the total dead weight of the structure.

Structures may be designed using the procedures of this section under the following conditions:

(i) The entire structure is designed using the lowest $R_w$ of the lateral force-resisting systems used.

(ii) The following two-stage static analysis procedures may be used for structures conforming to Section 2312 (d) 8, Item B (iv).

*(a)* The flexible upper portion shall be designed as a separate structure; supported laterally by the rigid lower portion, using the appropriate value of $R_w$.

*(b)* The rigid lower portion shall be designed as a separate structure using the appropriate value of $R_w$. The reactions from the upper portion shall be those determined from the analysis of the upper portion amplified by the ratio of the $R_w$ of the upper portion over the $R_w$ of the lower portion.

C. **Combinations along different axes.** In Seismic Zones 3 and 4 where a structure has a bearing wall system in only one direction the value of $R_w$ used for design in the orthagonal direction shall not be greater than that used for the bearing wall system.

Any combination of building frame systems, dual systems or moment-resisting frame systems may be used to resist seismic forces in structures less than 160 feet in height. Only combinations of dual systems and special moment-resisting space frames shall be used to resist seismic forces in structures exceeding 160 feet in height in Seismic Zones 3 and 4.

4. **Vertical distribution of force.** The total force shall be distributed over the height of the structure in conformance with Formulas (12-6), (12-7) and (12-8) in the absence of a more rigorous procedure.

$$V = F_t + \sum_{i=1}^{n} F_i \qquad (12\text{-}6)$$



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The concentrated force $F_t$, at the top, which is in addition to $F_n$, shall be determined from the formula:

$$F_t = 0.07TV \qquad (12\text{-}7)$$

The value of $T$ used for the purpose of calculating $F_t$ may be the period that corresponds with the design base shear as computed using Formula (12-1). $F_t$ need not exceed $0.25V$ and may be considered as zero (0) where $T$ is 0.7 seconds or less. The remaining portion of the base shear shall be distributed over the height of the structure, including Level $n$, according to the following formula:

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (12\text{-}8)$$

At each level designated as $x$, the force $F_x$ shall be applied over the area of the building in accordance with the mass distribution at that level. Stresses in each structural element shall be calculated as the effect of forces $F_x$ and $F_t$ applied at the appropriate levels above the base.

5. **Horizontal distribution of shear.** The design story shear, $V_x$, in any story is the sum of the forces $F_t$ and $F_x$ above that story. $V_x$ shall be distributed to the various elements of the vertical lateral force-resisting system in proportion to their rigidities, considering the rigidity of the diaphragm. See Section 2312 (h) 2 D for rigid elements that are not intended to be part of the lateral force-resisting systems.

To account for the uncertainties in locations of loads, the mass at each level shall be assumed to be displaced from the calculated center of mass in each direction a distance equal to five percent of the building dimension at that level perpendicular to the direction of the force under consideration. The effect of this displacement on the story shear distribution shall be considered.

6. **Horizontal torsional moments.** Provision shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. Diaphragms shall be considered flexible for purposes of this paragraph when the maximum lateral deformation of the diaphragm is more than two times the average story drift of the associated story. This may be determined by comparing the computed midpoint in-plane deflection of the diaphragm under lateral load with the story drift of adjoining vertical resisting elements under equivalent tributary lateral load.

The torsional design moment at a given story shall be the moment resulting from eccentricities between applied design lateral forces at levels above that story and the vertical resisting elements in that story plus an accidental torsion.

The accidental torsional moment shall be determined by assuming the mass is displaced as required by Section 2312 (e) 5.

Where torsional irregularity exists, as defined in Table No. 23-N, the effects



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shall be accounted for by increasing the accidental torsion at each level by an amplification factor, $A_x$, determined from the following formula:

$$A_x = \left[\frac{\delta max}{1.2\,\delta avg}\right]^2 \qquad (12\text{-}9)$$

**WHERE:**

$\delta max$ = The maximum displacement at Level $x$.

$\delta avg$ = The average of the displacements at the extreme points of the structure at Level $x$.

The value of $A_x$ need not exceed 3.0

The more severe loading for each element shall be considered for design.

7. **Overturning.** A. Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 2312 (e) 4. At any level, the overturning moments to be resisted shall be determined using those seismic forces ($F_t$ and $F_x$) which act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 2312 (e) 5. Overturning effects on every element shall be carried down to the foundation. See Section 2312 (h) for combining gravity and seismic forces.

B. In Seismic Zones 3 and 4, where a lateral load-resisting element is discontinuous, such as for vertical irregularity Type D in Table No. 23-M or plan irregularity Type D in Table No. 23-N, columns supporting such elements shall have the strength to resist the axial force resulting from the following load combinations, in addition to all other applicable load combinations:

$$1.0\ DL + 0.8\ LL + 3\ (R_w/8)E$$

$$0.85\ DL + 3\ (R_w/8)E$$

(i) The axial forces in such columns need not exceed the capacity of other elements of the structure to transfer such loads to the column.

(ii) Such columns shall be capable of carrying the above-described axial forces without exceeding the axial load strength of the column. For designs using working stress methods this capacity may be determined using an allowable stress increase of 1.7.

(iii) Such columns shall meet the following detailing or member limitations:

Chapter 26, Section 2625 (e), for concrete, and Chapter 27, Section 2722 (d), for steel in structures in Seismic Zones 3 and 4.

Chapter 26, Section 2625 (k), for concrete, and Chapter 27, Section 2721 (e), for steel in structures in Seismic Zone 2.

C. See Section 2910 (d) for overturning moments to be resisted at the foundation soil interface.

8. **Story drift limitation.** Story drift is the displacement of one level relative to the level above or below due to the design lateral forces. Calculated drift shall include translational and torsional deflections.



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Calculated story drift shall not exceed $0.04/R_w$ nor 0.005 times the story height for buildings less than 65 feet in height. For buildings greater in height, the calculated story drift shall not exceed $0.03/R_w$ nor 0.004 times the story height.

These drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety.

The design lateral forces used to determine the calculated drift may be derived from a value of $C$ based on the period determined from Formula (12-5) neglecting the lower bound ratio for $C/R_w$ of 0.075 of Section 2312 (e) 2 A and the 80 percent limitation of Section 2312 (e) 2 B (ii).

9. **P-delta effects.** The resulting member forces and moments and the story drifts induced by P-delta effects shall be considered in the evaluation of overall structural frame stability. P-delta need not be considered when the ratio of secondary moment to primary moment does not exceed 0.10; the ratio may be evaluated for any story as the product of the total dead and live load above the story times the seismic drift in that story divided by the product of the seismic shear in that story times the height of that story. In Zones 3 and 4, designs conforming to the drift limitations in Section 2312 (e) 8 may be deemed to satisfy this requirement.

10. **Vertical component of seismic forces.** The following requirements apply in Seismic Zones 3 and 4 only.

Horizontal cantilever components shall be designed for a net upward force of $0.2\,W_p$.

In addition to all other applicable load combinations horizontal prestressed components shall be designed using not more than 50 percent of the dead load for the gravity load, alone or in combination with the lateral force effects.

(f) **Dynamic lateral force procedure.** 1. **General.** Dynamic analyses procedures, when used, shall conform to the criteria established in this section. The analysis shall be based on an appropriate ground motion representation and shall be performed using accepted principles of dynamics. Structures which are designed in accordance with this section shall comply with all other applicable requirements of these provisions.

2. **Ground motion.** The ground motion representation may be one of the following:

(i) The response spectra given in Figure No. 3.

(ii) Elastic design response spectra developed for the specific site. The ground motion represented by the spectra shall be based on the geologic, tectonic, seismic recurrence information and foundation material properties associated with the specific site. The spectra shall be representative of motions which can be generated by all known faults which can affect this site.

(iii) Ground motion time histories developed for the specific site shall be representative of actual earthquake motions. Response spectra from time



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histories, either individually or in combination, shall approximate the site design spectrum conforming to Section 2312 (f) 2 (ii).

(iv) The vertical component of ground motion may be defined by scaling corresponding horizontal accelerations by a factor of two thirds. Alternate factors may be used when substantiated by site specific data.

3. **Mathematical model.** A mathematical model of the physical structure shall represent the spatial distribution of the mass stiffness of the structure to an extent which is adequate for the calculation of the significant features of its dynamic response. A three-dimensional model shall be used for the dynamic analysis of struetures with highly irregular plan configurations such as those having a plan irregularity defined in Table No. 23-N and having a rigid or semirigid diaphragm.

4. **Description of analysis procedures.** A. **Response spectrum analysis.** An elastie dynamic analysis of a structure utilizing the peak dynamic response of all modes having a significant contribution to total structural response. Peak modal responses are calculated using the ordinates of the appropriate response spectrum curve which correspond to the modal periods. Maximum modal contributions are combined in a statistical manner to obtain an approximate total struetural response.

B. **Time history analysis.** An analysis of the dynamic response of a structure at each increment of time when the base is subjeeted to a specifie ground motion time history.

5. **Response spectrum analysis.** A. **Number of modes.** The requirement of Seetion 2312 (f) 4 A that all significant modes be included may be satisfied by demonstrating that for the modes considered at least 90 percent of the participating mass of the structure is included in the calculation of response for each principal horizontal direction.

B. **Combining modes.** The peak member forces, displacements, story forces, story shears and base reactions for each mode shall be combined by recognized methods. When three-dimensional models are used for analysis, modal interaction effects shall be considered when eombining modal maxima.

C. **Scaling of results.** The base shear for a given direction determined using these procedures, when less than the values below, shall be scaled up to these values.

(i) The base shear shall be increased to the following percentage of the values determined from the procedures of Section 2312 (e):

*(a)* 100 percent for irregular buildings.

*(b)* 90 percent for regular buildings, except that the base shear shall not be less than 80 percent of that determined from Section 2312 (e) using the period, $T$, caleulated from Method A.

All corresponding response parameters, including deflections, member forces and moments, shall be inereased proportionately.

(ii) The base shear for a given direction determined using these procedures



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need not exceed that required by paragraph (i) above. All corresponding response parameters may be adjusted proportionately.

D. **Directional effects.** Directional effects for horizontal ground motion shall conform to the requirements of Section 2312 (e) 1. The effects of vertical ground motions on horizontal cantilevers and prestressed elements shall be considered in accordance with Section 2312 (e) 10. Alternately, vertical seismic response may be determined by dynamic response methods; in no case shall the response used for design be less than that obtained by the static method.

E. **Torsion.** The analysis shall account for torsional effects, including accidental torsional effects as preseribed in Section 2312 (e) 6. Where three-dimensional models are used for analysis, effects of accidental torsion shall be accounted for by appropriate adjustments in the model such as adjustment of mass locations, or by equivalent statie procedures such as provided in Section 2312 (e) 6.

F. **Dual systems.** Where the lateral force-resisting system consists of a dual system as defined in Section 2312 (d) 6 E, the combined system shall be eapable of resisting the base shear determined in accordance with this section. The backup special moment-resisting space frame shall be capable of resisting 25 percent of the base shear used for the design of the total system. This 25 percent of the total base shear may be applied to the backup space frame using either the procedures of Section 2312 (e) 4 or those of Section 2312 (f) 5.

6. **Time history analysis.** Time history analyses shall meet the requirements of Section 2312 (d) 10.

(g) **Lateral Force on Elements of Structures and Nonstructural Components Supported by Structures.** 1. **General.** Parts and portions of structures, permanent nonstructural eomponents, the attachments for them and the attachments for equipment supported by a structure shall be designed to resist seismic forces prescribed in Section 2312 (g).

Attachments shall include anchorages and required bracing. Friction shall not be considered to provide resistance to seismic forces.

> **EXCEPTION:** Friction may be utilized to resist shear when the normal forces at the support interface are due to the effects of lateral forces and the effects of gravity forces are neglected.

Nonrigid equipment which is needed for Occupancy Category 1, emergency operations or for life-safety systems, or whose failure would cause a life hazard, shall be designed for seismic forces.

> **EXCEPTION:** Equipment weighing less than 400 pounds, furniture, or temporary or movable equipment.

2. **Design for total lateral force.** Each element or component and its connections to the structure shall be designed to resist a total lateral seismic force, $F_p$, given by the following formula:

$$F_p = Z I C_p W_p \qquad (12\text{-}10)$$

The values of $Z$ and $I$ shall be the values used for the building.



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**EXCEPTIONS:** 1. For anchorage of machinery and equipment required for life-safety systems, the value of $I$ shall be taken as 1.5.

2. For the design of tanks and vessels containing sufficient quantities of highly toxic or explosive substances to be hazardous to the safety of the general public if released, the value of $I$ shall be taken as 1.5.

3. The value of $I$ for panel connectors shall be 1.0 for the entire connector.

The coefficient, $C_p$, is for rigid elements and components. Rigid elements are defined as those having a fixed base period less than or equal to 0.06 second. Nonrigid elements are defined as those having a fixed base period greater than 0.06 second.

The values of $C_p$ for nonrigid items or nonrigid or flexibly supported items shall be determined considering both the dynamic properties of the element or component and those of the structure which supports it, but the value shall not be less than that listed in Table No. 23-P. A nonrigid or flexibly supported item is one for which the period of the system, including the item, is greater than 0.06 second. In the absence of a detailed analysis, the value of $C_p$ for a nonrigid or flexibly supported item on a structure above grade shall be taken as twice the value listed in Table No. 23-P, but need not exceed 2.0.

The value of $C_p$ for elements or components supported at or below ground level may be two thirds of the value set forth in Table No. 23-P. However, the design lateral forces for an element or component shall not be less than would be obtained by treating the item as an independent structure and using the provisions of Section 2312 (i).

The design lateral forces determined using Formula (12-10) shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Formula (12-10) shall be used to design elements or components and their connections and anchorage to the structure, and to design members and connections which transfer the forces to the seismic-resisting systems.

For applicable forces in diaphragms and connectors for exterior panels, refer to Sections 2312 (h) 2 D and 2312 (h) 2 I.

Forces shall be applied in the horizontal directions which result in the most critical loadings for design.

3. **Specifying lateral forces.** Design specifications for equipment shall either specify the design lateral forces prescribed herein or reference these provisions.

4. **Essential or hazardous facilities and life-safety systems.** For equipment in facilities assigned to Occupancy Categories I and II and for life-safety systems, the design and detailing of equipment which needs to be functional following a major earthquake shall consider the effect of drift.

5. **Alternative designs.** Where an approved national standard or approved physical test data provide a basis for the earthquake-resistant design of a particular type of equipment or other nonstructural component, such a standard or data may be accepted as a basis for design of the items with the following limitations:

(i) These provisions shall provide minimum values for the design of the



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anchorage and the members and connections which transfer the forces to the seismic-resisting system.

(ii) The force, $F_p$, and the overturning moment used in the design of the nonstructural component shall not be less than 80 percent of the values that would be obtained using these provisions.

(h) **Detailed Systems Design Requirements.** 1. **General.** All structural framing systems shall comply with the requirements of Section 2312 (d). Only the elements of the designated seismic-force-resisting system shall be used to resist design forces. The individual components shall be designed to resist the prescribed design seismic forces acting on them. The components shall also comply with the specific requirements for the material contained in Chapters 24 through 28. In addition, such framing systems and components shall comply with the detailed system design requirements contained in Section 2312 (h).

All building components in Seismic Zones 2, 3 and 4 shall be designed to resist the effects of the seismic forces prescribed herein and the effects of gravity loadings from dead, floor, live and snow loads.

Consideration shall be given to design for uplift effects caused by seismic loads. For materials which use working stress procedures, dead loads shall be multiplied by 0.85 when used to reduce uplift.

In Seismic Zones 2, 3 and 4, provision shall be made for the effects of earthquake forces acting in a direction other than the principal axes in each of the following circumstances:

The structure has plan irregularity Type E as given in Table No. 23-N.

The structure has plan irregularity Type A as given in Table No. 23-N for both major axes.

A column of a structure forms part of two or more intersecting lateral force-resisting systems.

**EXCEPTION:** If the axial load in the column due to seismic forces acting in either direction is less than 20 percent of the column allowable axial load.

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of the two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

2. **Structural framing systems.** A. **General.** Four types of general building framing systems defined in Section 2312 (d) 6 are recognized in these provisions and shown in Table No. 23-O. Each type is subdivided by the types of vertical elements used to resist lateral seismic forces. Special framing requirements are given in this section and in Chapters 24 through 27.

B. **Detailing requirements for combinations of systems.** For components



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common to different structural systems, the more restrictive detailing requirements shall be used.

C. **Connections.** Connections which resist seismic forces shall be designed and detailed on the drawings.

D. **Deformation compatibility.**

(i) All framing elements not required by design to be part of the lateral force-resisting system shall be investigated and shown to be adequate for vertical load-carrying capacity when displaced $3(R_w/8)$ times the displacements resulting from the required lateral forces. P-delta effects on such elements shall be accounted for. For designs using working stress methods, this capacity may be determined using an allowable stress increase of 1.7. The rigidity of other elements shall also be considered.

(ii) Moment-resistant space frames may be enclosed by or adjoined by more rigid elements which would tend to prevent the space frame from resisting lateral forces where it can be shown that the action or failure of the more rigid elements will not impair the vertical and lateral load resisting ability of the space frame.

(iii) Exterior nonbearing, nonshear wall panels or elements which are attached to or enclose the exterior shall be designed to resist the forces per Formula (12-10) and shall accommodate movements of the structure resulting from lateral forces or temperature changes. Such elements shall be supported by means of cast-in-place concrete or by mechanical connections and fasteners in accordance with the following provisions:

Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind, $3(R_w/8)$ times the calculated elastic story drift caused by design seismic forces, or 1/2 inch, whichever is greater.

Connections to permit movement in the plane of the panel for story drift shall be sliding connections using slotted or oversize holes, connections which permit movement by bending of steel, or other connections providing equivalent sliding and ductility capacity.

Bodies of connections shall have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds.

The body of the connection shall be designed for one and one-third times the force determined by Formula (12-10).

All elements of the connecting system such as bolts, inserts, welds, dowels, etc., shall be designed for four times the forces determined by Formula (12-10).

Fasteners embedded in concrete shall be attached to, or hooked around, reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

The value of the coefficient $I$ shall be 1.0 for the entire connection.

E. **Ties and continuity.** All parts of a structure shall be interconnected and the connections shall be capable of transmitting the seismic force, induced by the



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parts being connected. As a minimum, any smaller portion of the building shall be tied to the remainder of the building with elements having at least a strength to resist $\frac{Z}{3}$ times the weight of the smaller portion.

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall be not less than $\frac{Z}{5}$ times the dead plus live load.

F. **Collector elements.** Collector elements shall be provided which are capable of transferring the seismic forces originating in other portions of the building to the element providing the resistance to those forces.

G. **Concrete frames.** Concrete space frames required by design to be part of the lateral force-resisting system shall conform to the following:

(i) In Seismic Zones 3 and 4 they shall be special moment-resisting space frames.

(ii) In Seismic Zone 2 they shall, as a minimum, be intermediate moment-resisting space frames.

H. **Anchorage of concrete or masonry walls.** Concrete or masonry walls shall be anchored to all floors and roofs which provide lateral support for the wall. The anchorage shall provide a positive direct connection between the wall and floor or roof construction capable of resisting the horizontal forces specified in Section 2312 (g) or Section 2310. Requirements for developing anchorage forces in diaphragms are given in Section 2312 (h) 2 I below. Diaphragm deformation shall be considered in the design of the supported walls.

I. **Diaphragms.**

(i) The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection which will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads.

(ii) Floor and roof diaphragms shall be designed to resist the forces determined in accordance with the following formula:

$$F_{px} = \left( \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} \right) w_{px} \qquad (12\text{-}11)$$

The force $F_{px}$ determined from Formula (12-11) need not exceed $0.75\,Z\,I\,w_{px}$, but shall not be less than $0.35\,Z\,I\,w_{px}$.

When the diaphragm is required to transfer lateral forces from the vertical resisting elements above the diaphragm to other vertical resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Formula (12-11).



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(iii) Diaphragms supporting concrete or masonry walls shall have continuous ties or struts between diaphragm chords to distribute the anchorage forces specified in Section 2312 (h) 2 H. Added chords may be used to form subdiaphragms to transmit the anchorage forces to the main crossties.

(iv) Where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall conform to Section 2312 (h) 2 H above. In Seismic Zones Nos. 3 and 4 anchorage shall not be accomplished by use of toe nails or nails subject to withdrawal, nor shall wood ledgers or framing be used in cross-grain bending or cross-grain tension, and the continuous ties required by paragraph (iii) above shall be in addition to the diaphragm sheathing.

(v) Connections of diaphragms to the vertical elements and to collectors and connections of collectors to the vertical elements in structures in Seismic Zones 3 and 4, having a plan irregularity of Type A, B, C or D in Table No. 23-N, shall be designed without considering one-third increase usually permitted in allowable stresses for elements resisting earthquake forces.

(vi) In structures in Seismic Zones 3 and 4 having a plan irregularity of Type B in Table No. 23-N, diaphragm chords and drag members shall be designed considering independent movement of the projecting wings of the structure. Each of these diaphragm elements shall be designed for the more severe of the following two assumptions:

Motion of the projecting wings in the same direction.

Motion of the projecting wings in opposing directions.

**EXCEPTION:** This requirement may be deemed satisfied if the procedures of Section 2312 (f) in conjunction with a three-dimensional model have been used to determine the lateral seismic forces for design.

J. **Framing below the base.** The strength and stiffness of the framing between the base and the foundation shall not be less than that of the superstructure. The special detailing requirements of Chapters 26 and 27, as appropriate, shall apply to columns supporting discontinuous lateral force-resisting elements and to SMRSF, IMRSF and EBF system elements below the base which are required to transmit the forces resulting from lateral loads to the foundation.

K. **Building separations.** All structures shall be separated from adjoining structures. Separations shall allow for 3 $(R_w/8)$ times the displacement due to seismic forces.

(i) **Nonbuilding Structures.** 1. **General.** A. Nonbuilding structures include all self-supporting structures other than buildings which carry gravity loads and resist the effects of earthquake. Nonbuilding structures shall be designed to resist the minimum lateral forces specified in this section. Design shall conform to the applicable provisions of other sections as modified by the provisions contained in Section 2312 (i).

B. The minimum design lateral forces prescribed in this section are at a service level (rather than yield or ultimate level). The design of nonbuilding structures shall provide sufficient strength and ductility, consistent with the provisions



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specified herein for buildings, to resist the effects of seismic ground motions as represented by these design forces.

When applicable, allowable stresses and other detailed design criteria shall be obtained from other sections or their referenced standards.

When applicable design stresses and other design criteria are not contained in or referenced by this code or the U.B.C. Standards, such criteria shall be obtained from approved national standards.

C. The weight $W$ for nonbuilding structures shall include all dead load as defined for buildings in Section 2312 (e) 1. For purposes of calculating design seismic forces in nonbuilding structures, $W$ shall also include all normal operating contents for items such as tanks, vessels, bins and piping.

D. The fundamental period of the structure shall be determined by rational methods such as by using Method B in Section 2312 (e) 2.

E. The drift limitations of Section 2312 (e) 8 need not apply to nonbuilding structures. Drift limitations shall be established for structural or nonstructural elements whose failure would cause life hazards. P-delta effects shall be considered for structures whose calculated drifts exceed the values in Section 2312 (e) 8.

F. In Seismic Zones 3 and 4, structures which support flexible nonstructural elements whose combined weight exceeds 25 percent of the weight of the structure shall be designed considering interaction effects between the structure and the supported elements.

2. **Lateral force.** Lateral force procedures for nonbuilding structures with structural systems similar to buildings [those with structural systems which are listed in Table No. 23 (O).] shall be selected in accordance with the provisions of Section 2312 (d).

**EXCEPTION:** Intermediate moment-resisting space frames (IMRSF) may be used in Zones Nos. 3 and 4 for nonbuilding structures in Occupancy Categories III and IV if (1) the structure is less than 50 feet in height and (2) an $R_w = 4.0$ is used for design.

Rigid structures (those with period $T$ less than 0.06 second), including their anchorages, shall be designed for the lateral force obtained from Formula (12-12).

$$V = 0.5ZIW \qquad (12\text{-}12)$$

The force $V$ shall be distributed according to the distribution of mass and shall be assumed to act in any horizontal direction.

3. **Tanks with supported bottoms.** Flat bottom tanks or other tanks with supported bottoms, founded at or below grade, shall be designed to resist the seismic forces calculated using the procedures in Section 2312 (i) for rigid structures considering the entire weight of the tank and its contents. Alternatively, such tanks may be designed using one of the two procedures described below.

A response spectrum analysis, which includes consideration of the actual ground motion anticipated at the site and the inertial effects of the contained fluid.

A design basis prescribed for the particular type of tank by an approved national standard, provided that the seismic zones and occupancy categories shall be in



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conformance with the provisions of Sections 2312 (d) 2 and 2312 (d) 4, respectively.

4. **Other nonbuilding structures.** Nonbuilding structures which are not covered by Section 2312 (i) 2 and 3 shall be designed to resist minimum seismic lateral forces not less than those determined in accordance with the provisions in Section 2312 (e) with the following additions and exceptions:

(i) The factor $R_w$ shall be as given in Table No. 23-Q. The ratio $C/R_w$ used for design shall be not less than 0.5.

(ii) The vertical distribution of the lateral seismic forces in structures covered by this section may be determined by using the provisions of Section 2312 (e) 4 or by using the procedures of Section 2312 (f).

**EXCEPTION:** For irregular structures assigned to Occupancy Categories I and II which cannot be modeled as a single mass the procedures of Section 2312 (f) shall be used.

(iii) Where an approved national standard provides a basis for the earthquake-resistant design of a particular type of nonbuilding structure covered by this Section 2312 (i) 4, such a standard may be used, subject to the limitations in this subsection:

The seismic zones and occupancy categories shall be in conformance with the provisions of Sections 2312 (d) 5 and 2312 (d) 4, respectively.

The values for total lateral force and total base overturning moment used in design shall not be less than 80 percent of the values that would be obtained using these provisions.

(j) **Earthquake-recording Instrumentations.** For earthquake-recording instrumentations see Appendix Chapter 23, Division II.



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## TABLE NO. 23-A—UNIFORM AND CONCENTRATED LOADS

| USE OR OCCUPANCY | | UNIFORM LOAD[1] | CONCENTRATED LOAD |
|---|---|---|---|
| CATEGORY | DESCRIPTION | | |
| 1. Access floor systems | Office use | 50 | 2000[2] |
| | Computer use | 100 | 2000[2] |
| 2. Armories | | 150 | 0 |
| 3. Assembly areas[3] and auditoriums and balconies therewith | Fixed seating areas | 50 | 0 |
| | Movable seating and other areas | 100 | 0 |
| | Stage areas and enclosed platforms | 125 | 0 |
| 4. Cornices, marquees and residential balconies | | 60 | 0 |
| 5. Exit facilities[4] | | 100 | 0[5] |
| 6. Garages | General storage and/or repair | 100 | [6] |
| | Private or pleasure-type motor vehicle storage | 50 | [6] |
| 7. Hospitals | Wards and rooms | 40 | 1000[2] |
| 8. Libraries | Reading rooms | 60 | 1000[2] |
| | Stack rooms | 125 | 1500[2] |
| 9. Manufacturing | Light | 75 | 2000[2] |
| | Heavy | 125 | 3000[2] |
| 10. Offices | | 50 | 2000[2] |
| 11. Printing plants | Press rooms | 150 | 2500[2] |
| | Composing and linotype rooms | 100 | 2000[2] |
| 12. Residential[7] | | 40 | 0[5] |
| 13. Rest rooms[8] | | | |
| 14. Reviewing stands, grandstands and bleachers | | 100 | 0 |
| 15. Roof deck | Same as area served or for the type of occupancy accommodated | | |
| 16. Schools | Classrooms | 40 | 1000[2] |
| 17. Sidewalks and driveways | Public access | 250 | [6] |
| 18. Storage | Light | 125 | |
| | Heavy | 250 | |
| 19. Stores | Retail | 75 | 2000[2] |
| | Wholesale | 100 | 3000[2] |

*(Continued)*



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[1]See Section 2306 for live load reductions.

[2]See Section 2304 (c), first paragraph, for area of load application.

[3]Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, playgrounds, plazas, terraces and similar occupancies which are generally accessible to the public.

[4]Exit facilities shall include such uses as corridors serving an occupant load of 10 or more persons, exterior exit balconies, stairways, fire escapes and similar uses.

[5]Individual stair treads shall be designed to support a 300-pound concentrated load placed in a position which would cause maximum stress. Stair stringers may be designed for the uniform load set forth in the table.

[6]See Section 2304(e), second paragraph, for concentrated loads.

[7]Residential occupancies include private dwellings, apartments and hotel guest rooms.

[8]Rest room loads shall be not less than the load for the occupancy with which they are associated, but need not exceed 50 pounds per square foot.



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## TABLE NO. 23-B—SPECIAL LOADS[1]

| USE | | VERTICAL LOAD | LATERAL LOAD |
|---|---|---|---|
| CATEGORY | DESCRIPTION | (Pounds per Square Foot Unless Otherwise Noted) | |
| 1. Construction, public access at site (live load) | Walkway, see Sec. 4406 | 150 | |
| | Canopy, see Sec. 4407 | 150 | |
| 2. Grandstands, reviewing stands and bleachers (live load) | Seats and footboards | 120[2] | See Footnote 3 |
| 3. Stage accessories (live load) | Gridirons and fly galleries | 75 | |
| | Loft block wells[4] | 250 | 250 |
| | Head block wells and sheave beams[4] | 250 | 250 |
| 4. Ceiling framing (live load) | Over stages | 20 | |
| | All uses except over stages | 10[5] | |
| 5. Partitions and interior walls, see Sec. 2309 (live load) | | | 5 |
| 6. Elevators and dumbwaiters (dead and live load) | | 2 × Total loads[6] | |
| 7. Mechanical and electrical equipment (dead load) | | Total loads | |
| 8. Cranes (dead and live load) | Total load including impact increase | 1.25 × Total load[7] | 0.10 × Total load[8] |
| 9. Balcony railings, guard rails and handrails | Exit facilities serving an occupant load greater than 50 | | 50[9] |
| | Other | | 20[9] |
| 10. Storage racks | Over 8 feet high | Total loads[10] | See Table No. 23-P |
| 11. Fire sprinkler structural support | | 250 pounds plus weight of water-filled pipe | See Table No. 23-P |

[1]The tabulated loads are minimum loads. Where other vertical loads required by this code or required by the design would cause greater stresses they shall be used.

[2]Pounds per lineal foot.

[3]Lateral sway bracing loads of 24 pounds per foot parallel and 10 pounds per foot perpendicular to seat and footboards.

[4]All loads are in pounds per lineal foot. Head block wells and sheave beams shall be designed



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for all loft block well loads tributary thereto. Sheave blocks shall be designed with a factor of safety of five.

[5]Does not apply to ceilings which have sufficient total access from below, such that access is not required within the space above the ceiling. Does not apply to ceilings if the attic areas above the ceiling are not provided with access. This live load need not be considered acting simultaneously with other live loads imposed upon the ceiling framing or its supporting structure.

[6]Where Appendix Chapter 51 has been adopted, see reference standard cited therein for additional design requirements.

[7]The impact factors included are for cranes with steel wheels riding on steel rails. They may be modified if substantiating technical data acceptable to the building official is submitted. Live loads on crane support girders and their connections shall be taken as the maximum crane wheel loads. For pendant-operated traveling crane support girders and their connections, the impact factors shall be 1.10.

[8]This applies in the direction parallel to the runway rails (longitudinal). The factor for forces perpendicular to the rail is 0.20 × the transverse traveling loads (trolley, cab, hooks and lifted loads). Forces shall be applied at top of rail and may be distributed among rails of multiple rail cranes and shall be distributed with due regard for lateral stiffness of the structures supporting these rails.

[9]A load per lineal foot to be applied horizontally at right angles to the top rail.

[10]Vertical members of storage racks shall be protected from impact forces of operating equipment or racks shall be designed so that failure of one vertical member will not cause collapse of more than the bay or bays directly supported by that member.



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## TABLE NO. 23-C—MINIMUM ROOF LIVE LOADS[1]

| ROOF SLOPE | METHOD 1 | | | METHOD 2 | | |
|---|---|---|---|---|---|---|
| | TRIBUTARY LOADED AREA IN SQUARE FEET FOR ANY STRUCTURAL MEMBER | | | UNIFORM LOAD[2] | RATE OF REDUCTION *r* (Percent) | MAXIMUM REDUCTION *R* (Percent) |
| | 0 to 200 | 201 to 600 | Over 600 | | | |
| 1. Flat or rise less than 4 inches per foot. Arch or dome with rise less than one eighth of span | 20 | 16 | 12 | 20 | .08 | 40 |
| 2. Rise 4 inches per foot to less than 12 inches per foot. Arch or dome with rise one eighth of span to less than three eighths of span | 16 | 14 | 12 | 16 | .06 | 25 |
| 3. Rise 12 inches per foot and greater. Arch or dome with rise three eighths of span or greater | 12 | 12 | 12 | 12 | No Reductions Permitted | |
| 4. Awnings except cloth covered[3] | 5 | 5 | 5 | 5 | | |
| 5. Greenhouses, lath houses and agricultural buildings[4] | 10 | 10 | 10 | 10 | | |

[1]Where snow loads occur, the roof structure shall be designed for such loads as determined by the building official. See Section 2305 (d). For special purpose roofs, see Section 2305 (e).

[2]See Section 2306 for live load reductions. The rate of reduction *r* in Section 2306 Formula (6-1) shall be as indicated in the table. The maximum reduction *R* shall not exceed the value indicated in the table.

[3]As defined in Section 4506.

[4]See Section 2305 (e) for concentrated load requirements for greenhouse roof members.



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## TABLE NO. 23-D—MAXIMUM ALLOWABLE DEFLECTION FOR STRUCTURAL MEMBERS[1]

| TYPE OF MEMBER | MEMBER LOADED WITH LIVE LOAD ONLY (L.L.) | MEMBER LOADED WITH LIVE LOAD PLUS DEAD LOAD (L.L. + K.D.L.) |
|---|---|---|
| Roof Member Supporting Plaster or Floor Member | $L/360$ | $L/240$ |

[1]Sufficient slope or camber shall be povided for flat roofs in accordance with Section 2305 (f).

$L.L.$ = Live load

$D.L.$ = Dead load

$K$ = Factor as determined by Table No. 23-E

$L$ = Length of member in same units as deflection

## TABLE NO. 23-E—VALUE OF "K"

| WOOD | | REINFORCED CONCRETE[2] | STEEL |
|---|---|---|---|
| Unseasoned | Seasoned[1] | | |
| 1.0 | 0.5 | $[2 - 1.2\,(A'_s/A_s)] \geqq 0.6$ | 0 |

[1]Seasoned lumber is lumber having a moisture content of less than 16 percent at time of installation and used under dry conditions of use such as in covered structures.

[2]See also Section 2609.

$A'_s$ = Area of compression reinforcement.

$A_s$ = Area of nonprestressed tension reinforcement.

## TABLE NO. 23-F—WIND STAGNATION PRESSURE ($q_s$) AT STANDARD HEIGHT OF 30 FEET

| Basic wind speed (mph)[1] | 70 | 80 | 90 | 100 | 110 | 120 | 130 |
|---|---|---|---|---|---|---|---|
| Pressure $q_s$ (psf) | 13 | 17 | 21 | 26 | 31 | 37 | 44 |

[1]Wind speed from Section 2311 (b).

## TABLE NO. 23-G—COMBINED HEIGHT, EXPOSURE AND GUST FACTOR COEFFICIENT ($C_e$)

| HEIGHT ABOVE AVERAGE LEVEL OF ADJOINING GROUND, IN FEET | EXPOSURE C | EXPOSURE B |
|---|---|---|
| 0- 20 | 1.2 | 0.7 |
| 20- 40 | 1.3 | 0.8 |
| 40- 60 | 1.5 | 1.0 |
| 60-100 | 1.6 | 1.1 |
| 100-150 | 1.8 | 1.3 |
| 150-200 | 1.9 | 1.4 |
| 200-300 | 2.1 | 1.6 |
| 300-400 | 2.2 | 1.8 |



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## TABLE NO. 23-H—PRESSURE COEFFICIENTS ($C_q$)

| STRUCTURE OR PART THEREOF | DESCRIPTION | $C_q$ FACTOR |
|---|---|---|
| 1. Primary frames and systems | **Method 1** (Normal force method) | |
| | Walls: | |
| | Windward wall | 0.8 inward |
| | Leeward wall | 0.5 outward |
| | Roofs[1]: | |
| | Wind perpendicular to ridge | |
| | Leeward roof or flat roof | 0.7 outward |
| | Windward roof | |
| | less than 2:12 | 0.7 outward |
| | Slope 2:12 to less than 9:12 | 0.9 outward or 0.3 inward |
| | Slope 9:12 to 12:12 | 0.4 inward |
| | Slope > 12:12 | 0.7 inward |
| | Wind parallel to ridge and flat roofs | 0.7 outward |
| | **Method 2** (Projected area method) | |
| | On vertical projected area | |
| | Structures 40 feet or less in height | 1.3 horizontal any direction |
| | Structures over 40 feet in height | 1.4 horizontal any direction |
| | On horizontal projected area[1] | 0.7 upward |
| 2. Elements and components | Wall elements | |
| | All structures | 1.2 inward |
| | Enclosed structures | 1.1 outward |
| | Open structures | 1.6 outward |
| | Parapets | 1.3 inward or outward |
| | Roof elements | |
| | Enclosed structures | |
| | Slope < 9:12 | 1.1 outward |
| | Slope 9:12 to 12:12 | 1.1 outward or 0.8 inward |
| | Slope > 12:12 | 1.1 outward or inward |
| | Open structures | |
| | Slope < 9:12 | 1.6 outward |
| | Slope 9:12 to 12:12 | 1.6 outward or 0.8 inward |
| | Slope > 12:12 | 1.6 outward or 1.1 inward |

*(Continued)*



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| STRUCTURE OR PART THEREOF | DESCRIPTION | $C_q$ FACTOR |
|---|---|---|
| 3. Local areas at discontinuities[2] | Wall corners | 2.0 outward |
| | Canopies or overhangs at eaves or rakes | 2.8 upward |
| | Roof ridges at ends of buildings or eaves and roof edges at building corners | 3.0 upward |
| | Eaves or rakes without overhangs away from building corners and ridges away from ends of building | 2.0 upward |
| | Cladding connections | |
| | Add 0.5 to outward or upward $C_q$ for appropriate location | |
| 4. Chimneys, tanks and solid towers | Square or rectangular | 1.4 any direction |
| | Hexagonal or octagonal | 1.1 any direction |
| | Round or elliptical | 0.8 any direction |
| 5. Open-frame towers[3,4] | Square and rectangular | |
| | Diagonal | 4.0 |
| | Normal | 3.6 |
| | Triangular | 3.2 |
| 6. Tower Accessories (such as ladders, conduit, lights and elevators) | Cylindrical members | |
| | 2 inches or less in diameter | 1.0 |
| | Over 2 inches in diameter | 0.8 |
| | Flat or angular members | 1.3 |
| 7. Signs, flagpoles, lightpoles, minor structures[4] | | 1.4 any direction |

[1]For one story or the top story of multistory open structures an additional outward $C_q$ factor of 0.5 shall be used. The most critical combination shall be used for design. For definition of open structure see Section 2311 (j).

[2]Local pressures shall apply over a distance from the discontinuity of 10 feet or 0.1 times the least width of the structure, whichever is smaller.

[3]Wind pressures shall be applied to the total normal projected area of all the elements of one face. The forces shall be assumed to act parallel to wind direction.

[4]Factors for cylindrical elements are two thirds of those for flat or angular elements.



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**TABLE NO. 23-I**
**SEISMIC ZONE FACTOR *Z***

| ZONE | 1 | 2A | 2B | 3 | 4 |
|---|---|---|---|---|---|
| $Z$ | 0.075 | 0.15 | 0.20 | 0.30 | 0.40 |

The zone shall be determined from the seismic zone map in Figure No. 2.

**TABLE NO. 23-J**
**SITE COEFFICIENTS[1]**

| TYPE | DESCRIPTION | *S* FACTOR |
|---|---|---|
| $S_1$ | A soil profile with either:<br>(a) A rock-like material characterized by a shear-wave velocity greater than 2,500 feet per second or by other suitable means of classification, or<br>(b) Stiff or dense soil condition where the soil depth is less than 200 feet. | 1.0 |
| $S_2$ | A soil profile with dense or stiff soil conditions, where the soil depth exceeds 200 feet. | 1.2 |
| $S_3$ | A soil profile 40 feet or more in depth and containing more than 20 feet of soft to medium stiff clay but not more than 40 feet of soft clay. | 1.5 |
| $S_4$ | A soil profile containing more than 40 feet of soft clay. | 2.0 |

[1]The site factor shall be established from properly substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type soil profile $S_3$ shall be used. Soil profile $S_4$ need not be assumed unless the building official determines that soil profile $S_4$ may be present at the site, or in the event that soil profile $S_4$ is established by geotechnical data.



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## TABLE NO. 23-K
## OCCUPANCY CATEGORIES

| OCCUPANCY CATEGORIES | OCCUPANCY TYPE OR FUNCTIONS OF STRUCTURE |
|---|---|
| I. Essential Facilities | Hospitals and other medical facilities having surgery and emergency treatment areas. |
| | Fire and police stations. |
| | Tanks or other structures containing, housing or supporting water or other fire-suppression materials or equipment required for the protection of essential or hazardous facilities, or special occupancy structures. |
| | Emergency vehicle shelters and garages. |
| | Structures and equipment in emergency-preparedness centers. |
| | Stand-by power generating equipment for essential facilities. |
| | Structures and equipment in government communication centers and other facilities required for emergency response. |
| II. Hazardous Facilities | Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released. |
| III. Special Occupancy Structure | Covered structures whose primary occupancy is public assembly—capacity > 300 persons. |
| | Buildings for schools through secondary or day-care centers—capacity > 250 students. |
| | Buildings for colleges or adult education schools—capacity > 500 students. |
| | Medical facilities with 50 or more resident incapacitated patients, but not included above. |
| | Jails and detention facilities. |
| | All structures with occupancy > 5000 persons. |
| | Structures and equipment in power generating stations and other public utility facilities not included above, and required for continued operation. |
| IV. Standard Occupancy Structure | All structures having occupancies or functions not listed above. |



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## TABLE NO. 23-L
## OCCUPANCY REQUIREMENTS

| OCCUPANCY CATEGORY[1] | IMPORTANCE FACTOR[2] I |
|---|---|
| I. Essential facilities | 1.25 |
| II. Hazardous facilities | 1.25 |
| III. Special occupancy structures | 1.0 |
| IV. Standard occupancy structures | 1.0 |

[1]Occupancy types or functions of structures within each category are listed in Table No. 23-K. Review and inspection requirements are given in Sections 305 and 306.

[2]For life-safety-related equipment, see Section 2312 (g) 1.

## TABLE NO. 23-M
## VERTICAL STRUCTURAL IRREGULARITIES

| IRREGULARITY TYPE AND DEFINITION | REFERENCE SECTION |
|---|---|
| A. **Stiffness Irregularity—Soft Story**<br>A soft story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the average stiffness of the three stories above. | 2312 (d) 8 C (ii) |
| B. **Weight (mass) Irregularity**<br>Mass irregularity shall be considered to exist where the effective mass of any story is more than 150 percent of the effective mass of an adjacent story. A roof which is lighter than the floor below need not be considered. | 2312 (d) 8 C (ii) |
| C. **Vertical Geometric Irregularity**<br>Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force-resisting system in any story is more than 130 percent of that in an adjacent story. One-story penthouses need not be considered. | 2312 (d) 8 C (ii) |
| D. **In-plane Discontinuity in Vertical Lateral Force-resisting Element**<br>An in-plane offset of the lateral load-resisting elements greater than the length of those elements. | 2312 (e) 7 |
| E. **Discontinuity in Capacity—Weak Story**<br>A weak story is one in which the story strength is less than 80 percent of that in the story above. The story strength is the total strength of all seismic resisting elements sharing the story shear for the direction under consideration. | 2312 (d) 9 A |



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## TABLE NO. 23-N
## PLAN STRUCTURAL IRREGULARITIES

| IRREGULARITY TYPE AND DEFINITION | REFERENCE SECTION |
|---|---|
| A. **Torsional Irregularity—to be considered when diaphragms are not flexible.** | |
| Torsional irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts of the two ends of the structure. | 2312 (h) 2 I (v) |
| B. **Reentrant Corners** | |
| Plan configurations of a structure and its lateral force-resisting system contain reentrant corners, where both projections of the structure beyond a reentrant corner are greater than 15 percent of the plan dimension of the structure in the given direction. | 2312 (h) 2 I (v)<br>2312 (h) 2 I (vi) |
| C. **Diaphragm Discontinuity** | |
| Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50 percent from one story to the next. | 2312 (h) 2 I (v) |
| D. **Out-of-plane Offsets** | |
| Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements. | 2312 (e) 7.<br>2312 (h) 2 I (v) |
| E. **Nonparallel Systems** | |
| The vertical lateral load-resisting elements are not parallel to nor symmetric about the major orthogonal axes of the lateral force-resisting system. | 2312 (h) 1 |



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## TABLE NO. 23-O
## STRUCTURAL SYSTEMS

| BASIC STRUCTURAL SYSTEM[1] | LATERAL LOAD-RESISTING SYSTEM-DESCRIPTION | $R_W$[2] | $H$[3] |
|---|---|---|---|
| A. Bearing Wall System | 1. Light-framed walls with shear panels | | |
| | a. Plywood walls for structures three-stories or less | 8 | 65 |
| | b. All other light framed walls | 6 | 65 |
| | 2. Shear Walls | | |
| | a. Concrete | 6 | 160 |
| | b. Masonry | 6 | 160 |
| | 3. Light steel-framed bearing walls with tension-only bracing | 4 | 65 |
| | 4. Braced frames where bracing carries gravity loads | | |
| | a. Steel | 6 | 160 |
| | b. Concrete[4] | 4 | — |
| | c. Heavy timber | 4 | 65 |
| B. Building Frame System | 1. Steel eccentrically braced frame (EBF) | 10 | 240 |
| | 2. Light-framed walls with shear panels | | |
| | a. Plywood walls for structures three-stories or less | 9 | 65 |
| | b. All other light-framed walls | 7 | 65 |
| | 3. Shear walls | | |
| | a. Concrete | 8 | 240 |
| | b. Masonry | 8 | 160 |
| | 4. Concentrically braced frames | | |
| | a. Steel | 8 | 160 |
| | b. Concrete[4] | 8 | — |
| | c. Heavy timber | 8 | 65 |



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| | | | |
|---|---|---|---|
| C. Moment-resisting Frame System | 1. Special moment-resisting space frames (SMRSF) | | |
| | a. Steel | 12 | N.L. |
| | b. Concrete | 12 | N.L. |
| | 2. Concrete intermediate moment-resisting space frames (IMRSF)[6] | 7 | — |
| | 3. Ordinary moment-resisting space frames (OMRSF) | | |
| | a. Steel | 6 | 160 |
| | b. Concrete[7] | 5 | — |
| D. Dual System | 1. Shear walls | | |
| | a. Concrete with SMRSF | 12 | N.L. |
| | b. Concrete with Concrete IMRSF | 9 | 160 |
| | e. Masonry with SMRSF | 8 | 160 |
| | d. Masonry with concrete IMRSF[4] | 7 | — |
| | 2. Steel EBF with steel SMRSF | 12 | N.L. |
| | 3. Concentrically braced frames | | |
| | a. Steel with steel SMRSF | 10 | N.L. |
| | b. Concrete with concrete SMRSF[4] | 9 | — |
| | c. Concrete with concrete IMRSF[4] | 6 | — |
| E. Undefined Systems | See Sections 2312 (d) 8 C and 2312 (d) 9 B | — | — |

[1]Basic structural systems are defined in Section 2312 (d) 6.
[2]See Section 2312 (e) 3 for combination of structural system.
[3]*H*—Height limit applicable to Seismic Zones Nos. 3 and 4. See Section 2312 (d) 7 for exception.
[4]Prohibited in Seismic Zones Nos. 3 and 4.
[5]N.L.—No Limit.
[6]Prohibited in Seismic Zones Nos. 3 and 4, except as permitted in Section 2312 (i) 2.
[7]Prohibited in Seismic Zones Nos. 2, 3 and 4.





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## TABLE NO. 23-P
## HORIZONTAL FORCE FACTOR $C_p$
### Applicable to Rigid Items[1]

| ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS | VALUE OF $C_p$[2] | NOTE |
|---|---|---|
| **I. Part of Portion of Structure** | | |
| 1. Walls, including the following: | | |
| a. Unbraced (cantilevered) parapets. | 2.0 | |
| b. Other exterior walls above the ground floor. | 0.75 | |
| c. All interior bearing and nonbearing walls and partitions. | 0.75 | 2 |
| d. Masonry or concrete fences over 6 feet high. | 0.75 | |
| 2. Penthouse (except where framed by an extension of the building frame). | 0.75 | |
| 3. Connections for prefabricated structural elements other than walls, with force applied at center of gravity. | 0.75 | 3 |
| 4. Diaphragms. | — | 4 |
| **II. Nonstructural Components** | | |
| 1. Exterior and interior ornamentations and appendages. | 2.0 | |
| 2. Chimneys, stacks, trussed towers, and tanks on legs. | | |
| a. Supported on or projecting as an unbraced cantilever above the roof more than one-half its total height. | 2.0 | |
| b. All others, including those supported below the roof with unbraced projection above the roof less than one-half its height, or braced or guyed to the structural frame at or above its center of mass. | 0.75 | |
| 3. Signs and billboards. | 2.0 | |
| 4. Mechanical, plumbing and electrical equipment and machinery and associated piping. | 0.75 | 5 |
| 5. Tanks and vessels (plus contents), including support systems and anchorage. | 0.75 | |
| 6. Storage racks (include contents). | 0.75 | |
| 7. Anchorage for permanent floor-supported cabinets and bookstacks more than 5 feet in height (includes contents). | 0.75 | |
| 8. Anchorage for suspended ceilings and light fixtures—see also Section 4701 (c). | 0.75 | 3,6 and 8 |
| 9. Access floor systems. | 0.75 | 3 and 7 |

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[1]See Section 2312 (g) 2 for the definition of "rigid."

[2]See Section 2312 (h) 2 D.

[3]Applies to Seismic Zones 2, 3 and 4 only.

[4]See Section 2312 (h) 2 I.

[5]Equipment and machinery shall include but not be limited to such items as boilers, heat exchangers, chillers, pumps, motors, air-handling units, cooling towers, transformers, switch gear, control panels and life-safety equipment. It shall include sprinkler systems, other major piping and the ducting, serving such equipment and machinery.

[6]Ceiling weight shall include all light fixtures and other equipment or partitions which are laterally supported by the ceiling. For purposes of determining the lateral seismic force, a ceiling weight of not less than four pounds per square foot shall be used.

[7]$W_p$ for access floor systems shall be the dead load of the access floor system plus 25 percent of the floor live load plus a 10 psf partition load allowance.

[8]Ceilings constructed of lath and plaster or gypsum board screw or nail attached to suspended members that support a ceiling at one level extending from wall to wall need not be analyzed, provided the walls are not over 50 feet apart.

[9]See Section 2312 (g) 2 for items supported at or below grade.





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## TABLE NO. 23-Q
## $R_w$ FACTORS FOR NONBUILDING STRUCTURES

| STRUCTURE TYPE | $R_w$ |
|---|---|
| 1. Tanks, vessels or pressurized spheres on braced or unbraced legs. | 3 |
| 2. Cast-in-place concrete silos and chimneys having walls continuous to the foundation. | 5 |
| 3. Distributed mass cantilever structures such as: stacks, chimneys, silos and skirt-supported vertical vessels. | 4 |
| 4. Trussed towers (freestanding or guyed), guyed stacks and chimneys. | 4 |
| 5. Inverted pendulum-type structures. | 3 |
| 6. Cooling towers. | 5 |
| 7. Bins and hoppers on braced or unbraced legs. | 4 |
| 8. Storage racks. | 5 |
| 9. Signs and billboards. | 5 |
| 10. Amusement structures and monuments. | 3 |
| 11. All other self-supporting structures not otherwise covered. | 4 |



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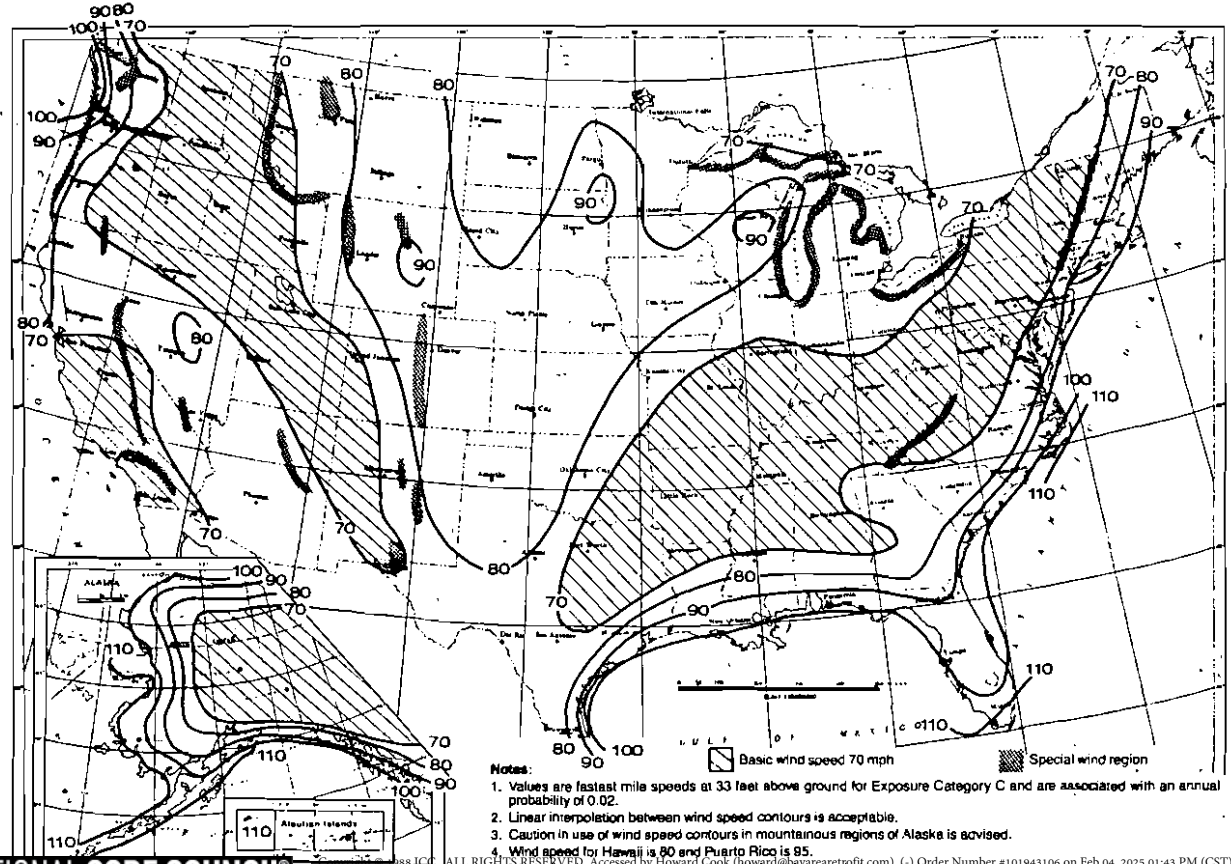


FIGURE NO. 1—BASIC WIND SPEEDS IN MILES PER HOUR





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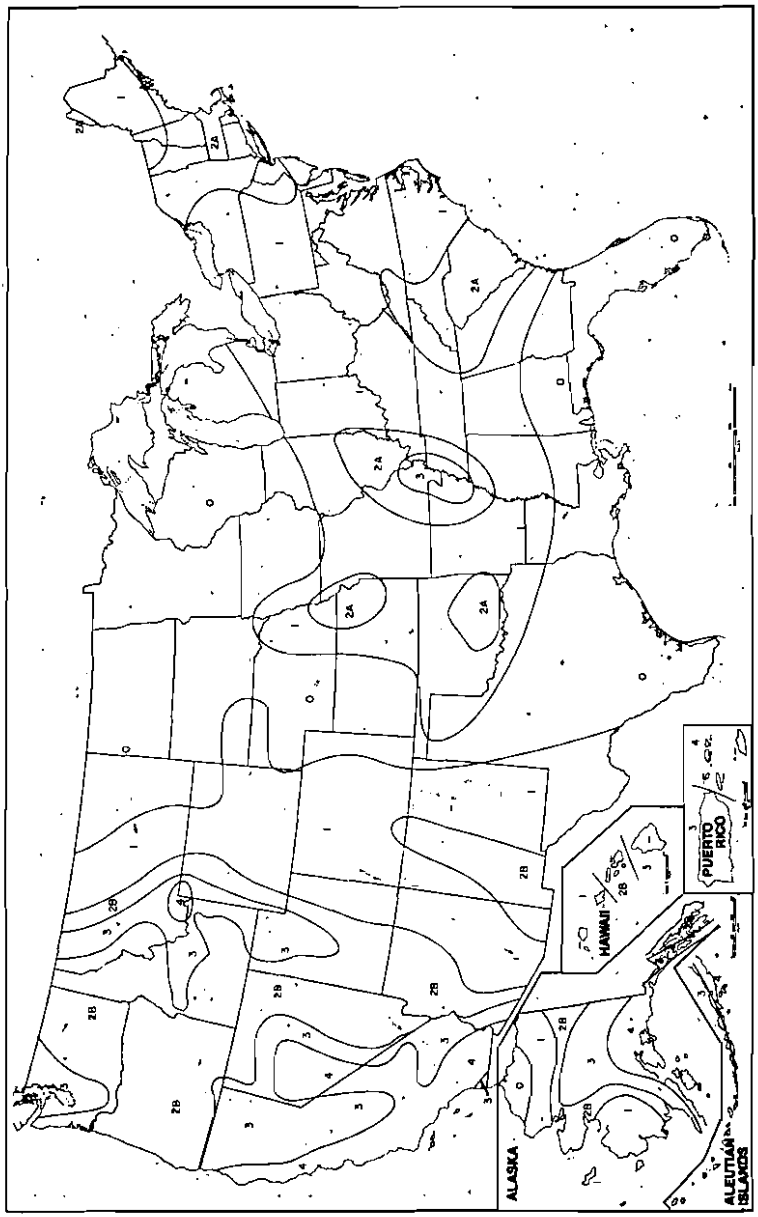


**FIGURE NO. 2—SEISMIC ZONE MAP OF THE UNITED STATES**
**For areas outside of the United States, see Appendix Chapter 23**



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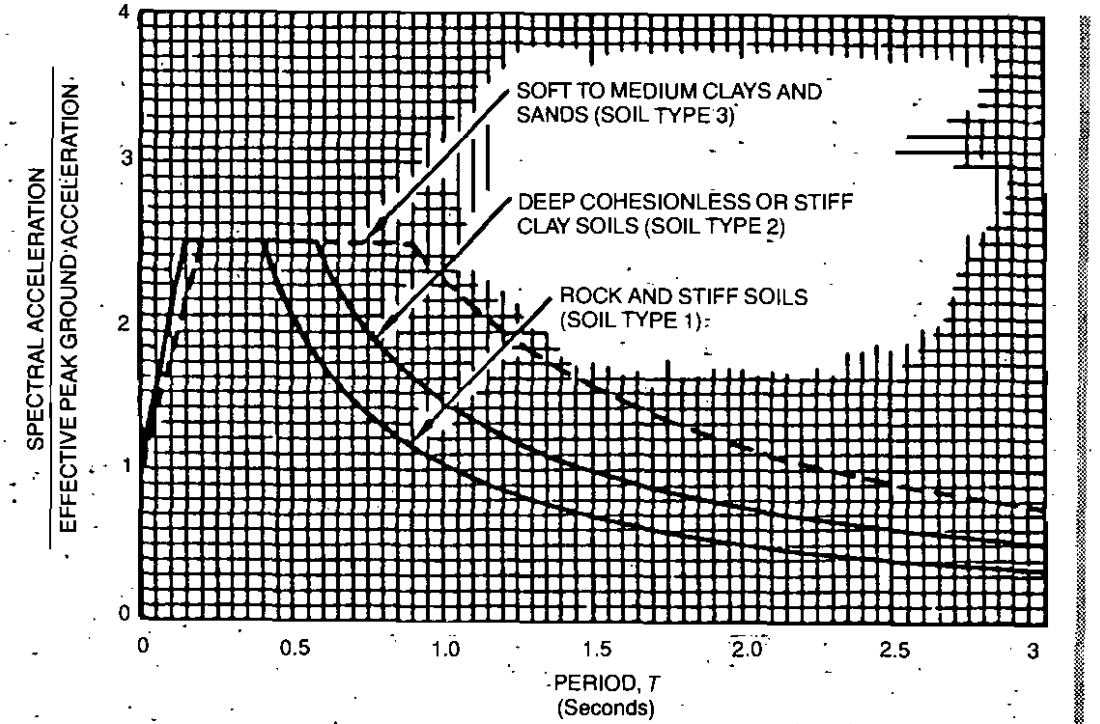


**FIGURE NO. 3—NORMALIZED RESPONSE SPECTRA SHAPES**





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# Chapter 24
# MASONRY

## General

**Sec. 2401.** (a) **Scope.** The materials, design, construction and quality control of masonry shall be in accordance with this chapter.

(b) **Definitions.** For the purpose of this chapter, certain terms are defined as follows:

**AREAS:**

**Bedded area** is the area of the surface of a masonry unit which is in contact with mortar in the plane of the joint.

**Effective area of reinforcement** ($A_s$) is the cross-sectional area of reinforcement multiplied by the cosine of the angle between the reinforcement and the direction for which effective area is to be determined.

**Gross area** is the total cross-sectional area of a specified section.

**Net area** is the gross cross-sectional area minus the area of ungrouted cores, notches, cells and unbedded areas. Net area is the actual surface area of a cross section of masonry.

**Transformed area** is the equivalent area of one material to a second based on the ratio of moduli of elasticity of the first material to the second.

**BOND:**

**Adhesion bond** is the adhesion between masonry units and mortar or grout.

**Reinforcing bond** is the adhesion between steel reinforcement and mortar or grout.

**CELL** is a void space having a gross cross-sectional area greater than 1 1/2 square inches.

**CLEANOUT** is an opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

**COLUMN** is a vertical structural member whose horizontal dimension measured at right angles to the thickness does not exceed three times the thickness.

**DIMENSIONS:**

**Actual dimensions** are the measured dimensions of a designated item; for example, a designated masonry unit or wall, as used in the structure. The actual dimension shall not vary from the specified dimension by more than the amount allowed in the appropriate standard of quality in Section 2402 of this chapter.

**Nominal dimensions** of masonry units are equal to its specified dimensions plus the thickness of the joint with which the unit is laid.

**Specified dimensions** are the dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure. Unless otherwise stated, all calculations shall be made using or based on specified dimensions.



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**GROUT LIFT** is an increment of grout height within the total pour; a pour may consist of one or more grout lifts.

**GROUT POUR** is the total height of masonry wall to be poured prior to the erection of additional masonry. A grout pour will consist of one or more grout lifts.

**GROUTED MASONRY:**

**Grouted hollow-unit masonry** is that form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.

**Grouted multiwythe masonry** is that form of grouted masonry construction in which the space between the wythes is solidly or periodically filled with grout.

**JOINTS:**

**Bed joint** is the mortar joint that is horizontal at the time the masonry units are placed.

**Collar joint** is the vertical, longitudinal, mortar or grouted joint.

**Head joint** is the mortar joint having a vertical transverse plane.

**MASONRY UNIT** is brick, tile, stone, glass block or concrete block conforming to the requirements specified in Section 2402.

**Hollow-masonry unit** is a masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is less than 75 percent of the gross cross-sectional area in the same plane.

**Solid-masonry unit** is a masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of the gross cross-sectional area in the same plane.

**PRISM** is an assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

**REINFORCED MASONRY** is that form of masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces and is designed in accordance with Section 2409.

**SHELL** is the outer portion of a hollow masonry unit as placed in masonry.

**WALL TIE** is a mechanical fastener which connects wythes of masonry to each other or to other materials.

**WALLS:**

**Bonded wall** is a masonry wall in which two or more wythes are bonded to act as a structural unit.

**Cavity wall** is a wall containing continuous air space with a minimum width of 2 inches and a maximum width of 4 1/2 inches between wythes which are tied with metal ties.

**WEB** is an interior solid portion of a hollow masonry unit as placed in masonry.

**WYTHE** is the portion of a wall which is one masonry unit in thickness. A collar joint is not considered a wythe.



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(c) **Notation.**

$a$ = height of wall or segment for cantilevered condition, or one-half height of wall or segment for fixed conditions top and bottom.

$A_b$ = cross-sectional area of anchor bolt, square inch.

$A_e$ = effective area of masonry.

$A_p$ = area of tension (pullout) cone of an embedded anchor bolt projected onto the surface of masonry, square inch.

$A_s$ = effective cross-sectional area of reinforcement in a column or flexural member.

$A_v$ = area of steel required for shear reinforcement perpendicular to the longitudinal reinforcement.

$A'_s$ = effective cross-sectional area of compression reinforcement in a flexural member.

$b$ = effective width of rectangular member or width of flange for T and I sections.

$b_t$ = computed tension force on anchor bolts, pounds.

$b_v$ = computed shear force on anchor bolts, pounds.

$b'$ = width of web in T and I member.

$B_t$ = allowable tension force on anchor bolts, pounds.

$B_v$ = allowable shear force on anchor bolts, pounds.

$c$ = distance from the neutral axis to extreme fiber.

$d$ = distance from the compression face of a flexural member to the centroid of longitudinal tensile reinforcement.

$d'$ = distance from the compression face of a flexural member to the centroid of longitudinal compression reinforcement.

$d_b$ = diameter of the reinforcing bar.

$E_m$ = modulus of elasticity of masonry.

$E_s$ = modulus of elasticity of steel, 29,000,000 psi.

$f_a$ = computed axial compressive stress due to design axial load.

$f_b$ = computed flexural stress in the extreme fiber due to design bending loads only.

$f_{md}$ = computed compressive stress in masonry due to dead load only.

$f_s$ = computed stress in reinforcement due to design loads.

$f_y$ = tensile yield stress of reinforcement.

$f_v$ = computed shear stress due to design load.

$f'_m$ = specified compressive strength of masonry at the age of 28 days.

$F_a$ = allowable average axial compressive stress for centroidally applied axial load only.

$F_b$ = allowable flexural compressive stress if members were carrying bending load only.

$F_{br}$ = allowable bearing stress.



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$F_s$ = allowable stress in reinforcement.
$F_{sc}$ = allowable compressive stress in column reinforcement.
$F_t$ = allowable flexural tensile stress in masonry.
$F_v$ = allowable shear stress in masonry.
$G$ = shear modulus of masonry.
$h$ = actual height of a prism.
$h'$ = effective height of a wall or column.
$I$ = moment of inertia about the neutral axis of the cross-sectional area.
$j$ = ratio or distance between centroid of flexural compressive forces and centroid of tensile forces to depth, $d$.
$k$ = the ratio of depth of the compressive stress in a flexural member to the depth, $d$.
$l_b$ = embedment depth of anchor bolts, inch.
$l_{be}$ = anchor bolt edge distance, the least length measured from the edge of masonry to the surface of the anchor bolt, inch.
$l_d$ = required development length of reinforcement.
$L$ = length of a wall or segment.
$M$ = design moment.
$M_c$ = moment capacity of compression steel in a flexural member about the centroid of the tensile force.
$M_m$ = the moment of the compressive force in the masonry about the centroid of the tensile force in the reinforcement.
$M_s$ = the moment of the tensile force in the reinforcement about the centroid of the compressive force in the masonry.
$n$ = modular ratio = $E_s/E_m$.
$p$ = ratio of the area of flexural tensile reinforcement, $A_s$, to the area $(bd)$.
$P$ = design axial load.
$P_a$ = allowable centroidal axial load for reinforced masonry columns.
$r_b$ = ratio of the area of bars cut off to the total area of bars at the section.
$s$ = spacing of stirrups or of bent bars in a direction parallel to that of the main reinforcement.
$t$ = effective thickness of a wythe, wall or column.
$u$ = bond stress per unit of surface area of bar.
$V$ = total design shear force.
$\Sigma o$ = sum of the perimeters of all the longitudinal reinforcement.

## Material Standards

**Sec. 2402.** (a) **Quality.** Materials used in masonry shall conform to the requirements stated herein. If no requirements are specified in this section for a material, quality shall be based upon generally accepted good practice, subject to the approval of the building official.



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(b) **Standards of Quality.**

1. **Aggregates:**
   A. U.B.C. Standard No. 24-21, Aggregate for Masonry Mortar.
   B. U.B.C. Standard No. 24-23, Aggregate for Masonry Grout.
2. **Cement:**
   A. U.B.C. Standard No. 24-16, Masonry Cement.
   B. U.B.C. Standard No. 26-1, Portland Cement.
   C. Plastic Cement: Plastic cement shall meet the requirements for portland cement as set forth in U.B.C. Standard No. 26-1 except in respect to limitations on insoluble residue, air entrainment, and additions subsequent to calcination. Approved types of plasticizing agents shall be added to portland cement Type I or II in the manufacturing process, but not in excess of 12 percent of the total volume.
3. **Lime:**
   A. U.B.C. Standard No. 24-17, Quick Lime for Structural Purposes.
   B. U.B.C. Standard No. 24-18, Hydrated Lime for Masonry Purposes.
4. **Masonry units—clay or shale:**
   A. U.B.C. Standard No. 24-8, Structural Clay Load-bearing Wall Tile.
   B. U.B.C. Standard No. 24-9, Structural Clay Nonload-bearing Tile.
   C. U.B.C. Standard No. 24-1, Section 24.101, Building Brick (Solid Units).
   D. U.B.C. Standard No. 24-25, Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units.
      (i) Load-bearing glazed brick shall conform to the weathering and structural requirements of U.B.C. Standard No. 24-1, Section 24.104, Facing Brick.
   E. U.B.C. Standard No. 24-8, Structural Clay Facing Tile.
   F. U.B.C. Standard No. 24-1, Section 24.104, Facing Brick (Solid Units).
   G. U.B.C. Standard No. 24-1, Section 24.105, Hollow Brick.
5. **Masonry units—concrete:**
   A. U.B.C. Standard No. 24-3, Concrete Building Brick.
   B. U.B.C. Standard No. 24-4, Hollow and Solid Load-bearing Concrete Masonry Units.
   C. U.B.C. Standard No. 24-6, Nonload-bearing Concrete Masonry Units.
6. **Masonry units—other:**
   A. **Calcium silicate:**
      (i) U.B.C. Standard No. 24-2, Calcium Silicate Face Brick (Sand-Lime Brick).
   B. **Glass block:**
      (i) Glass block may be solid or hollow and contain inserts.



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(ii) All mortar contact surfaces shall be treated to ensure adhesion between mortar and glass.

C. U.B.C. Standard No. 24-14, Unburned Clay Masonry Units.

D. U.B.C. Standard No. 24-13, Cast Stone.

E. **Reclaimed units:**

(i) Reclaimed or previously used masonry units shall meet the applicable requirements as for new masonry units of the same material for their intended use.

7. **Metal ties and anchors:**

A. Metal ties and anchors shall be made of a material having a minimum tensile yield stress of 30,000 psi.

B. All such items not fully embedded in mortar or grout shall be coated with copper, cadmium, zinc or a metal having at least equivalent corrosion-resistant properties.

8. **Mortar:**

U.B.C. Standard No. 24-20, Mortar for Unit Masonry.

9. **Grout:**

U.B.C. Standard No. 24-29, Grout for Masonry and Section 2403 (d).

10. **Reinforcement:**

A. U.B.C. Standard No. 24-15, Part I, Joint Reinforcement for Masonry, and Part II Cold Drawn Steel Wire for Concrete Reinforcement.

B. U.B.C. Standard No. 26-4, Deformed and Plain Billet-steel Bars for Conerete Reinforeement.

C. U.B.C. Standard No. 26-4, Rail-steel Deformed and Plain Bars for Concrete Reinforeement.

D. U.B.C. Standard No. 26-4, Axle-steel Deformed and Plain Bars for Concrete Reinforcement.

E. U.B.C. Standard No. 26-4, Deformed Low-alloy Bars.

11. **Water.** Water used in mortar or grout shall be clean and free of deleterious amounts of acid, alkalies or organic material or other harmful substances.

## Mortar and Grout

**Sec. 2403.** (a) **General.** Mortar and grout shall comply with the provisions of this section. Special mortars, grouts or bonding systems may be used, subject to satisfactory evidence of their capabilities when approved by the building official.

(b) **Materials.** Materials used as ingredients in mortar and grout shall conform to the applicable requirements given in Section 2402. Cementitious materials shall be lime, masonry cement or portland cement.

(c) **Mortar.** 1. **General.** Mortar shall consist of a mixture of cementitious material and aggregate to which sufficient water and approved additives, if any, have been added to achieve a workable, plastic consistency.

2. **Selecting proportions.** Proportions of ingredients and any additives shall be



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based on laboratory or field experience with the mortar ingredients and the masonry units to be used. The mortar shall be specified by the proportions of its constituents in terms of parts by volume. Water content shall be adjusted to provide proper workability under existing field conditions. When the proportion of ingredients is not specified, the proportions by mortar type shall be used as given in Table No. 24-A.

(d) **Grout.** 1. **General.** Grout shall consist of a mixture of cementitious materials and aggregate to which water has been added such that the mixture will flow without segregation of the constituents.

2. **Selecting proportions.** Proportions of ingredients and any additives shall be based on laboratory or field experience with the grout ingredients and the masonry units to be used. The grout shall be specified by the proportion of its constituents in terms of parts by volume. Water content shall be adjusted to provide proper workability and to enable proper placement under existing field conditions, without segregation. When the proportion of ingredients is not specified, the proportions by grout type shall be used as given in Table No. 24-B or a minimum compressive strength shall be specified of at least 2000 psi.

(e) **Additives and Admixtures.** 1. **General.** Additives and admixtures to mortar or grout shall not be used unless approved by the building official.

2. **Antifreeze compounds.** Antifreeze liquids, chloride salts or other such substances shall not be used in mortar or grout.

3. **Air entrainment.** Air-entraining substances shall not be used in mortar or grout unless tests are conducted to determine compliance with the requirements of this code.

4. **Colors.** Only pure mineral oxide, carbon black or synthetic colors may be used. Carbon black shall be limited to a maximum of 3 percent of the weight of the cement.

## Construction

**Sec. 2404.** (a) **General.** Masonry shall be constructed according to the provisions of this section.

(b) **Materials—Handling, Storage and Preparation.** All materials shall comply with applicable requirements of Section 2402. Storage, handling and preparation at the site shall conform also to the following:

1. Masonry materials shall be stored so that at the time of use the materials are clean and structurally suitable for the intended use.

2. All metal reinforcement shall be free from loose rust and other coatings that would inhibit reinforcing bond.

3. At the time of laying, burned clay units and sand lime units shall have a rate of absorption not exceeding .025 ounce per square inch during a period of one minute. In the absorption test the surface of the unit shall be held 1/8 inch below the surface of the water.

4. Concrete masonry units shall not be wetted unless otherwise approved.



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5. Materials shall be stored in a manner such that deterioration or intrusion of foreign materials is prevented and that the material will be capable of meeting applicable requirements at the time of mixing.

6. The method of measuring materials for mortar and grout shall be such that proportions of the materials can be controlled.

7. Mortar or grout mixed at the jobsite shall be mixed for a period of time not less than 3 minutes nor more than 10 minutes in a mechanical mixer with the amount of water required to provide the desired workability. Hand mixing of small amounts of mortar is permitted. Mortar may be retempered. Mortar or grout which has hardened or stiffened due to hydration of the cement shall not be used, but under no case shall mortar be used two and one-half hours, nor grout used one and one-half hours, after the initial mixing water has been added to the dry ingredients at the jobsite.

(c) **Cold Weather Construction.** 1. **General.** All materials shall be delivered in a usable condition and stored to prevent wetting by capillary action, rain and snow.

The tops of all walls not enclosed or sheltered shall be covered with a strong weather-resistive material at the end of each day or shutdown.

Partially completed walls shall be covered at all times when work is not in progress. Covers shall be draped over the wall and extend a minimum of 2 feet down both sides and shall be securely held in place, except when additional protection is required in Section 2404 (c) 4.

2. **Execution—Preparation.** If ice or snow has inadvertently formed on masonry bed, it shall be thawed by application of heat carefully applied until top surface of the masonry is dry to the touch.

A section of masonry deemed frozen and damaged shall be removed before continuing construction of that section.

3. **Construction.** Masonry units shall be dry. Wet or frozen masonry units shall not be laid.

Air temperature 40°F. to 32°F.: Sand or mixing water shall be heated to produce mortar temperatures between 40°F. and 120°F.

Air temperature 32°F. to 25°F.: Sand and mixing water shall be heated to produce mortar temperatures between 40°F. and 120°F. Maintain temperatures of mortar on boards above freezing.

Air temperature 25°F. to 20°F.: Sand and mixing water shall be heated to produce mortar temperatures between 40°F. and 120°F. Maintain mortar temperatures on boards above freezing. Salamanders or other sources of heat shall be used on both sides of walls under construction. Windbreaks shall be employed when wind is in exeess of 15 mph.

Air temperature 20°F. and below: Sand and mixing water shall be heated to provide mortar temperatures between 40°F. and 120°F. Enclosure and auxiliary heat shall be provided to maintain air temperature above 32°F. Temperature of units when laid shall be not less than 20°F.

4. **Protection.** When the mean daily air temperature is 40°F. to 32°F., masonry



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shall be protected from rain or snow for 24 hours by covering with weather-resistive membrane.

When the mean daily air temperature is 32°F. to 25°F., masonry shall be completely covered with weather-resistive membrane for 24 hours.

When the mean daily air temperature is 25°F. to 20°F., masonry shall be completely covered with insulating blankets or equally protected for 24 hours.

When the mean daily air temperature is 20°F. and below, masonry temperature shall be maintained above 32°F. for 24 hours by enclosure and supplementary heat, by electric heating blankets, infrared heat lamps or other approved methods.

5. **Placing grout and protection of grouted masonry.** When air temperatures fall below 40°F., grout mixing water and aggregate shall be heated to produce grout temperatures between 40°F. and 120°F.

Masonry to be grouted shall be maintained above freezing during grout placement and for at least 24 hours after placement.

Where atmospheric temperatures fall below 20°F., enclosures shall be provided around the masonry during grout placement and for at least 24 hours after placement.

(d) **Placing Masonry Units.** 1. **Mortar.** The mortar shall be sufficiently plastic and units shall be placed with sufficient pressure to extrude mortar from the joint and produce a tight joint. Deep furrowing which produces voids shall not be used.

The initial bed joint thickness shall be not less than 1/4 inch nor more than 1 inch; subsequent bed joints shall be not less than 1/4 inch nor more than 5/8 inch in thickness.

2. **Surfaces.** Surfaces to be in contact with mortar or grout shall be clean and free of deleterious materials.

3. **Solid masonry units.** Solid masonry units shall have full head and bed joints.

4. **Hollow-masonry units.** All head and bed joints shall be filled solidly with mortar for a distance in from the face of the unit not less than the thickness of the shell.

Head joints of open-end units with beveled ends need not be mortared. The beveled ends shall form a grout key which permits grout within 5/8 inch of the face of the unit. The units shall be tightly butted to prevent leakage of grout.

(e) **Reinforcement Placing.** Reinforcing details shall conform to the requirements of Section 2409 (e). Metal reinforcement shall be located in accordance with the plans and specifications. Reinforcement shall be secured against displacement prior to grouting by wire positioners or other suitable devices at intervals not exceeding 200 bar diameters nor 10 feet.

Tolerances for the placement of steel in walls and flexural elements shall be plus or minus 1/2 inch for $d$ equal to 8 inches or less, plus or minus one inch for $d$ equal to 24 inches or less but greater than 8 inches, and plus or minus 1 1/4 inch for $d$ greater than 24 inches.



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Toleranee for longitudinal location of reinforcement shall be plus or minus 2 inches.

(f) **Grouted Masonry.** 1. **General conditions.** Grouted masonry shall be constructed in such a manner that all elements of the masonry act together as a structural element.

Prior to grouting, the grout space shall be clean so that all spaces to be filled with grout do not contain mortar projections greater than 1/2 inch, mortar droppings or other foreign material. Grout shall be placed so that all spaces designated to be grouted shall be filled with grout and the grout shall be confined to those specific spaces.

Grout materials and water content shall be controlled to provide adequate fluidity for placement, without segregation of the constituents and shall be mixed thoroughly.

The grouting of any section of wall shall be completed in one day with no interruptions greater than one hour.

Between grout pours, a horizontal construction joint shall be formed by stopping all wythes at the same elevation and with the grout stopping a minimum of 1 1/2 inches below a mortar joint, except at top of wall. Where bond beams occur, stop grout pour a minimum of 1/2 inch below the top of the masonry.

Size and height limitations of the grout space or cell shall not be less than shown in Table No. 24-G. Higher grout pours or smaller cavity widths or cell size than shown in Table No. 24-G may be used when approved, if it is demonstrated that grout spaces are properly filled.

When required by Table No. 24-G, cleanouts shall be provided in the bottom course at every vertical bar but shall not be spaced more than 32 inches on center for solidly grouted masonry. When cleanouts are required, they shall be sealed after inspection and before grouting.

Units may be laid to the full height of the grout pour and grout shall be placed in a continuous pour in grout lifts not exceeding 6 feet.

All cells and spaces containing reinforcing bars shall be filled with grout.

2. **Construction requirements.** Reinforcement shall be placed prior to grouting. Bolts shall be accurately set with templates or by approved equivalent means and held in place to prevent movement.

Segregation of the grout materials and damage to the masonry shall be avoided during the grouting process.

Grout shall be consolidated by mechanical vibration during placing before loss of plasticity in a manner to fill the grout space. Grout pours greater than 12 inches shall be reconsolidated by mechanical vibration to minimize voids due to water loss. Grout pours 12 inches or less in height shall be mechanically vibrated, or puddled.

In one-story buildings having wood-frame exterior walls, foundations not over 24 inches high measured from the top of the footing may be constructed of hollow masonry units laid in running bond without mortared head joints. Any standard shape unit may be used, provided the masonry units permit horizontal flow of



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grout to adjacent units. Grout shall be solidly poured to the full height in one lift and shall be puddled or mechanically vibrated.

In nonstructural elements, including fireplaces and residential chimneys, which do not exceed 8 feet in height above the highest point of lateral support, mortar of pouring consistency may be substituted for grout when the masonry is constructed and grouted in pours of 12 inches or less.

In multiwythe grouted masonry, vertical barriers of masonry shall be built across the grout space. The grouting of any section of wall between barriers shall be completed in one day with no interruption longer than one hour.

(g) **Aluminum Equipment.** Grout shall not be handled nor pumped utilizing aluminum equipment unless it can be demonstrated with the materials and equipment to be used that there will be no deleterious effect on the strength of the grout.

(h) **Joint Steel.** Wire joint reinforcement used in the design as principal reinforcing in hollow unit construction shall be continuous between supports unless splices are made by lapping:

1. Fifty-four wire diameters in a grouted cell, or
2. Seventy-five wire diameters in the mortared bed joint, or
3. In alternate bed joints of running bond masonry a distance not less than 54 diameters plus twice the spacing of the bed joints, or
4. As required by calculation and specific location in areas of minimum stress, such as points of inflection.

Side wires shall be deformed and shall conform to U.B.C. Standard No. 24-15, Part I, Joint Reinforcement for Masonry.

## Quality Control

**Sec. 2405.** (a) **General.** Quality control shall ensure that materials, construction and workmanship are in compliance with the plans and specifications, and the applicable requirements of this chapter. When required, inspection records shall be maintained and made available to the building official.

(b) **Scope.** Quality control shall include, but is not limited to, assurance that:

1. Masonry units, reinforcement, cement, lime, aggregate and all other materials meet the requirements of the applicable standards of quality and that they are properly stored and prepared for use.
2. Mortar and grout are properly mixed using specified proportions of ingredients. The method of measuring materials for mortar and grout shall be such that proportions of materials are controlled.
3. Construction details, procedures and workmanship are in accordance with the plans and specifications.
4. Placement, splices and bar diameters are in accordance with the provisions of this chapter and the plans and specifications.

(c) **Quality Control Testing.** 1. **Sampling and testing of masonry units.** The sampling and testing of clay or shale masonry units [Section 2402 (b) 4] shall be in accordance with the provisions of U.B.C. Standard No. 24-24.



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The sampling and testing of concrete masonry units [Section 2402 (b) 5] shall be in accordance with the provisions of U.B.C. Standard No. 24-7.

The sampling and testing of unburned clay masonry units [Section 2402 (b) 6 C] shall be in accordanee with the provisions of U.B.C. Standard No. 24-14.

Cast stone [Section 2402 (b) 6 D] shall be tested in accordance with U.B.C. Standard No. 24-13.

2. **Masonry prism testing.** When the compressive strength of masonry is specified to be verified by masonry prism tests, the following requirements shall be met:

A. A set of five masonry prisms shall be built and tested in accordance with U.B.C. Standard No. 24-26 prior to the start of construction.

B. During construction, a set of three masonry prisms shall be built and tested in accordance with U.B.C. Standard No. 24-26 for each 5,000 square feet of wall area, but not less than one set of three masonry prisms for the project.

C. The compressive strength of masonry determined in accordance with U.B.C. Standard No. 24-26 for each set of prisms shall equal or exceed $f'_m$.

3. **Mortar testing.** When required by the building official, mortar shall be tested in aeeordance with U.B.C. Standard No. 24-22.

## Allowable Stresses

**Sec. 2406.** (a) **General.** Stresses in clay or concrete masonry under service loads shall not exceed the values given in this section.

(b) **Specified Compressive Strength of Masonry, $f'_m$.** The allowable stresses for the design of masonry shall be based on an $f'_m$ value selected in accordance with one of the following provisions exccpt as modified in Section 2407 (h) 4:

1. When the compressive strength of masonry is specified in the contract doeuments to be verified by masonry prism testing in accordance with Section 2405 (c) 2, the speeified compressive strength of masonry, $f'_m$ shall be selected based on an appropriate compressive strength of masonry which can be obtained with the materials and construetion practices specified for the project; or

2. When there is a masonry prism test record, approved by the building offieial, of at least 30 masonry prism tests conducted in accordance with U.B.C. Standard No. 24-26 and representative of the corresponding construction, the specified compressive strength of masonry, $f'_m$ may be selected on the basis of this record, but shall not exeeed 75 pereent of the average value of the prism test record; or

3. When neither of the above provisions are met, the speeified compressive strength of masonry, $f'_m$ shall be selected from Table No. 24-C.

(c) **Allowable Stresses in Masonry.** 1. **General.** When the quality control provisions do not include the requirements for speeial inspection as prescribed in Seetions 306 and 2405, the allowable design masonry stresses in this section shall be reduced by one half. Whenever special inspection is required for masonry construction, prism testing prior to and during construction as prescribed in Section 2405 (e) is also required.



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2. **Compressive stress, axial.** A. **Unreinforced masonry walls.**

$$F_a = 0.20 f'_m \left[1 - \left(\frac{h'}{42t}\right)^3\right] \quad \text{.....(6-1)}$$

B. **Unreinforced masonry columns.**

$$F_a = 0.20 f'_m \left[1 - \left(\frac{h'}{42t}\right)^3\right] \quad \text{.....(6-2)}$$

C. **Reinforced masonry walls.**

$$F_a = 0.20 f'_m \left[1 - \left(\frac{h'}{42t}\right)^3\right] \quad \text{.....(6-3)}$$

D. **Reinforced masonry columns.**

$$P_a = (0.20 f'_m A_e + 0.65 A_s F_{sc}) \left[1 - \left(\frac{h'}{42t}\right)^3\right] \quad \text{.....(6-4)}$$

$$F_a = P_a / A_e \quad \text{.....(6-5)}$$

3. **Compressive stress, flexural.**

$$F_b = 0.33 f'_m, \text{ 2000 psi maximum} \quad \text{.....(6-6)}$$

4. **Tensile stress, walls in flexure.** The allowable tensile stress for walls in flexure of masonry elements or members without tensile reinforcement using portland cement and hydrated lime Type M or S mortar shall not exceed the values which follow. For Type M and S masonry cement mortars, the values shall be reduced by 50 percent for clay units and 25 percent for concrete units. For Type N mortar, values shall be reduced by 25 percent.

Values for tension normal to head joints are for running bond; no tension is allowed across head joints in stack bond masonry. These values shall not be used for horizontal flexural members such as beams, girders or lintels.

Tension normal to bed joints ($F_t$, psi).

| | Clay Units | Concrete Units |
|---|---|---|
| Solid Units | 36 | 40 |
| Hollow Units | 22 | 25 |

Tension normal to head joints ($F_t$, psi).

| | Clay Units | Concrete Units |
|---|---|---|
| Solid Units | 72 | 80 |
| Hollow Units | 45 | 50 |

5. **Reinforcing bond stress** ($u$, psi).

| | |
|---|---|
| Plain Bars | 60 |
| Deformed Bars | 140 |



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6. **Shear stress, flexural members ($F_v$).**

A. No shear reinforcement,

$$F_v = 1.0\,(f'_m)^{1/2},\ 50 \text{ psi maximum} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6\text{-}7)$$

**EXCEPTION:** For a distance of one-sixteenth the clear span beyond the point of inflection the maximum stress shall be 20 psi.

B. Shear reinforcement designed to take entire shear force,

$$F_v = 3.0\,(f'_m)^{1/2},\ 150 \text{ psi maximum} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6\text{-}8)$$

7. **Shear stress, shear walls ($F_v$).**

A. Unreinforced masonry,

$$\text{Clay Units } F_v = .3\,(f'_m)^{1/2},\ 80 \text{ psi maximum} \quad \ldots\ldots\ldots\ldots\ldots (6\text{-}9)$$

| | M or S Mortar | N Mortar |
|---|---|---|
| Concrete Units | 34 psi | 23 psi |

The allowable shear stress in unreinforced masonry may be increased by 0.2 $f_{md}$, where $f_{md}$ is the compressive stress in the masonry due to dead load only.

B. With in-plane flexural reinforcement present, masonry taking all shear,

$$M/Vd < 1,\ F_v = 1/3\,(4 - \frac{M}{Vd})\,(f'_m)^{1/2},\ (80 - 45\,\frac{M}{Vd}) \text{ psi maximum} \quad \ldots\ldots (6\text{-}10)$$

$$M/Vd \geq 1,\ Fv = 1.0\,(f'_m)^{1/2},\ 35 \text{ psi maximum} \quad \ldots\ldots\ldots\ldots (6\text{-}11)$$

C. Shear reinforcement designed to take all the shear,

$$M/Vd < 1,\ F_v = 1/2\,(4 - \frac{M}{Vd})\,(f'_m)^{1/2},\ (120 - 45\,\frac{M}{Vd}) \text{ psi maximum} \quad \ldots\ldots (6\text{-}12)$$

$$M/Vd \geq 1,\ F_v = 1.5\,(f'_m)^{1/2},\ 75 \text{ psi maximum} \quad \ldots\ldots\ldots\ldots (6\text{-}13)$$

8. **Bearing stress.** A. On full area,

$$F_{br} = 0.26\,f'_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6\text{-}14)$$

B. On one-third area or less,

$$F_{br} = 0.38\,f'_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6\text{-}15)$$

This increase applies only when the least distance between the edges of the loaded and unloaded areas is a minimum of one fourth of the parallel side dimension of the loaded area. The allowable bearing stresses on a reasonably



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concentric area greater than one third but less than the full area shall be interpolated between the values of Formulas (6-14) and (6-15).

(d) **Allowable Stresses in Reinforcement (psi).** 1. **Tensile stress.**

A. Deformed bars,

$$F_s = 0.5 f_y, \text{ 24,000 psi maximum} \quad \text{(6-16)}$$

B. Wire reinforcement,

$$F_s = 0.5 f_y, \text{ 30,000 psi maximum} \quad \text{(6-17)}$$

C. Ties, anchors and smooth bars,

$$F_s = 0.4 f_y, \text{ 20,000 psi maximum} \quad \text{(6-18)}$$

2. **Compressive stress.** A. Deformed bars in columns,

$$F_{sc} = 0.4 f_y, \text{ 24,000 psi maximum} \quad \text{(6-19)}$$

B. Deformed bars in flexural members,

$$F_s = 0.5 f_y, \text{ 24,000 psi maximum} \quad \text{(6-20)}$$

(e) **Combined Compressive Stresses.** 1. **Unity formula.** Members subject to combined axial and flexural stresses shall be designed in accordance with accepted principles of mechanics or in accordance with the following formula:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1 \quad \text{(6-21)}$$

(f) **Modulus of Elasticity of Materials.** 1. **Modulus of elasticity of masonry.** The moduli for masonry may be estimated as provided below. Actual values, if required, shall be established by test. The modulus of elasticity of masonry shall be determined by the secant method in which the slope of the line for the modulus of elasticity is taken from $0.05 f'_m$ to a point on the curve at $0.33 f'_m$. These values are not reduced by one half per Section 2406 (c) 1.

A. Modulus of elasticity—clay/shale unit masonry.

$$E_m = 750 f'_m \quad \text{(6-22)}$$

B. Modulus of elasticity—concrete unit masonry.

$$E_m = 750 f'_m \quad \text{(6-23)}$$



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2. **Modulus of elasticity—steel.**

$$E_s = 29{,}000{,}000 \text{ psi} \quad \text{(6-24)}$$

(g) **Shear Modulus of Masonry.**

$$G = 0.4 E_m \quad \text{(6-25)}$$

(h) **Shear and Tension on Embedded Anchor Bolts.** 1. **General.** A. Allowable loads and placement requirements for plate anchor bolts, headed anchor bolts and bent bar anchor bolts shall be determined in accordance with this section. The bent bar anchor bolt shall have a hook with a 90-degree bend with an inside diameter of three bolt diameters, plus an extension of 1 1/2 bolt diameters at the free end.

B. The effective embedment length *lb* for plate or headed anchor bolts shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the plate or head of the anchorage, and *lb* for bent bar anchors shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the bent end minus one anchor bolt diameter. All bolts shall be grouted in place with at least 1 inch of grout between the bolt and the masonry.

2. **Tension.** Allowable loads in tension shall be the lesser value selected from Tables Nos. 24-D-1 and 24-D-2 or shall be determined from the lesser of Formula (6-26) or Formula (6-27).

$$B_t = 0.5 A_p \sqrt{f'm} \quad \text{(6-26)}$$

$$B_t = 0.2 A_b f_y \quad \text{(6-27)}$$

The area $A_p$ shall be the lesser of Formula (6-28) or Formula (6-29) and where the projected areas of adjacent anchor bolts overlap, $A_p$ of each anchor bolt shall be reduced by one half of the overlapping area.

$$A_p = \pi l_b^2 \quad \text{(6-28)}$$

$$A_p = \pi l_{be}^2 \quad \text{(6-29)}$$

3. **Shear.** Allowable loads in shear shall be the value selected from Table No. 24-E-1 or shall be determined from the lesser of Formula (6-30) or Formula (6-31).

$$B_v = 350 \sqrt[4]{f'_m A_b} \quad \text{(6-30)}$$

$$B_v = 0.12 A_b f_y \quad \text{(6-31)}$$

Where the anchor bolt edge distance $l_{be}$ is less than 12 bolt diameters, the value of $B_v$ shall be reduced by linear interpolation to zero at an $l_{be}$ distance of 1 1/2 inches.



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4. **Combined shear and tension.** Anchor bolts subjected to combined shear and tension shall be designed in accordance with Formula (6-32).

$$\frac{b_t}{B_t} + \frac{b_v}{B_v} \leq 1.0 \quad \text{.....(6-32)}$$

5. **Minimum edge distance.** The minimum value of $l_{be}$ measured from the edge of the masonry parallel with the anchor bolt to the surface of the anchor bolt shall be 1 1/2 inches.

6. **Minimum embedment depth.** The minimum embedment depth shall be four bolt diameters.

(i) **Load Tests.** When a load test is required, the member or portion of the structure under consideration shall be subject to a superimposed load equal to twice the design live load plus one half of the dead load. This load shall be left in position for a period of 24 hours before removal. If, during the test or upon removal of the load, the member or portion of the structure shows evidence of failure, such changes or modifications as are necessary to make the structure adequate for the rated capacity shall be made; or where lawful, a lower rating shall be established. A flexural member shall be considered to have passed the test if the maximum deflection $D$ at the end of the 24-hour period neither exceeds

$$D = \frac{L}{200} \text{ nor } D = \frac{L^2}{4000t} \quad \text{.....(6-33)}$$

and the beams and slabs show a recovery of at least 75 percent of the observed deflection within 24 hours after removal of the load.

(j) **Reuse of Masonry Units.** Masonry units may be reused when clean, whole and conforming to the other requirements of this section. All structural properties of masonry of reclaimed units, especially adhesion bond, shall be determined by approved test. The allowable working stresses shall not exceed 50 percent of that permitted for new masonry units of the same properties.

## Design, General Requirements

**Sec. 2407.** (a) **General.** The design of masonry structures shall comply with the provisions of this section. Plans submitted for approval shall describe the required design strengths of masonry materials and inspection requirements for which all parts of the structure were designed and any load test requirements.

(b) **Design Assumptions.** 1. **Working stress analysis.** The procedure presented is based on working stresses and linear stress-strain distribution assumptions with all stresses in the elastic range as follows:

(i) Plane sections before bending remain plane after bending.

(ii) Stress is proportional to strain.

(iii) Masonry elements combine to form a homogeneous member.

2. **Stack bond.** In bearing and nonbearing walls, except veneer walls, if less than 75 percent of the units in any transverse vertical plane lap the ends of the units



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below a distance less than one half the height of the unit, or less than one fourth the length of the unit, the wall should be considered laid in stack bond.

3. **Effective thickness.** A. **Single-wythe walls.** The effective thickness of single-wythe walls of either solid or hollow units is the specified thickness of the wall.

B. **Multiwythe walls.** The effective thickness of multiwythe walls is the specified thickness of the wall if the space between wythes is filled with mortar or grout. For walls with an open space between wythes, the effective thickness shall be determined as for cavity walls.

C. **Cavity walls.** If both wythes of a cavity wall are axially loaded, each wythe shall be considered to act independently and the effective thickness of each wythe is defined in Section 2407 (b) 3 A. If one wythe is axially loaded, the effective thickness of the cavity wall is taken as the square root of the sum of the squares of the specified thicknesses of the wythes.

If a cavity wall is composed of a single wythe and a multiwythe, and both sides are axially loaded, each side of the cavity wall shall be considered to act independently and the effective thickness of each side is as defined in Sections 2407 (b) 3 A and 2407 (b) 3 B. If one side is axially loaded, the effective thickness of the cavity wall is the square root of the sum of the squares of the specified thicknesses of the sides.

D. **Columns.** The effective thickness for rectangular columns in the direction considered is the specified thickness. The effective thickness for nonrectangular columns is the thickness of the square column with the same moment of inertia about its axis as that about the axis considered in the actual column.

4. **Effective height.** The effective height of columns and walls is at least the clear height of members laterally supported at the top and bottom in a direction normal to the member axis considered. For members not supported at the top normal to the axis considered, the effective height is twice the height of the member above the support. Effective height less than clear height may be used if justified.

5. **Effective area.** The effective cross-sectional area shall be based on the minimum bedded area of hollow units, or the gross area of solid units plus any grouted area. If hollow units are used with cells perpendicular to the direction of stress, the effective area shall be the lesser of the minimum bedded area or the minimum cross-sectional area. If bed joints are raked, the effective area shall be correspondingly redueed. Effective areas for cavity walls shall be that of the loaded wythes.

6. **Flexural resistance of cavity walls.** For computing the flexural resistance, lateral loads perpendicular to the planc of the wall shall be distributed to the wythes according to their respective flexural rigidities.

7. **Effective width of intersecting walls.** Where a shear wall is anchored to an intersecting wall or walls, the width of the overhanging flange formed by the intersected wall on either side of the shcar wall, which may be assumed working with the shear wall for purposes of flexural stiffness calculations, shall not exceed six times the thickness of the intersected wall. Limits of the effective flange may



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be waived if justified. Only the effective area of the wall parallel to the shear forces may be assumed to carry horizontal shear.

(c) **Design Loads.** 1. **General.** See Chapter 23 for design loads.

A. **Distribution of concentrated vertical loads in walls.** The length of wall, laid up in running bond, which may be considered capable of working at the maximum allowable compressive stress to resist vertical concentrated loads, shall not exceed the center-to-center distance between such loads, nor the width of bearing area plus four times the wall thickness. Concentrated vertical loads shall not be assumed distributed across continuous vertical mortar or control joints unless elements designed to distribute the concentrated vertical loads are employed.

2. **Loads on nonbearing walls.** Masonry walls used as interior partitions or as exterior surfaces of a building which do not carry vertical loads imposed by other elements of the building shall be designed to carry their own weight plus any superimposed finish and lateral forces. Bonding or anchorage of nonbearing walls shall be adequate to support the walls and to transfer lateral forces to the supporting structures.

(d) **Support of Masonry.** 1. **Vertical support.** Structural members providing vertical support of masonry shall provide a bearing surface on which the initial bed joint shall not be less than 1/4 inch nor more than 1 inch and shall be of noncombustible material, except where masonry is a nonstructural decorative feature or wearing surface.

2. **Vertical deflection.** Elements supporting masonry shall be designed so that their vertical deflection will not exceed 1/600 of the clear span under total loads. Lintels shall bear on supporting masonry on each end such that allowable stresses in the supporting masonry are not exceeded. The minimum bearing length is 4 inches.

3. **Lateral support.** Lateral support of masonry may be provided by cross-walls, columns, pilasters, counterforts or buttresses when spanning horizontally or by floors, beams, girts or roofs when spanning vertically.

(e) **Structural Continuity.** 1. **General.** Intersecting structural elements intended to act as a unit shall be anchored together to resist the design forces.

2. **Wall intersecting with floors or roofs.** Walls shall be anchored to all floors, roofs or other elements which provide lateral support for the wall. Where floors or roofs are designed to transmit horizontal forces to walls, the anchorage to the wall shall be designed to resist the horizontal force.

3. **Masonry elements.** A. **Multiwythe walls.** All wythes shall be bonded by grout or tied together by corrosion-resistant metal ties or joint reinforcement conforming to the requirements of Section 2402 and as follows.

(i) **Metal ties in cavity wall construction.** Metal ties shall be of sufficient length to engage all wythes. The portion of the tie within the wythe shall be completely embedded in mortar or grout. The ends of the ties shall be bent to 90-degree angles with an extension not less than 2 inches long. Ties not completely



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embedded in mortar or grout between wythes shall be a single piece of metal with each end engaged in each wythe.

There shall be at least one 3/16-inch-diameter metal tie for each 4 1/2 square feet of wall area. For cavity walls in which the width of the cavity is greater than 3 inches but not more than 4 1/2 inches, at least one 3/16-inch-diameter tie for each 3 square feet of wall area shall be provided.

Ties in alternate courses shall be staggered; the maximum vertical distance between ties shall not exceed 24 inches; the maximum horizontal distance between ties shall not exceed 36 inches.

Additional ties spaced not more than 36 inches apart shall be provided around and within 12 inches of the opening.

Metal ties of different size and spacing may be used if they provide equivalent strength between wythes.

(ii) **Metal ties for grouted multiwythe construction.** The two wythes shall be bonded together with at least one 3/16-inch-diameter metal wall tie for each 2 square feet of area. Metal ties of different size and spacing may be used if they provide equivalent strength between wythes.

(iii) **Joint reinforcement.** Prefabricated joint reinforcement for masonry walls shall have at least one crosswire of at least No. 9 gauge for each 2 square feet of wall area. The vertical spacing of the joint reinforcement shall not exceed 16 inches. The longitudinal wires shall be thoroughly embedded in the bed joint mortar. The joint reinforcement shall engage all wythes.

Where the space between metal tied wythes is solidly filled with grout or mortar the allowable stresses and other provisions for masonry bonded walls shall apply. Where the space is not filled, metal tied walls shall conform to the allowable stress, lateral support, thickness (excluding cavity), height and metal tie requirements for cavity walls.

B. **Stack bond.** Where masonry units are laid in stack bond, each wythe shall have longitudinal reinforcement consisting of at least two continuous corrosion-resistant wires with a minimum cross-sectional area of 0.017 square inch each in the horizontal bed joints spaced not more than 16 inches on center vertically. The wires shall be located near the opposite faces of the wythes.

(f) **Protection of Ties, Bolts and Joint Reinforcement.** A minimum of 5/8-inch mortar cover shall be provided between ties or joint reinforcement and any exposed face. The thickness of grout or mortar between masonry units and joint reinforcement or bolts shall be not less than 1/4 inch, except that 1/4 inch or smaller diameter reinforcement or bolts may be placed in bed joints which are at least twice the thickness of the reinforcement.

(g) **Pipes and Conduits Embedded in Masonry.** Pipe or conduit shall not be embedded in any masonry so as to reduce the capacity to less than that necessary for required stability or required fire protection.

**EXCEPTIONS:** 1. Rigid electric conduits may be embedded in structural masonry when their location has been detailed on the approved plan.



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2. Any pipe or conduit may pass vertically or horizontally through any masonry by means of a sleeve at least large enough to pass any hub or coupling on the pipe line. Such sleeves shall be placed not closer than three diameters, center to center, nor shall they unduly impair the strength of construction.

3. Placement of pipes or conduits in unfilled cores of hollow unit masonry shall not be considered as embedment.

(h) **Special Provisions in Areas of Seismic Risk.** 1. **General.** Masonry structures constructed in the seismic zones shown in Figure No. 2 of Chapter 23 shall be designed in accordance with the design requirements of this chapter and the special provisions for each seismic zone given in this section.

2. **Special provisions for Seismic Zones Nos. 0 and 1.** There are no special design and construction provisions in this section for structures built in Seismic Zones Nos. 0 and 1.

3. **Special provisions for Seismic Zone No. 2.** Masonry structures in Seismic Zone No. 2 shall comply with the following special provisions.

A. **Materials.** The following materials shall not be used as part of the structural frame: Type O mortar, masonry cement, plastic cement, nonload-bearing masonry units and glass block.

B. **Wall reinforcement.** Vertical reinforcement of at least 0.20 square inch in cross-sectional area shall be provided continuously from support to support at each corner, at each side of each opening, at the ends of walls and at a maximum spacing of 4 feet apart, horizontally throughout the wall.

Horizontal reinforcement not less than 0.2 square inch in cross-sectional area shall be provided: (1) at the bottom and top of wall openings and shall extend not less than 24 inches nor less than 40 bar diameters past the opening, (2) continuously at structurally connected roof and floor levels and at the top of walls, (3) at the bottom of the wall or in the top of the foundations when dowelled to the wall, (4) at maximum spacing of 10 feet unless uniformly distributed joint reinforcement is provided. Reinforcement at the top and bottom of openings when continuous in the wall may be used in determining the maximum spacing specified in Item No. (1) above.

C. **Stack bond.** Where stack bond is used, the minimum horizontal reinforcement ratio shall be $.0007bt$. This ratio shall be satisfied by uniformly distributed joint reinforcement or by horizontal reinforcement spaced not over 4 feet and fully embedded in grout or mortar.

4. **Special provisions for Seismic Zones Nos. 3 and 4.** All masonry structures built in Seismic Zones Nos. 3 and 4 shall be designed and constructed in accordance with requirements for Seismic Zone No. 2 and with the following additional requirements and limitations.

**EXCEPTION:** One- and two-story structures of Group R, Division 3 and Group M Occupancies in Seismic Zone No. 3 with $h'/t$ not greater than 27 and using running bond construction may be constructed in accordance with the requirements of Seismic Zone No. 2.

The $f'_m$ from Table No. 24-C shall be limited to a maximum of 1500 psi for



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concrete masonry and 2600 psi for clay masonry unless $f'_m$ is verified by prism tests as required in Section 2405 (c) 2.

Reinforced hollow-unit stacked bond construction which is part of the seismic resisting system shall use open-end units so that all head joints are made solid, shall use bond-beam units to facilitate the flow of grout and shall be grouted solid.

A. **Materials.** The following materials shall not be used as part of the structural frame: Type N mortar.

B. **Wall reinforcement.** All walls shall be reinforced with both vertical and horizontal reinforcement. The sum of the areas of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum area of reinforcement in either direction shall not be less than 0.0007 times the gross cross-sectional area of the wall. The spacing of reinforcement shall not exceed 4 feet. The diameter of reinforcement shall not be less than 3/8 inch except that joint reinforcement may be considered as part or all of the requirement for minimum reinforcement. Reinforcement shall be continuous around wall corners and through intersections. Only horizontal reinforcement which is continuous in the wall or element shall be considered in computing the minimum area of reinforcement. Reinforcement with splices conforming to Section 2409 (e) 6 shall be considered as continuous reinforcement.

C. **Column reinforcement.** The spacing of column ties shall not be more than: 8 inches the full height for columns stressed by tensile or compressive axial overturning forces due to the seismic loads of Section 2312; 8 inches for the tops and bottoms of all other columns for a distance of one sixth of the clear column height, but not less than 18 inches nor the maximum column dimension. Tie spacing for the remaining column height shall be not more than 16 bar diameters, 48 tie diameters or the least column dimension, but not more than 18 inches.

D. **Stack bond.** Where stack bond is used, the minimum horizontal reinforcement ratio shall be $.0015bt$. If open-end units are used and grouted solid, then the minimum horizontal reinforcement ratio shall be $.0007bt$.

E. **Minimum dimension.** (i) **Bearing walls.** The nominal thickness of reinforced masonry bearing walls shall not be less than 6 inches except that nominal 4-inch-thick load-bearing reinforced hollow-clay unit masonry walls may be used, provided net area unit strength exceeds 8000 psi, units are laid in running bond, bar sizes do not exceed 1/2 inch with no more than two bars or one splice in a cell, and joints are flush cut, concave or a protruding V section. Minimum bar coverage where exposed to weather may be 1 1/2 inches.

(ii) **Columns.** The least nominal dimension of a reinforced masonry column shall be 12 inches except that if the allowable stresses are reduced to one half the values given in Section 2406, the minimum nominal dimension shall be 8 inches.

F. **Shear walls.** (i) **Design loads.** When calculating shear or diagonal tension stresses, shear walls which resist seismic forces shall be designed to resist 1.5 times the forces required by Section 2312 (d).

(ii) **Reinforcement.** The portion of the reinforcement required to resist shear shall be uniformly distributed and shall be joint reinforcing, deformed bars, or a combination thereof. The maximum spacing of reinforcement in each direction



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shall be not less than the smaller of one-half the length or height of the element nor more than 48 inches.

Joint reinforcement used in exterior walls and considered in the determination of the shear strength of the member shall be hot-dipped galvanized in accordance with U.B.C. Standard No. 24-15.

Reinforcement required to resist in-plane shear shall be terminated with a standard hook or with an extension of proper embedment length beyond the reinforcing at the end of the wall section. The hook or extension may be turned up, down or horizontally. Provisions shall be made not to obstruct grout placement. Wall reinforcement terminating in columns or beams shall be fully anchored into these elements.

(iii) Multiwythe grouted masonry shear walls shall be designed with consideration of the adhesion bond strength between the grout and masonry units. When bond strengths are not known from previous tests, the bond strength shall be determined by test.

G. **Hooks.** The term "hook" or "standard hook" as used herein for tie anchorage in Seismic Zones No. 3 and No. 4 shall mean a minimum turn of 135 degrees plus an extension of at least six bar diameters, but not less than 4 inches at the free end of the bar.

**EXCEPTION:** Where the ties are placed in the horizontal bed joints, the hook shall consist of a 90-degree bend having a radius of not less than four tie diameters plus an extension of 32 tie diameters.

H. **Mortar joints between masonry and concrete.** Concrete abutting structural masonry such as at starter courses or at wall intersections not designed as true separation joints shall be roughened to a full amplitude of 1/16 inch and shall be bonded to the masonry per the requirements of this chapter as if it were masonry. Unless keys or proper reinforcement are provided, vertical joints as per Section 2407 (b) 2 shall be considered to be stack bond and the reinforcement as required for stack bond shall extend through the joint and be anchored into the concrete.

(i) **Empirical Requirements.** 1. **General.** These empirical procedures may be used when approved by the building official.

2. **Ratio of height or length to thickness.** The ratio of unsupported height to thickness or the ratio of unsupported length to thickness (one or the other but not both) for solid masonry walls or bearing partitions shall not exceed 20, and shall not exceed 18 for walls of hollow masonry or cavity walls. In computing the ratio for cavity walls, the value of thickness shall be the sum of the nominal thicknesses of the inner and outer widths of the masonry. In walls composed of different kinds or classes of units or mortars, the ratio of height or length to thickness shall not exceed that allowed for the weakest of the combination of units and mortars of which the member is composed.

3. **Minimum thickness.** The minimum thickness of bearing walls of unreinforced masonry shall be 12 inches for the uppermost 35 feet of their height, and shall be increased 4 inches in thickness for each successive 35 feet or fraction thereof measured downward from the top of the wall.



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**EXCEPTIONS:** 1. The thickness of unreinforced grouted brick masonry walls may be 2 inches less than required by this subsection, but in no case less than 6 inches.

2. In buildings not more than three stories or 35 feet in height, masonry walls may be of 8-inch nominal thickness. Solid masonry walls in one-story buildings may be of 6-inch nominal thickness when not over 9 feet in height, provided that when gable construction is used an additional 6 feet are permitted to the peak of the gable.

When a change in thickness due to minimum thickness requirements occurs between floor levels, the greater thickness shall be carried to the higher floor level.

4. **Stresses.** The stress in unreinforced bearing walls, or portions thereof, shall not exceed the values set forth in Table No. 24-H. Bolt values shall not exceed those set forth in Table No. 24-J.

5. **Glass masonry.** A. **General.** Masonry of glass blocks may be used in nonload-bearing exterior or interior walls and in openings which might otherwise be filled with windows, either isolated or in continuous bands, provided the glass block panels have a minimum thickness of 3 inches at the mortar joint and the mortared surfaces of the blocks are treated for mortar bonding.

B. **Mortar joints.** Glass block shall be laid in Type N mortar. Both vertical and horizontal mortar joints shall be at least 1/4 inch and not more than 3/8 inch thick and shall be completely filled.

C. **Horizontal forces.** The panels shall be restrained laterally to resist the horizontal forces specified in Chapter 23 for bearing walls.

D. **Reinforcing.** Glass block panels shall have reinforcement in the horizontal mortar joint, extending from end to end of mortar joints, but not across expansion joints, with joints spliced by lapping the reinforcement not less than 6 inches. The reinforcement shall be placed in the joint immediately below and above any openings within a panel. The reinforcement shall consist of not less than two parallel longitudinal, galvanized steel wires, No. 9 gauge or larger, spaced 2 inches apart, and having welded thereto No. 9 or heavier gauge cross wires at intervals not exceeding 8 inches.

E. **Size of panels.** Glass block panels for exterior walls shall not exceed 144 square feet of unsupported wall surface nor 15 feet in any dimension. For interior walls, glass block panels shall not exceed 250 square feet of unsupported area nor 25 feet in any dimension.

F. **Expansion joints.** Exterior glass block shall be provided with 1/2-inch expansion joints at the sides and top. Expansion joints shall be entirely free of mortar and shall be filled with resilient material.

6. **Unburned clay masonry.** A. **General.** Masonry of stabilized unburned clay units shall not be used in any building more than one story in height. The unsupported height of every wall of unburned clay units shall be not more than ten times the thickness of such walls. Bearing walls shall in no case be less than 16 inches. All footing walls which support masonry of unburned clay units shall extend to an elevation not less than 6 inches above the adjacent ground at all points.



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B. Bolt values shall not exceed those set forth in Table No. 24-I.

7. **Stone masonry.** A. **General.** Stone masonry is that form of construction made with natural or cast stone in which the units are laid and set in mortar with all joints filled.

B. **Construction.** In ashlar masonry, bond stones uniformly distributed shall be provided to the extent of not less than 10 percent of the area of exposed facets. Rubble stone masonry 24 inches or less in thickness shall have bond stones with a maximum spacing of 3 feet vertically and 3 feet horizontally and, if the masonry is of greater thickness than 24 inches, shall have one bond stone for each 6 square feet of wall surface on both sides.

C. **Minimum thickness.** The thickness of stone masonry bearing walls shall not be less than 16 inches.

## Design, Unreinforced Masonry

**Sec. 2408.** (a) **General.** The requirements of this section are in addition to the requirements of Section 2407 and govern masonry in which reinforcement is not used to resist design forces.

(b) **Compression in Walls and Columns.** 1. **Axial loads in walls.** Stresses due to compressive forces applied at the centroid of a wall may be computed assuming uniform distribution over the effective area.

$$f_a = P/A_e \quad \text{(8-1)}$$

2. **Axial loads in columns.** Stresses due to compressive forces applied at the centroid may be computed assuming uniform distribution over the effective area, Formula (8-1).

3. **Bending or combined bending and axial loads.** A. **Compressive stresses.** Compressive stresses due to combined bending and axial load shall satisfy the requirements of Section 2406 (e).

B. **Tensile stresses.** Resultant tensile stress due to combined bending and axial load shall not exceed the allowable flexural tensile stress, $F_t$.

(c) **Flexural Design.** Stresses due to flexure shall not exceed the values given in Section 2406 (c), where:

$$f_b = Mc/I \quad \text{(8-2)}$$

(d) **Shear in Flexural Members and Shear Walls.** 1. **Shear.** The following formula shall be the basis of shear calculations:

$$f_v = V/A_e \quad \text{(8-3)}$$

(e) **Corbels.** The slope of corbelling (angle measured from the horizontal to the face of the corbelled surface) of unreinforced masonry shall not be less than 60 degrees.



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The maximum horizontal projection of corbelling from the plane of the wall shall be such that allowable stresses are not exceeded.

## Design, Reinforced Masonry

**Sec. 2409.** (a) **General.** 1. **Scope.** The requirements of this section are in addition to the requirements of Section 2407 and govern masonry in which reinforcement is used to resist forces. The use of plain bars larger than 1/4 inch in diameter is not permitted.

2. **Design assumption.** The following assumptions are in addition to those stated in Section 2407 (b) 1:

A. Masonry carries no tensile stress.

B. Reinforcement is completely surrounded by and bonded to masonry material so that they work together as a homogenous material within the range of working stresses.

(b) **Compression in Walls and Columns.** 1. **Walls, axial loads.** Stresses due to compressive forces applied at the centroid of the member may be computed assuming uniform distribution over the effective area.

$$f_a = P/A_e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9\text{-}1)$$

2. **Walls, bending or combined bending and axial loads.** Stresses due to combined bending and axial loads shall satisfy the requirements of Section 2406 (e) where $f_a$ is given by Formula (9-1). Walls subjected to bending with or without axial loads shall meet all applicable requirements for flexural design.

The design of walls with an $h'/t$ ratio larger than 30 shall be based on forces and moments determined from analysis of the structure. Such analysis shall take into account influence of axial loads and variable moment of inertia on member stiffness and fixed-end moments, effect of deflections on moments and forces and the effects of duration of loads.

3. **Columns, axial loads.** Stresses due to compressive forces applied at the centroid of the member may be computed assuming uniform distribution over the effective area.

A. The allowable actual load $P_a$ shall be given by Formula (6-4).

B. The allowable axial stress is given by:

$$F_a = \frac{P_a}{A_e} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9\text{-}2)$$

4. **Columns, bending or combined bending and axial loads.** Stresses due to combined bending and axial loads shall satisfy the requirements of Section 2406 (e) where $f_a/F_a$ is replaced by $P/P_a$. Columns subjected to bending shall meet all applicable requirements for flexural design.

5. **Reinforcement for columns.** A. **Vertical reinforcement.** The area of vertical reinforcement shall be not less than .005 $A_e$ and not more than 0.04 $A_e$. At least four No. 3 bars shall be provided.



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B. **Lateral ties.** All longitudinal bars for columns shall be enclosed by lateral ties. Lateral support shall be provided to the longitudinal bars by the corner of a complete tie having an included angle of not more than 135 degrees or by a hook at the end of a tie. The corner bars shall have such support provided by a complete tie enclosing the longitudinal bars. Alternate longitudinal bars shall have such lateral support provided by ties and no bar shall be farther than 6 inches from such laterally supported bar.

Lateral ties and longitudinal bars shall be placed not less than 1 1/2 inches and not more than 5 inches from the surface of the column. Lateral ties may be against the longitudinal bars or placed in the horizontal bed joints if the requirements of Section 2407 (f) are met. Spacing of ties shall be not more than 16 longitudinal bar diameters, 48 tie diameters or the least dimension of the column but not more than 18 inches.

Ties shall be at least 1/4 inch in diameter for No. 7 or smaller longitudinal bars and No. 3 for larger longitudinal bars. Ties less than 3/8 inch in diameter may be used for longitudinal bars larger than No. 7, provided the total cross-sectional area of such smaller ties crossing a longitudinal plane is equal to that of the larger ties at their required spacing.

C. **Anchor bolt ties.** Additional ties shall be provided around anchor bolts which are set in the top of the column. Such ties shall engage at least four bolts or, alternately, at least four vertical column bars or a combination of bolts and bars totaling four in number. Such ties shall be located within the top 5 inches of the column and shall provide a total of 0.4 square inch or more in cross-sectional area. The uppermost tie shall be within 2 inches of the top of the column.

(c) **Flexural Design.** 1. **Rectangular flexural elements.** Rectangular flexural elements shall be designed in accordance with the following equations or other methods based on the assumptions given in Sections 2407 (b) and 2409 (a).

A. Compressive stress in the masonry:

$$f_b = \frac{M}{bd^2}\left(\frac{2}{jk}\right) \quad \text{.....(9-3)}$$

B. Tensile stress in the longitudinal reinforcement:

$$f_s = \frac{M}{A_s jd} \quad \text{.....(9-4)}$$

C. Design coefficients:

$$k = \left[(np)^2 + 2np\right]^{1/2} - np \quad \text{.....(9-5)}$$

or,

$$k = \frac{1}{1 + \frac{f_s}{nf_b}} \quad \text{.....(9-6)}$$



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$$j = 1 - \frac{k}{3} \quad \text{.....(9-7)}$$

2. **Nonrectangular flexural elements.** Flexural elements of nonrectangular cross section shall be designed in accordance with the assumptions given in Sections 2407 (b) and 2409 (a).

3. **Lateral support.** The clear distance between lateral support of a beam shall not exceed 32 times the least width of the compression area.

4. **Effective width *(b)* of compression area.** In computing flexural stresses in walls where reinforcement occurs, the effective width assumed for running bond masonry shall not exceed six times the nominal wall thickness nor the center-to-center distance between reinforcement. Where stack bond is used, the effective width shall not exceed three times the nominal wall thickness nor the center-to-center distance between reinforcement or the length of one unit, unless grouted solid using open ended joints.

5. **Bond of flexural reinforcement.** In flexural members in which tensile reinforcement is parallel to the compressive face, the bond stress shall be computed by the formula:

$$u = \frac{V}{\Sigma o\, jd} \quad \text{.....(9-8)}$$

(d) **Shear in Flexural Members and Shear Walls.** 1. The shear stress in flexural members and shear walls shall be computed by:

$$f_v = \frac{V}{bjd} \quad \text{.....(9-9)}$$

For members of T or I section, $b'$ shall be substituted for $b$. Where $f_v$ as computed by Formula (9-9) exceeds the allowable shear stress in masonry, $F_v$, web reinforcement shall be provided and designed to carry the total shear force.

Both vertical and horizontal shear stresses shall be considered.

2. The area required for shear reinforcement placed perpendicular to the longitudinal reinforcement shall be computed by:

$$A_v = \frac{sV}{F_s d} \quad \text{.....(9-10)}$$

Where web reinforcement is required, it shall be so spaced that every 45-degree line (representing a potential diagonal crack) extending from a point at $d/2$ of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement.

(e) **Reinforcing Requirements and Details.** 1. **Maximum reinforcing size.** The maximum size of reinforcing shall be No. 11. Maximum steel area in cells shall be 6 percent of the cell area without splices and 12 percent of the cell area with splices.



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2. **Spacing of longitudinal reinforcement.** The clear distance between parallel bars, except in columns, shall be not less than the nominal diameter of the bars nor 1 inch, except that bars in a splice may be in contact. This clear distance requirement applies to the clear distance between a contact splice and adjacent splices or bars. The minimum clear distance between parallel bars in columns shall be two and one-half times the bar diameter.

The clear distance between the surface of a bar and any surface of a masonry unit shall be not less than 1/4 inch for fine grout and 1/2 inch for coarse grout. Cross webs of hollow units may be used as support for horizontal reinforcement.

All reinforcing bars, except joint reinforcing, shall be completely embedded in mortar or grout and have a minimum cover, including the masonry unit, of at least 3/4 inch; 1 1/2 inches of cover when exposed to weather and 2 inches of cover when exposed to soil.

3. **Anchorage of flexural reinforcement.** A. The tension or compression in any bar at any section must be developed on each side of that section by the required development length. The development length of the bar may be achieved by a combination of an embedment length, anchorage or, for tension only, hooks.

The required development length for deformed bars or deformed wire shall be calculated by:

$$l_d = 0.002\, d_b f_s \text{ for bars in tension} \quad \ldots\ldots\ldots\ldots\ldots (9\text{-}11)$$

$$l_d = 0.0015\, d_b f_s \text{ for bars in compression} \quad \ldots\ldots\ldots\ldots (9\text{-}12)$$

Development length for smooth bars shall be 2.0 times the length by Formula (9-11).

B. Except at supports or at the free end of cantilevers, every reinforcing bar shall be extended beyond the point at which it is no longer needed to resist tensile stress for a distance equal to 12 bar diameters or the depth of the beam, whichever is greater. No flexural bar shall be terminated in a tensile zone unless one of the following conditions is satisfied:

(i) The shear is not over one-half that permitted, including allowance for shear reinforcement, if any.

(ii) Additional shear reinforcement in excess of that required is provided each way from the cutoff a distance equal to the depth of the beam. The shear reinforcement spacing shall not exceed $d/8r_b$, where $r_b$ is the ratio of the area of bars cut off to the total area of bars at the section.

(iii) The continuing bars provide double the area required for flexure at that point or double the perimeter required for reinforcing bond.

C. At least one third of the total reinforcement provided for negative moment at the support shall be extended beyond the extreme position of the point of inflection a distance sufficient to develop one half the allowable stress in the bar, not less than one sixteenth of the clear span, nor the depth $d$ of the member, whichever is greater.



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D. Tensile reinforcement for negative moment in any span of a continuous restrained or cantilever beam, or in any member of a rigid frame, shall be adequately anchored by reinforcing bond, hooks or mechanical anchors in or through the supporting member.

E. At least one third of the required positive moment reinforcement in simple beams or at the freely supported end of continuous beams shall extend along the same face of the beam into the support at least 6 inches. At least one fourth of the required positive moment reinforcement at the continuous end of continuous beams shall extend along the same face of the beam into the support at least 6 inches.

F. Compression reinforcement in flexural members shall be anchored by ties or stirrups not less than 1/4 inch in diameter, spaced not farther apart than 16 bar diameters or 48 tie diameters. Such ties or stirrups shall be used throughout the distance where compression steel is required.

G. In regions of moment where the design tensile stresses in the steel are greater than 80 percent of the allowable steel tensile stress ($F_s$), the lap length of splices shall be increased not less than 50 percent of the minimum required length. Other equivalent means of stress transfer to accomplish the same 50 percent inerease may be used.

4. **Anchorage of shear reinforcement.** A. Single separate bars used as shear reinforcement shall be anchored at each end by one of the following methods:

(i) Hooking tightly around the longitudinal reinforcement through 180 degrees.

(ii) Embedment above or below the mid-depth of the beam on the compression side a distance sufficient to develop the stress in the bar for plain or deformed bars.

(iii) By a standard hook [see Section 2409 (e) 5] considered as developing 7500 psi, plus embedment sufficient to develop the remainder of the stress to which the bar is subjected. The effective embedded length shall not be assumed to exceed the distance between the mid-depth of the beam and the tangent of the hook.

B. The ends of bars forming a single U or multiple U stirrup shall be anchored by one of the methods of Section 2409 (e) 4 A or shall be bent through an angle of at least 90 degrees tightly around a longitudinal reinforcing bar not less in diameter than the stirrup bar, and shall project beyond the bend at least 12 diameters of the stirrup.

C. The loops or closed ends of simple U or multiple U stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90 degrees and project beyond the end of the bend at least 12 diameters of the stirrup bar.

5. **Hooks.** A. The term "standard hook" shall mean one of the following:

(i) A 180-degree turn plus extension of at least 4 bar diameters but not less than 2 1/2 inches at free end of bar.



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(ii) A 90-degree turn plus extension of at least 12 bar diameters at free end of bar.

(iii) For stirrup and tie anchorage only either a 90-degree or a 135-degree turn, plus an extension of at least 6 bar diameters, but not less than 2 1/2 inches at the free end of the bar.

B. The diameter of bend measured on the inside of the bar, other than for stirrups and ties, shall be not less than values specified in Table No. 24-F. Except for Grade 40 bars in sizes No. 3 through No. 11, inclusive, the minimum diameter of bend shall be not less than 5 bar diameters.

C. Inside diameter of bend for No. 4 or smaller stirrups and ties shall be not less than 4 bar diameters. Inside diameter of bend for No. 5 or larger stirrups and ties shall be not less than given in Table No. 24-F.

D. Hooks shall not be permitted in the tension portion of any beam, except at the ends of simple or cantilever beams or at the freely supported end of continuous or restrained beams.

E. Hooks shall not be assumed to carry a load which would produce a tensile stress in the bar greater than 7500 psi.

F. Hooks shall not be considered effective in adding to the compressive resistance of bars.

G. Any mechanical device capable of developing the strength of the bar without damage to the masonry may be used in lieu of a hook. Data must be presented to show the adequacy of such devices.

6. **Splices.** The amount of lap of lapped splices shall be sufficient to transfer the allowable stress of the reinforcement as in Section 2409 (e) 3. In no case shall the length of the lapped splice be less than 30 bar diameters for compression and 40 bar diameters for tension.

Welded or mechanical connections shall develop 125 percent of the specified yield strength of the bar in tension.

**EXCEPTION:** For compression bars in columns that are not part of the seismic system and are not subject to flexure, the compressive strength only need be developed.

When adjacent splices in grouted masonry are from 0 to 3 inches apart, the lap length shall be increased by 1.3 times.

## Design, Composite Construction

**Sec. 2410.** (a) **General.** 1. The requirements of this section are in addition to the requirements of Section 2407, 2408 or 2409 and govern masonry in which at least one wythe has strength or composition characteristics different from the other wythe or wythes and are adequately bonded to act as a single structural element.

2. The following assumptions are in addition to those stated in Section 2407 (b):

A. Analysis shall be based on elastic transformed section of the net area.

B. The maximum computed stress in any portion of composite masonry shall not exceed the allowable stress for the material of that portion.



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(b) **Determination of Moduli of Elasticity.** The modulus of elasticity of each type of masonry in composite construction shall be measured by test if the modular ratio exceeds 2 to 1 as determined by Section 2406. When tests are required, the secant method with a 5 percent offset shall be used.

(c) **Structural Continuity.** 1. **Bonding of wythes.** All wythes of composite masonry elements shall be tied together as in Section 2407 (e) 3 A as a minimum requirement. Additional ties or the combination of grout and metal ties shall be used to transfer the calculated stress.

2. **Material properties.** A. The effect of dimensional changes of the various materials and different boundary conditions of various wythes shall be included in the design.

(d) **Design Procedure.** One material is chosen as the reference material, and the other materials are transformed to an equivalent area of the reference material by multiplying the area of the second material by the ratio of the modulus of elasticity of the second material to that of the reference material.

Thickness of the transformed area and its distance perpendicular to a given bending axis remain unchanged.

Effective height or length of the element remains unchanged.

## Design, Reinforced Masonry Slender Wall

**Sec. 2411.** (a) **General.** In lieu of the procedure prescribed in Section 2409, the procedures set forth in this section, which considers the slenderness of walls by representing effects of axial forces and deflection in calculation of moments, may be used when the vertical load stress at the location of maximum moment does not exceed $0.04 f'_m$ as computed by the following formula:

$$\frac{P_w + P_o}{A_g} \leq 0.04 f'_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11\text{-}1)$$

**WHERE:**

$P_o$ = load from tributary floor or roof area.

$P_w$ = weight of the wall tributary to section under consideration.

$f'_m$ = specified compressive masonry stress as determined by Section 2406 (b). The value of $f'_m$ shall not exceed 6000 psi.

$A_g$ = gross area of wall.

(b) **Slender Wall Design Procedure.** 1. **Maximum and minimum reinforcement.** The reinforcement shall not exceed the following ratios, $p_g$, of reinforcement area to gross masonry area:

| | $f_y$ = 40 ksi | $f_y$ = 60 ksi |
|---|---|---|
| Concrete Block Masonry | 0.0048 | 0.0032 |
| Hollow Brick Masonry and Two-wythe Brick Masonry | 0.0060 | 0.0040 |

Minimum reinforcement shall be provided in accordance with Section 2407 (h) 4 B for all seismic areas when using this method of analysis.



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2. **Moment and deflection calculations.** All moment and deflection calculations in Section 2411 (b) are based on simple support conditions top and bottom. Other support and fixity conditions, moments and deflections shall be calculated using established principles of mechanics.

3. **Strength design.** A. **Load factors.** Factored loads shall be based on:

$$U = 1.4D + 1.7L, \text{ or} \quad (11\text{-}2)$$

$$U = 0.75(1.4D + 1.7L + 1.87E), \text{ or} \quad (11\text{-}3)$$

$$U = 0.75(1.4D + 1.7L + 1.7W), \text{ or} \quad (11\text{-}4)$$

$$U = 0.9D + 1.43E, \text{ or} \quad (11\text{-}5)$$

$$U = 0.9D + 1.3W \quad (11\text{-}6)$$

**WHERE:**

$D$ = dead loads, or related internal moments and forces.

$E$ = load effects of earthquake, or related internal moments and forces.

$L$ = live loads, or related internal moments and forces.

$U$ = required strength to resist factored loads, or related internal moments and forces.

$W$ = wind load, or related internal moments and forces.

B. **Required moment.** Required moment and axial force shall be determined at the midheight of the wall and shall be used for design. The moment strength, $M_u$, shall be at least equal to:

$$M_u = \frac{w_u h^2}{8} + P_{ou}\frac{e}{2} + (P_{wu} + P_{ou})\Delta_u \quad (11\text{-}7)$$

**WHERE:**

$w_u$ = factored distributed lateral load.

$h$ = height of the wall between points of support.

$P_{wu}$ = factored weight of the wall tributary to the section under consideration.

$\Delta_u$ = horizontal deflection at midheight under factored load; $P\Delta$ effects shall be included in deflection calculation.

$P_{ou}$ = factored load from tributary floor or roof loads.

$e$ = eccentricity of $P_{ou}$.

$P_u$ = axial load at midheight of wall, including tributary wall weight.

$$P_u = P_{wu} + P_{ou} \quad (11\text{-}8)$$

C. **Design strength.** Design strength provided by the reinforced masonry wall cross section in terms of axial force and moment shall be computed as the nominal strength (see Section 2602, Definitions) multiplied by a strength reduction factor, $\phi$, as set forth in Formula (11-9).

$$M_u \leq \phi M_n \quad (11\text{-}9)$$



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**WHERE:**

$M_n$ = nominal moment strength found for cross sections subjected to combined flexure and given axial load.

$M_n = A_{se} f_y (d - a/2)$

$A_{se} = \dfrac{A_s f_y + P_u}{f_y}$, effective area of steel.

$a = \dfrac{P_u + A_s f_y}{0.85 f'_m b}$, depth of stress block due to factored loads.

The strength reduction factor for flexure, $\phi$, shall be as follows:

| | Special Inspection | |
|---|---|---|
| | Yes | No |
| Concrete Block and Hollow Brick (Designated 6-inch thickness or greater) and two-wythe brick masonry | 0.8 | 0.5 |
| Hollow Brick Masonry (Designated 5-inch or less thickness) | 0.6* | 0.4* |

*EXCEPTION: $\phi = 0.8$ for special inspection and $\phi = 0.5$ for noncontinuous inspection when vertical reinforcing bars are held in position at the top, bottom and at intervals not farther apart than 200 bar diameters.

D. **Design assumptions for nominal strength.** Nominal strength of singly reinforced masonry wall cross sections to combined flexure and axial load shall be based on applicable conditions of equilibrium and compatibility of strains. Strain in reinforcement and masonry walls shall be assumed directly proportional to the distance from the neutral axis.

Maximum usable strain at extreme masonry compression fiber shall be assumed equal to 0.003.

Stress in reinforcement below specified yield strength $f_y$ for grade of reinforcement used shall be taken as $E_s$ times steel strain. For strains greater than that corresponding to $f_y$, stress in reinforcement shall be considered independent of strain and equal to $f_y$.

Tensile strength of masonry walls shall be neglected in flexural calculations of strength, except when computing requirements for deflection.

Relationship between masonry compressive stress and masonry strain may be assumed to be rectangular as defined by the following:

(i) Masonry stress of $0.85 f'_m$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = 0.85 c$ from the fiber of maximum compressive strain.

(ii) Distance $c$ from fiber of maximum strain to the neutral axis shall be measured in a direction perpendicular to that axis.



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4. **Deflection design.** The midheight deflection, $\Delta_s$, under service lateral and vertical loads (without load factors) shall be limited by the relation

$$\Delta_s = 0.007h \quad \text{(11-10)}$$

**EXCEPTION:** For hollow brick masonry designated 5 inches or less in thickness where vertical reinforcement bars are not held in position at the top, bottom and at intervals not farther apart than 200 bar diameters, use

$$\Delta_s = 0.005h \quad \text{(11-11)}$$

The midheight deflection shall be computed with the following formula:

$$\Delta_s \begin{cases} \dfrac{5 M_s h^2}{48 E_m I_g} \text{ (for } M_s < M_{cr}) & \text{(11-12)} \\ \dfrac{5 M_{cr} h^2}{48 E_m I_g} + \dfrac{5 (M_s - M_{cr}) h^2}{48 E_m I_{cr}} \text{ (for } M_{cr} \le M_s \le M_n) & \text{(11-13)} \end{cases}$$

**WHERE:**

$h$ = height of the wall.

$M_s$ = service moment at the midheight of the panel, including $P\Delta$ effects.

$I_g, I_{cr}$ = gross, cracked moment of inertia of the wall cross section.

$M_{cr}$ = cracking moment strength of the masonry wall.

$M_n$ = nominal moment strength of the masonry wall.

The cracking moment strength of the wall shall be determined from the formula:

$$M_{cr} = Sf_r \quad \text{(11-14)}$$

**WHERE:**

$S$ = section modulus.

$f_r$ = modulus of rupture shall be assumed as follows for calculating deflection:

| | $f_r$ psi |
|---|---|
| Concrete Masonry Units | $2.5\sqrt{f'_m}$ psi |
| Hollow Brick Units | $2.5\sqrt{f'_m}$ psi |
| Two-wythe Brick Walls | $2.0\sqrt{f'_m}$ psi |



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## Strength Design, Reinforced Masonry Shear Wall

**Sec. 2412.** (a) **Notations.**

$A_n$ = net cross-sectional area perpendicular to axial load, square inches.

$A_{mv}$ = net area of masonry section bounded by wall thickness and length of section in the direction of shear force considered, square inches.

$A_s$ = area of tension reinforcement, square inches.

$a_b$ = length of compressive stress block, inches.

$b$ = effective width of wall, inches.

$C_d$ = masonry shear strength coefficient as obtained from Table No. 24-L.

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$D$ = dead loads or related internal moments and forces.

$E$ = load effects of earthquake or related internal moments and forces.

$E_s$ = modulus of elasticity of steel, 29,000,000 psi.

$e_{mu}$ = maximum useable compressive strain of masonry.

$F$ = loads due to weight and pressure of fluids or related moments and forces.

$F_s$ = allowable stress in reinforcement, psi.

$f_s$ = computed stress in reinforcement, psi.

$f'_m$ = specified compressive strength of masonry at the age of 28 days, psi.

$f_y$ = specified yield strength of reinforcement, psi.

$H$ = loads due to weight and pressure of soil, water in soil or related internal moments and forces.

$L$ = live loads or related internal moments and forces.

$L_w$ = length of wall.

$P_b$ = nominal balanced design axial strength.

$P_n$ = nominal axial load strength at given eccentricity.

$P_o$ = nominal axial strength without bending loads.

$P_u$ = required axial strength.

$T$ = time dependent factor for sustained load.

$U$ = required strength to resist factored loads, or related internal moments and forces.

$V_n$ = nominal shear strength.

$V_m$ = nominal shear strength provided by masonry.

$V_s$ = nominal shear strength provided by shear reinforcement.

$W$ = wind load or related internal moments and forces.

$\rho_n$ = ratio of distributed shear reinforcement on a plane perpendicular to plane of $A_{mv}$.

$\phi$ = strength reduction factor.



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(b) **General.** The procedures set forth in this section, based on strength design may be used as an alternative to the procedure prescribed in Section 2409 for the design of reinforced hollow-unit concrete and clay masonry shear walls.

(c) **Quality Control Provisions.** Special inspection during construction of the shear wall shall be provided as set forth in Section 306.

$f'_m$ shall be verified in accordance with Section 2406 (b) 2 or 3.

(d) **Shear Wall Design Procedure.** 1. **Required strength.** The required strength shall be determined as follows:

A. For earthquake loading, the load factors shall be:

$$U = 1.4(D+L+E) \quad \text{.....(12-1)}$$

$$U = 0.9D \pm 1.4E \quad \text{.....(12-2)}$$

B. Required strength $U$ to resist dead load $D$ and live load $L$ shall be at least equal to:

$$U = 1.4D + 1.7L \quad \text{.....(12-3)}$$

C. If resistance to structural effects of a specified wind load $W$ are included in design, the following combinations of $D$, $L$ and $W$ shall be investigated to determine the greatest required strength $U$.

$$U = 0.75(1.4D + 1.7L + 1.7W) \quad \text{.....(12-4)}$$

where load combinations shall include both full value and zero value of $L$ to determine the more severe condition, and

$$U = 0.9D + 1.3W \quad \text{.....(12-5)}$$

but for any combination of $D$, $L$ and $W$, required strength $U$ shall be not less than Formula (12-3).

D. If resistance to earth pressure $H$ is included in design, required strength $U$ shall be at least equal to

$$U = 1.4D + 1.7L + 1.7H \quad \text{.....(12-6)}$$

except that where $D$ or $L$ reduces the effect of $H$, $0.9D$ shall be substituted for $1.4D$ and zero value of $L$ shall be used to determine the greatest required strength $U$. For any combination of $D$, $L$ and $H$, required strength $U$ shall be not less than Formula (12-3).

E. If resistance to loadings due to weight and pressure of fluids with well-defined densities and controllable maximum heights $F$ is included in design, such loading shall have a load factor of 1.4 and be added to all loading combinations that include live load.

F. If resistance to impact effects is taken into account in design, such effects shall be included with live load, $L$.

G. Where structural effects $T$ of differential settlement, creep, shrinkage or



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temperature change may be significant in design, required strength $U$ shall be at least equal to

$$U = 0.75(1.4D + 1.4T + 1.7L) \quad \text{.....(12-7)}$$

but required strength $U$ shall be not less than

$$U = 1.4(D + T) \quad \text{.....(12-8)}$$

2. **Design strength.** Design strength provided by the shear wall cross section in terms of axial force, shear and moment shall be computed as the nominal strength multiplied by the strength reduction factor $\phi$.

Shear walls shall be proportioned such that the design strength exceeds the required strength.

Strength reduction factor $\phi$ shall be as follows:

A. Axial load and axial load with flexure $\phi = 0.65$

For members in which $f_y$ does not exceed 60,000 psi, with symmetrical reinforcement, $\phi$ may be increased linearly to 0.85 as $\phi P_n$ decreases from $0.10 f'_m A_n$ or $0.25 P_b$ to zero.

For solid grouted walls $P_b$ may be calculated by Formula (12-9)

$$P_b = 0.85 f'_m b a_b \quad \text{.....(12-9)}$$

where

$$a_b = 0.85 [e_{mu}/(e_{mu} + f_y/E_s)]d \quad \text{.....(12-10)}$$

B. Shear $\phi = 0.60$

The shear-strength reduction factor may be 0.80 for any shear wall when its nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength for the factored-load combination.

3. **Design assumptions for nominal strength.** Nominal strength of shear wall cross sections shall be based on assumptions prescribed in Section 2411 (b) 3 D.

The maximum usable strain, $e_{mu}$, at the extreme masonry compression fiber shall not exceed 0.003.

$f'_m$ shall not be less than 1,500 psi nor greater than 4,000 psi.

4. **Reinforcement.** Reinforcement shall be in accordance with the following:

A. Minimum reinforcement shall be provided in accordance with Section 2407 (h) 4 B for all seismic areas using this method of analysis.

B. When the shear wall failure mode is in flexure, the nominal flexural strength of the shear wall shall be at least three times the cracking moment strength of the wall from Formula (11-14).

C. All continuous reinforcement shall be anchored or spliced in accordance with Seetions 2409 (e) 1, 2, 3 A (with $f_s = 0.5 f_y$), 3 B, 3 D, 3 F and 3 G (with $F_s = f_y$).

D. The minimum amount of vertical reinforcement shall not be less than one-half the horizontal reinforeement.



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E. Maximum spacing of horizontal reinforcement within the region defined in Section 2412 (d) 6 C (i) shall not exeeed three times nominal wall thickness or 24 inches, whichever is less.

5. **Axial strength.** The nominal axial strength of the shear wall supporting axial loads only shall be calculated by Formula (12-11).

$$P_o = 0.85 f'_m (A_n - A_s) + f_y A_s \quad \text{.....(12-11)}$$

Axial design strength provided by the shear wall eross section shall satisfy Formula (12-12).

$$P_u \leq \phi_i (0.80) P_o \quad \text{.....(12-12)}$$

6. **Shear strength.** Shear strength shall be as follows:

A. The nominal shear strength shall be determined using either Section 2412 (d) 6 B or C. Table No. 24-K gives the maximum nominal shear strength values.

B. The nominal shear strength of the shear wall shall be determined from Formula (12-13), except as provided in Section 2412 (d) 6 C.

$$V_n = V_m + V_s \quad \text{.....(12-13)}$$

where

$$V_m = C_d A_{mv} (f'_m)^{1/2} \quad \text{.....(12-14)}$$

and

$$V_s = A_{mv} \rho_n f_y \quad \text{.....(12-15)}$$

C. For a shear wall whose nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength two shear regions exist.

(i) For all cross sections within the region defined by the base of the shear wall and a plane at a distance $L_w$ above the base of the shear wall the nominal shear strength shall be determined from Formula (12-16).

$$V_n = A_{mv} \rho_n f_y \quad \text{.....(12-16)}$$

The required shear strength for this region shall be calculated at a distance $L_w/2$ above the base of the shear wall but not to exeeed one-half story height.

(ii) For the other region the nominal shear strength of the shear wall shall be determined from Formula (12-13).

7. **Boundary member.** Boundary members shall be as follows:

A. The need for boundary members at boundaries of the shear wall shall be determined using either Section 2412 (d) 7 B or C.

B. Boundary members shall be provided when the failure mode is flexure and when the maximum extreme fiber stress, corresponding to factored forces, exceeds $0.2 f'_m$. The boundary member may be discontinued where the



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calculated compressive stress is less than $0.15 f'_m$. Stresses may be calculated for the factored forces using a linearly elastic model and gross-section properties.

C. Boundary members shall be provided to confine all vertical reinforcement whose corresponding masonry compressive stress, corresponding to factored forces, exceeds $0.4 f'_m$ when the failure mode is flexure.

D. The minimum length of the boundary member shall be three times the thickness of the wall.

E. Boundary members shall be confined with a minimum of No. 3 bars at a maximum of 8-inch spacing or equivalent within the grouted core and within the region defined by the base of the shear wall and a plane at a distance $L_w$ above the base of the shear wall.

**TABLE NO. 24-A—MORTAR PROPORTIONS FOR UNIT MASONRY**

| MORTAR | TYPE | PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS) | | | | | AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION |
|---|---|---|---|---|---|---|---|
| | | PORTLAND CEMENT OR BLENDED CEMENT[1] | MASONRY CEMENT[2] | | | HYDRATED LIME OR LIME PUTTY[1] | |
| | | | M | S | N | | |
| Cement-lime | M | 1 | — | — | — | 1/4 | Not less than 2 1/4 and not more than 3 times the sum of the separate volumes of cementitious materials. |
| | S | 1 | — | — | — | over 1/4 to 1/2 | |
| | N | 1 | — | — | — | over 1/2 to 1 1/4 | |
| | O | 1 | — | — | — | over 1 1/4 to 2 1/2 | |
| Masonry cement | M | 1 | — | — | 1 | — | |
| | M | — | 1 | — | — | — | |
| | S | 1/2 | — | — | 1 | — | |
| | S | — | — | 1 | — | — | |
| | N | — | — | — | 1 | — | |
| | O | — | — | — | 1 | — | |

[1]When plastic cement is used in lieu of portland cement, hydrated lime or putty may be added, but not in excess of one tenth of the volume of cement.

[2]Masonry cement conforming to the requirements of U.B.C. Standard No. 24-16.



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## TABLE NO. 24-B—GROUT PROPORTIONS BY VOLUME[1]

| TYPE | PARTS BY VOLUME OF PORTLAND CEMENT OR BLENDED CEMENT | PARTS BY VOLUME OF HYDRATED LIME OR LIME PUTTY | AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION | |
|---|---|---|---|---|
| | | | Fine | Coarse |
| Fine grout | 1 | 0 to 1/10 | 2 1/4 to 3 times the sum of the volumes of the cementitious materials | |
| Coarse grout | 1 | 0 to 1/10 | 2 1/4 to 3 times the sum of the volumes of the cementitious materials | 1 to 2 times the sum of the volumes of the cementitious materials |

[1]Grout shall attain a minimum compressive strength at 28 days of 2,000 psi. The building official may require a compressive field strength test of grout made in accordance with the U.B.C. Standard No. 24-22.

## TABLE NO. 24-C—SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, $f'_m$ (psi)[2] BASED ON SPECIFYING THE COMPRESSIVE STRENGTH OF MASONRY UNITS

| Compressive Strength of Clay Masonry Units[1] (psi) | Specified Compressive Strength of Masonry, $f'_m$ | |
|---|---|---|
| | Type M or S Mortar[3] (psi) | Type N Mortar[3] (psi) |
| 14,000 or more | 5,300 | 4,400 |
| 12,000 | 4,700 | 3,800 |
| 10,000 | 4,000 | 3,300 |
| 8,000 | 3,350 | 2,700 |
| 6,000 | 2,700 | 2,200 |
| 4,000 | 2,000 | 1,600 |
| **Compressive Strength of Concrete Masonry Units[4] (psi)** | **Specified Compressive Strength of Masonry, $f'_m$** | |
| | **Type M or S Mortar[3] (psi)** | **Type N Mortar[3] (psi)** |
| 4,800 or more | 3,000 | 2,800 |
| 3,750 | 2,500 | 2,350 |
| 2,800 | 2,000 | 1,850 |
| 1,900 | 1,500 | 1,350 |
| 1,250 | 1,000 | 950 |

[1]Compressive strength of solid clay masonry units is based on gross area. Compressive strength of hollow clay masonry units is based on minimum net area. Values may be interpolated.

*(Continued)*



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[2]Assumed assemblage. The specified compressive strength of masonry $f'_m$ is based on gross area strength when using solid units or solid grouted masonry and net area strength when using ungrouted hollow units.

[3]Mortar for unit masonry, proportion specification, as specified in Table No. 24-A. These values apply to portland cement-lime mortars without added air-entraining materials.

[4]Net area compressive strength of concrete masonry units is determined in accordance with U.B.C. Standard No. 24-7. Values may be interpolated. In grouted concrete masonry the compressive strength of grout shall be equal to or greater than the compressive strength of the concrete masonry units.

## TABLE NO. 24-D-1—ALLOWABLE TENSION, $B_t$, ON BENT BAR ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1 2 3]

| | EMBEDMENT LENGTH, $l_b$, or EDGE DISTANCE, $l_{be}$, inches | | | | | | |
|---|---|---|---|---|---|---|---|
| $f'_m$ (psi) | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| 1500 | 240 | 550 | 970 | 1520 | 2190 | 3890 | 6080 |
| 1800 | 270 | 600 | 1070 | 1670 | 2400 | 4260 | 6660 |
| 2000 | 280 | 630 | 1120 | 1760 | 2520 | 4500 | 7020 |
| 2500 | 310 | 710 | 1260 | 1960 | 2830 | 5030 | 7850 |
| 3000 | 340 | 770 | 1380 | 2150 | 3100 | 5510 | 8600 |
| 4000 | 400 | 890 | 1590 | 2480 | 3580 | 6360 | 9930 |
| 5000 | 440 | 1000 | 1780 | 2780 | 4000 | 7110 | 11,100 |
| 6000 | 480 | 1090 | 1950 | 3040 | 4380 | 7790 | 12,200 |

[1]The allowable tension values in Table No. 24-D-1 are based on compressive strength of masonry assemblages. Where yield strength of anchor bolt steel governs, the allowable tension in pounds is given in Table No. 24-D-2.

[2]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2406 (h) 1 A.

[3]Values shown are for work with or without special inspection.

## TABLE NO. 24-D-2—ALLOWABLE TENSION, $B_t$, ON BENT BAR ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1 2]

| BENT BAR ANCHOR BOLT DIAMETER, inches | | | | | | |
|---|---|---|---|---|---|---|
| 3/8 | 1/2 | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 |
| 790 | 1410 | 2210 | 3180 | 4330 | 5650 | 7160 |

[1]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2406 (h) 1 A.

[2]Values shown are for work with or without special inspection.



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## TABLE NO. 24-E—ALLOWABLE SHEAR, $B_v$, ON BENT BAR ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1] [2]

| | BENT BAR ANCHOR BOLT DIAMETER, inches | | | | | | |
|---|---|---|---|---|---|---|---|
| $f'_m$ (psi) | 3/8 | 1/2 | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 |
| 1500 | 480 | 850 | 1330 | 1780 | 1920 | 2050 | 2170 |
| 1800 | 480 | 850 | 1330 | 1860 | 2010 | 2150 | 2280 |
| 2000 | 480 | 850 | 1330 | 1900 | 2060 | 2200 | 2340 |
| 2500 | 480 | 850 | 1330 | 1900 | 2180 | 2330 | 2470 |
| 3000 | 480 | 850 | 1330 | 1900 | 2280 | 2440 | 2590 |
| 4000 | 480 | 850 | 1330 | 1900 | 2450 | 2620 | 2780 |
| 5000 | 480 | 850 | 1330 | 1900 | 2590 | 2770 | 2940 |
| 6000 | 480 | 850 | 1330 | 1900 | 2600 | 2900 | 3080 |

[1]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2406 (h) 1 A.

[2]Values shown are for work with or without special inspection.

## TABLE NO. 24-F—MINIMUM DIAMETERS OF BEND

| BAR SIZE | MINIMUM DIAMETER |
|---|---|
| No. 3 through No. 8 | 6 bar diameters |
| No. 9 through No. 11 | 8 bar diameters |



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## TABLE NO. 24-G—GROUTING LIMITATIONS

| GROUT TYPE | GROUT POUR[2] MAXIMUM HEIGHT (Feet) | LEAST CLEAR DIMENSIONS[1] Width of Grout Space[5] (In.)[3] | LEAST CLEAR DIMENSIONS[1] Cell Dimensions[6] (In. × In.) | CLEANOUTS REQUIRED[4] |
|---|---|---|---|---|
| Fine | 1 | 3/4 | 1 1/2 × 2 | No |
| Fine | 5 | 1 1/2 | 1 1/2 × 2 | No |
| Fine | 8 | 1 1/2 | 1 1/2 × 3 | Yes |
| Fine | 12 | 1 1/2 | 1 3/4 × 3 | Yes |
| Fine | 24 | 2 | 3 × 3 | Yes |
| Coarse | 1 | 1 1/2 | 1 1/2 × 3 | No |
| Coarse | 5 | 2 | 2 1/2 × 3 | No |
| Coarse | 8 | 2 | 3 × 3 | Yes |
| Coarse | 12 | 2 1/2 | 3 × 3 | Yes |
| Coarse | 24 | 3 | 3 × 4 | Yes |

[1]The clear dimension is the cell or grout space width less mortar projections.

[2]For grout pours over 5 feet high, see Section 2404 (f) 1.

[3]Grout space width shall be increased by the horizontal projection of the diameters of the horizontal bars within the cross section of the grout space.

[4]Cleanouts may be omitted if approved provisions are made to keep the grout space clean prior to grouting.

[5]For grout spaces in grouted multiwythe masonry.

[6]For grout cells in grouted hollow unit masonry.



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## TABLE NO. 24-H—ALLOWABLE WORKING STRESSES IN UNREINFORCED UNIT MASONRY

| MATERIAL | TYPE M | TYPE S | TYPE M OR TYPE S MORTAR | | | | TYPE N | | |
|---|---|---|---|---|---|---|---|---|---|
| | Compression[1] | Compression[1] | Shear or Tension in Flexure[2,3] | | Tension in Flexure[4] | | Compression[1] | Shear or Tension in Flexure[2,3] | |
| 1. Special inspection required | No | No | Yes | No | Yes | No | No | Yes | No |
| 2. Solid brick masonry | | | | | | | | | |
| 4500 plus psi | 250 | 225 | 20 | 10 | 40 | 20 | 200 | 15 | 7.5 |
| 2500-4500 psi | 175 | 160 | 20 | 10 | 40 | 20 | 140 | 15 | 7.5 |
| 1500-2500 psi | 125 | 115 | 20 | 10 | 40 | 20 | 100 | 15 | 7.5 |
| 3. Solid concrete unit masonry | | | | | | | | | |
| Grade N | 175 | 160 | 12 | 6 | 24 | 12 | 140 | 12 | 6 |
| Grade S | 125 | 115 | 12 | 6 | 24 | 12 | 100 | 12 | 6 |
| 4. Grouted masonry | | | | | | | | | |
| 4500 plus psi | 350 | 275 | 25 | 12.5 | 50 | 25 | | | |
| 2500-4500 psi | 275 | 215 | 25 | 12.5 | 50 | 25 | | | |
| 1500-2500 psi | 225 | 175 | 25 | 12.5 | 50 | 25 | | | |
| 5. Hollow unit masonry[5] | 170 | 150 | 12 | 6 | 24 | 12 | 140 | 10 | 5 |
| 6. Cavity wall masonry solid units[5] | | | | | | | | | |
| Grade N or 2500 psi plus | 140 | 130 | 12 | 6 | 30 | 15 | 110 | 10 | 5 |
| Grade S or 1500-2500 psi | 100 | 90 | 12 | 6 | 30 | 15 | 80 | 10 | 5 |
| Hollow units[5] | 70 | 60 | 12 | 6 | 30 | 15 | 50 | 10 | 5 |
| 7. Stone masonry | | | | | | | | | |
| Cast stone | 400 | 360 | 8 | 4 | — | — | 320 | 8 | 4 |
| Natural stone | 140 | 120 | 8 | 4 | — | — | 100 | 8 | 4 |
| 8. Unburned clay masonry | 30 | 30 | 8 | 4 | — | — | — | — | — |

[1]Allowable axial or flexural compressive stresses in pounds per square inch gross cross-sectional area (except as noted). The allowable working stresses in bearing directly under concentrated loads may be 50 percent greater than these values.

[2]This value of tension is based on tension across a bed joint, i.e., vertically in the normal masonry work.

[3]No tension allowed in stack bond across head joints.

[4]The values shown here are for tension in masonry in the direction of running bond, i.e., horizontally between supports.

[5]Net area in contact with mortar or net cross-sectional area.



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## TABLE NO. 24-I—ALLOWABLE SHEAR ON BOLTS FOR MASONRY OF UNBURNED CLAY UNITS

| DIAMETER OF BOLTS (Inches) | EMBEDMENTS (Inches) | SHEAR (Pounds) |
|---|---|---|
| 1/2 | — | — |
| 5/8 | 12 | 200 |
| 3/4 | 15 | 300 |
| 7/8 | 18 | 400 |
| 1 | 21 | 500 |
| 1 1/8 | 24 | 600 |

## TABLE NO. 24-J—ALLOWABLE SHEAR ON BOLTS FOR EMPIRICALLY DESIGNED MASONRY EXCEPT UNBURNED CLAY UNITS

| DIAMETER BOLT (Inches) | EMBEDMENT[1] (Inches) | SOLID MASONRY (Shear in Pounds) | GROUTED MASONRY (Shear in Pounds) |
|---|---|---|---|
| 1/2 | 4 | 350 | 550 |
| 5/8 | 4 | 500 | 750 |
| 3/4 | 5 | 750 | 1100 |
| 7/8 | 6 | 1000 | 1500 |
| 1 | 7 | 1250 | 1850[2] |
| 1 1/8 | 8 | 1500 | 2250[2] |

[1]An additional 2 inches of embedment shall be provided for anchor bolts located in the top of columns for buildings located in Seismic Zones Nos. 2, 3 and 4.

[2]Permitted only with not less than 2500 pounds per square inch units.

## TABLE NO. 24-K MAXIMUM NOMINAL SHEAR STRENGTH VALUES

| $M/Vd$[1] | $\frac{V_n}{A_e(f'_m)^{1/2}}$ |
|---|---|
| $\leq 0.25$ | 6.0 |
| $\geq 1.00$ | 4.0 |

[1]$M$ is the maximum bending moment that occurs simultaneously with the shear load $V$ at the section under consideration. Interpolation may be by straight line for $M/Vd$ values between 0.25 and 1.00.



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## TABLE NO. 24-L
## NOMINAL SHEAR STRENGTH COEFFICIENT

| $M/Vd$[1] | $C_d$ |
|---|---|
| ≤0.25 | 2.4 |
| ≥1.00 | 1.2 |

[1] $M$ is the maximum bending moment that occurs simultaneously with the shear load $V$ at the section under consideration. Interpolation may be by straight line for $M/Vd$ values between 0.25 and 1.00.



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# Chapter 25
# WOOD

## General

**Sec. 2501.** (a) **Quality and Design.** The quality and design of wood members and their fastenings shall conform to the provisions of this chapter and to the applicable standards listed in Chapter 60.

(b) **Workmanship.** All members shall be framed, anchored, tied and braced so as to develop the strength and rigidity necessary for the purposes for which they are used.

(c) **Fabrication.** Preparation, fabrication and installation of wood members and their fastenings shall conform to accepted engineering practices and to the requirements of this code.

(d) **Rejection.** The building official may deny permission for the use of a wood member where permissible grade characteristics or defects are present in such a combination that they affect the serviceability of the member.

(e) **Minimum Quality.** Minimum capacity of structural framing members may be established by performance tests. When tests are not made, capacity shall be based upon allowable stresses and design criteria specified in this code.

Studs, joists, rafters, foundation plates or sills, planking 2 inches or more in depth, beams, stringers, posts, structural sheathing and similar load-bearing members shall be of at least the minimum grades set forth in Table No. 25-A-1 or No. 25-A-2. Approved end-jointed lumber may be used interchangeably with solid-sawn members of the same species and grade. Such use shall include, but not be limited to, light framing joists, planks and decking.

Plywood shall be of species Group 1, 2, 3 or 4 and shall be one of the grades specified in U.B.C. Standard No. 25-9.

Particleboard shall conform to U.B.C. Standard No. 25-25.

Approved fire-retardant-treated wood shall be dried, following treatment, to a maximum moisture content as follows: solid-sawn lumber 2 inches in thickness or less to 19 percent, and plywood to 15 percent.

(f) **Shrinkage.** Consideration shall be given in the design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

## Definitions and Symbols

**Sec. 2502.** (a) **Definitions.** The following terms used in this chapter shall have the meanings indicated in this section:

**BLOCKED DIAPHRAGM** is a diaphragm in which all sheathing edges not occurring on framing members are supported on and connected to blocking.

**DIAPHRAGM** is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. When the term "diaphragm" is used, it includes horizontal bracing systems.



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**FIBERBOARD** is a fibrous-felted, homogeneous panel made from lignocellulosic fibers (usually wood or cane) and having a density of less than 31 pounds per cubic foot but more than 10 pounds per cubic foot, conforming to U.B.C. Standard No. 25-24.

**GLUED BUILT-UP MEMBERS** are structural elements, the sections of which are composed of built-up lumber, plywood or plywood in combination with lumber, all parts bonded together with adhesives.

**GRADE (Lumber),** the classification of lumber in regard to strength and utility in accordance with the grading rules of an approved lumber grading agency.

**HARDBOARD** is a fibrous-felted, homogeneous panel made from lignocellulosic fibers consolidated under heat and pressure in a hot press to a density not less than 31 pounds per cubic foot conforming to U.B.C. Standard No. 25-26.

**NOMINAL SIZE (Lumber),** the commercial size designation of width and depth, in standard sawn lumber and glued-laminated lumber grades; somewhat larger than the standard net size of dressed lumber, in accordance with U.B.C. Standard No. 25-1 for sawn lumber and U.B.C. Standard No. 25-10 for structural glued-laminated timber.

**NORMAL LOADING,** a design load that stresses a member or fastening to the full allowable stress tabulated in this chapter. This loading may be applied for approximately 10 years, either continuously or cumulatively, and 90 percent of this load may be applied for the remainder of the life of the member or fastening.

**PARTICLEBOARD** is a mat-formed panel consisting of particles of wood or combinations of wood particles and wood fibers bonded together with synthetic resins or other suitable bonding system by a bonding process in accordance with U.B.C. Standard No. 25-25.

**PLYWOOD,** a built-up panel of laminated veneers conforming to U.B.C. Standard No. 25-9.

**ROTATION** is the torsional movement of a diaphragm about a vertical axis.

**STRUCTURAL GLUED-LAMINATED TIMBER,** any member comprising an assembly of laminations of lumber in which the grain of all laminations is approximately parallel longitudinally, in which the laminations are bonded with adhesives, and which is fabricated in accordance with U.B.C. Standards No. 25-10 and No. 25-11.

**SUBDIAPHRAGM** is a portion of a larger diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

**TREATED WOOD,** wood treated with an approved preservative under the treating and quality control requirements specified in U.B.C. Standard No. 25-12.

**WOOD OF NATURAL RESISTANCE TO DECAY,** the heartwood of bald cypress, black locust, black walnut, the cedars and redwood.

(b) **Symbols.** The symbols used in this chapter have the following definitions:

$A$ = area of cross section.

$b$ = breadth (width) of rectangular member.



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$C$ = coefficient, constant or factor.
$C_c$ = curvature factor.
$C_F$ = size effect factor.
$C_f$ = form factor.
$C_s$ = slenderness factor.
$c$ = distance from neutral axis to extreme fiber.
$D$ = diameter.
$d$ = depth of rectangular member, or least dimension of compression member.
$E$ = modulus of elasticity.
$e$ = eccentricity.
$F_b$ = allowable unit stress for extreme fiber in bending.
$F'_b$ = allowable unit stress for extreme fiber in bending, adjusted for slenderness.
$f_b$ = actual unit stress for extreme fiber in bending.
$F_c$ = allowable unit stress in compression parallel to grain.
$F'_c$ = allowable unit stress in compression parallel to grain adjusted for *le/d* ratio where *d* is the least dimension.
$f_c$ = actual unit stress in compression parallel to grain.
$F_{c\perp}$ = allowable unit stress in compression perpendicular to grain.
$F'_{c\perp}$ = critical compression-perpendicular-to-grain value.
$f_{c\perp}$ = actual unit stress in compression perpendicular to grain.
$F_n$ = allowable unit stress acting perpendicular to the inclined surface, psi (Hankinson's Formula).
$F_r$ = allowable unit radial stress.
$f_r$ = actual unit radial stress.
$F_{rc}$ = allowable unit radial stress in compression.
$f_{rc}$ = actual unit radial stress in compression.
$F_{rt}$ = allowable unit radial stress in tension.
$f_{rt}$ = actual unit radial stress in tension.
$F_t$ = allowable unit stress in tension parallel to grain.
$f_t$ = actual unit stress in tension parallel to grain.
$F_v$ = allowable unit horizontal shear stress.
$f_v$ = actual unit horizontal shear stress.
$h$ = rise.
$I$ = moment of inertia.
$L$ = span length of beam, or unsupported length of column, feet.
$l$ = span length of beam, or unsupported length of column, ineh.
$le$ = effective span length of bending member or effective length of compression member, inches.



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$M$ = bending moment.
$m$ = unit bending moment.
$N$ = acting perpendicular to the inclined surface "*lb*" (Hankinson's Formula).
$P$ = total concentrated load, or axial compression load.
$P/A$ = induced axial load per unit of cross-sectional area.
$Q$ = statical moment of an area about the neutral axis.
$R$ = radius of curvature.
$R_H$ = horizontal reaction.
$R_V$ = vertical reaction.
$r$ = radius of gyration.
$S$ = section modulus.
$T$ = total axial tension load.
$t$ = thickness.
$V$ = shear force.
$W$ = total uniform load.
$w$ = uniform load per unit of length.
$\Delta_A$ = allowable deformation or deflection.
$\Delta_a$ = actual deformation or deflection.
$\theta$ = angle between the direction of load and the direction of grain, degrees (Hankinson's Formula).

## Size of Structural Members

**Sec. 2503.** Sizes of lumber and structural glued-laminated timber referred to in this code are nominal sizes. Computations to determine the required sizes of members shall be based on the net dimensions (actual sizes) and not the nominal sizes.

## Stresses

**Sec. 2504.** (a) **General.** Except as hereinafter provided, stresses shall not exceed the allowable unit stresses for the respective species and grades or fabricated products as set forth in Tables No. 25-A-1 and No. 25-A-2 for lumber, and Tables No. 25-C and No. 25-D for structural glued-laminated timber.

The values for $F_b$ and $F_c$ tabulated in Table No. 25-A-1 for visually stress-rated lumber and in Table No. 25-A-2 for machine-stress-rated lumber are for the design of structures when the strength of an individual member is premised on the assumption that each individual piece carries its design load.

The repetitive member design values for $F_b$ tabulated in Table No. 25-A-1 and Table No. 25-A-2 may be used for the design of an assembly of repetitive framing such as joists, rafters and studs not over 4 inches in thickness spaced not more than 24 inches, not less than three in number and joined by transverse load-distributing elements adequate to support the design load.



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Values for species and grades not tabulated shall be approved by the building official.

Values for plywood shall be in accordance with Table No. 25-B. All plywood when designed to be exposed in outdoor applications shall be of the exterior type, except as provided in Sections 2516 (i) and 2517 (h) 7.

(b) **Wood Poles or Piles.** The values tabulated in Table No. 25-E shall be used for the design of round timber poles and piles.

Poles and piles shall conform to the requirements set forth in U.B.C. Standards No. 25-13 and No. 25-14.

(c) **Adjustment of Stresses.** 1. **General.** The allowable unit stresses specified in this chapter shall be subject to the adjustments set forth in the footnotes to the appropriate stress tables and to the requirements of this subsection.

2. **Preservative treatment.** The values for wood pressure impregnated with an approved process and preservative need no adjustment for treatment but are subject to other adjustments.

3. **Fire-retardant treatment.** The values of lumber pressure impregnated with approved fire-retardant chemicals shall be reduced to 90 percent for horizontal shear, compression perpendicular to grain, compression parallel to grain and modulus of elasticity; 85 percent for extreme fiber in bending; and 80 percent for tension parallel to grain. The values for plywood so treated shall be reduced to 84 percent except for modulus of elasticity, which shall be reduced to 90 percent. Other adjustments are applicable except that the impact load duration factor shall not apply.

The values for fasteners specified in U.B.C. Standard No. 25-17 shall be reduced to 90 percent, except that values for light metal plate connectors shall be recommended by each truss plate manufacturer and approved by the building official.

Values for glue-laminated timber, including fastener designer loads, shall be recommended by the treater and approved by the building official.

In addition to the requirements specified in Section 407, fire-retardant lumber having structural applications shall be tested and identified by an approved inspection agency in accordance with U.B.C. Standard No. 25-29.

4. **Duration of load.** Values for wood and mechanical fastenings (when the wood determines the load capacity) are subject to the following adjustments for the various durations of loading:

(i) Where a member is fully stressed to the maximum allowable stress, either continuously or cumulatively, for more than 10 years under the conditions of maximum design load, the values shall not exceed 90 percent of those in the tables.

(ii) When the duration of the full maximum load during the life of the member does not exceed the period indicated below, the values may be increased in the tables as follows:

15 percent for two months' duration, as for snow

25 percent for seven days' duration, as for roof loads



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33 1/3 percent for wind or earthquake

100 percent for impact

The foregoing increases are not cumulative. For combined duration of loadings the resultant structural members shall not be smaller than required for the longer duration of loading.

The duration of load factors in this item shall not apply to compression-perpendicular-to-grain design values based on a deformation limit, or to modulus of elasticity.

(iii) Values for normal loading conditions may be used without regard to impact if the stress induced by impact does not exceed the values for normal loading.

5. **Size factor adjustment.** When the depth of a rectangular sawn bending member exceeds 12 inches, the allowable unit stress in bending $F_b$ shall be multiplied by the size factor $C_F$ as determined by the formula:

$$C_F = (12/d)^{1/9}$$

**WHERE:**

$C_F$ = size factor.

$d$ = depth of beam in inches.

For beams of circular cross section that have a diameter greater than 13.5 inches, or 12-inch or larger square beams loaded in the plane of the diagonal, the size factor $C_F$ may be determined on the basis of an equivalent conventionally loaded square beam of the same cross-sectional area.

Size factor adjustments are cumulative with form factor adjustments specified in Section 2504 (e) 7, except for lumber I beams and box beams, but are not cumulative with slenderness factor adjustments specified in Section 2504 (c) 6. Size factor adjustments for glued-laminated members shall be in accordance with Section 2511 (d) 5. The size factor adjustment shall not apply to visually graded lumber 2 inches to 4 inches thick or to machine-stress-rated lumber.

6. **Slenderness factor adjustments for beams.** When the depth of a beam exceeds its breadth, lateral support may be required and the slenderness factor $C_s$ shall be calculated by the following formula:

$$C_s = \sqrt{\frac{le\,d}{b^2}}$$

in which

$C_s$ = slenderness factor.

$le$ = effective length of beam, inches, from the following table.

$d$ = depth of beam, inches.

$b$ = breadth of beam, inches.



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**EFFECTIVE LENGTH OF BEAMS**

| TYPE OF BEAM SPAN AND NATURE OF LOAD | VALUE OF EFFECTIVE LENGTH, $l_e$ |
|---|---|
| Single-span beam, load concentrated at center | $1.61l_u$ |
| Single-span beam, uniformly distributed load | $1.92l_u$ |
| Single-span beam, equal end moments | $1.84l_u$ |
| Cantilever beam, load concentrated at unsupported end | $1.69l_u$ |
| Cantilever beam, uniformly distributed load | $1.06l_u$ |
| Cantilever beam, uniformly distributed load with concentrated load at cantilever end | $1.69l_u$ |
| Single-span or cantilever beam, any other load | $1.92l_u$ |
| $l_u$ = unsupported length of beam, inches. | |

The effective lengths, $l_e$, in the table are based on an $l_u/d$ ratio of 17. For other $l_u/d$ ratios, these effective lengths may be multiplied by a factor equal to $0.85 + 2.55/(l_u/d)$ except that this factor shall not apply to a single-span beam with equal end moments ($l_e = 1.84\,l_u$) or to a single span or cantilever beam with any load ($l_e = 1.92\,l_u$).

When the slenderness factor $C_s$ does not exceed 10, the full allowable unit stress in bending $F_b$ may be used.

When the slenderness factor $C_s$ is greater than 10 but does not exceed $C_k$, the allowable unit stress in bending $F'_b$ shall be determined from the following formula:

$$F'_b = F_b\left[1 - 1/3\left(\frac{C_s}{C_k}\right)^4\right]$$

in which

$C_k = .811\sqrt{E/F_b}$

$E$ = modulus of elasticity.

When the slenderness factor $C_s$ is greater than $C_k$ but less than 50, the allowable unit stress in bending $F'_b$ shall be determined by the following formula:

$$F'_b = \frac{0.438E}{(C_s)^2}$$

In no case shall $C_s$ exceed 50.

The design values for extreme fiber in bending, $F_b$, and modulus of elasticity, $E$, used in the formulas for $F'_b$ shall be modified to account for moisture service condition, duration of loading, temperature and type of treatment in accordance with Section 2504 (c) except that the modification for size factor shown in Section 2504 (c) 5 shall not be taken. Design values for extreme fiber in bending adjusted for slenderness factor, $F'_b$, are not subject to further modifications for moisture service condition, duration of loading, temperature, type of treatment or size.



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The design value for extreme fiber in bending, $F'_b$, shall not exceed the full design value for extreme fiber in bending, $F_b$, modified as allowed in this section, including the size factor adjustment.

When the compression edge of a beam is supported throughout its length to prevent its lateral displacement, and the ends at points of bearing have lateral support to prevent rotation, the unsupported length $l_u$ may be taken as zero.

When lateral support is provided to prevent rotation at the points of end bearing but no other lateral support is provided throughout the length of the beam, the unsupported length $l_u$ is the distance between such points of end bearing, or the length of cantilever.

When a beam is provided with lateral support to prevent rotational and lateral displacement at intermediate points as well as at the ends, the unsupported length $l_u$ is the distance between such points of intermediate lateral support.

7. **Form factor adjustments.** The allowable unit stress in bending for non-prismatic members shall not exceed the value established by multiplying such stress by the form factor $C_f$ determined as follows:

| Beam Section | Form Factor ($C_f$) |
|---|---|
| Circular | 1.180 |
| Square (with diagonal vertical) | 1.414 |
| Lumber I Beams and Box Beams | $0.81\left[1 + \left(\frac{d^2 + 143}{d^2 + 88} - 1\right)C_g\right]$ |

**WHERE:**

$C_f$ = form factor.

$C_g$ = support factor = $p^2(6 - 8p + 3p^2)(1 - q) + q$.

$p$ = ratio of depth of compression flange to full depth of beam.

$q$ = ratio of thickness of web or webs to the full width of beam.

The form factor adjustment shall be cumulative with the size factor adjustment, except for lumber I beams and box beams.

8. **Modulus of elasticity adjustment.** The use of average modulus of elasticity $E$ values are appropriate for the design of normal wood structural members and assemblies. In special applications where deflections are critical to the stability of structures or structural components, and where exposed to varying temperature and relative humidity under sustained loading conditions, the average values of the modulus of elasticity $E$ listed in Tables Nos. 25-A-1, 25-A-2, 25-C-1, 25-C-2, 25-D and 25-E shall be reduced to account for variability. Coefficients of variation $C_v$ in the modulus of elasticity $E$ for lumber and glued-laminated timber are as follows:



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| | $C_v$ |
|---|---|
| Visually graded sawn lumber | 0.25 |
| Machine stress-rated sawn lumber | 0.11 |
| Glued-laminated timber | 0.10* |

*Applies to six or more laminations.

The average modulus of elasticity $E$ values listed in the tables shall be multiplied by $1 \div C_v$ or $1 - 1.65\,C_v$ to obtain a modulus of elasticity $E$ value exceeded by 84 percent or 95 percent individual pieces, respectively.

The duration-of-load adjustments specified in Item No. 4 do not apply to modulus of elasticity values.

9. **Temperature.** The allowable unit stresses specified in this chapter and as modified in this section apply to uses within the range of climatic temperature ordinarily encountered in buildings. When manufacturing or equipment processes subject members to prolonged temperatures above this range, but not exceeding 150°F., the allowable design stresses shall be decreased by the appropriate reduction factors specified in U.B.C. Standard No. 25-27. Wood members shall not be used in areas subject to temperatures above 150°F. unless the exposure is infrequent and any permanent loss in strength is accounted for in the design.

10. **Moisture service conditions.** Where sawn lumber and fastenings are exposed to service conditions causing the wood to possess more than 19 percent moisture content, the tabulated design values shall be reduced as specified in Table No. 25-A-1, Footnotes 6 and 7. Where glued-laminated timber exceeds 16 percent moisture content, the tabulated design values shall be reduced as specified in Table No. 25-C-1, Footnote 2.

11. **Bolted joints.** Adjustments for bolt values used in conjunction with metal side plates shall be in accordance with U.B.C. Standard No. 25-17 and Section 2517 15 (d).

## Identification

**Sec. 2505.** All lumber, plywood, particleboard, structural glued-laminated timber, end-jointed lumber, fiberboard sheathing (when used structurally), hardboard siding (when used structurally), piles and poles regulated by this chapter shall conform to the applicable standards or grading rules specified in this code and shall be so identified by the grade mark or a Certificate of Inspection issued by an approved agency.

All preservatively treated wood required to be treated under Section 2516 (c) shall be identified by the quality mark of an approved inspection agency in accordance with U.B.C. Standard No. 25-12, Division II.

## Horizontal Member Design

**Sec. 2506.** (a) **Beam Span.** For simple beams, the span shall be taken as the distance from face to face of supports, plus one half the required length of bearing at each end; for continuous beams, the span is the distance between centers of bearings on supports over which the beam is continuous.



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(b) **Flexure.** 1. **Circular cross section.** A beam of circular cross section may be assumed to have the same strength in flexure as a square beam having the same cross-sectional area. If a circular beam is tapered, it shall be considered a beam of variable cross section.

2. **Notching.** If possible, notching of beams should be avoided. Notches in sawn lumber bending members shall not exceed one sixth the depth of the member and shall not be located in the middle third of the span. Where members are notched at the ends, the notch depth shall not exceed one fourth the beam depth. The tension side of sawn lumber bending members of 4 inches or greater nominal thickness shall not be notched except at ends of members. Cantilevered portions of beams less than 4 inches in nominal thickness shall not be notched unless the reduced section properties and lumber defects are considered in the design. For effects of notch on shear strength, see Section 2506 (d).

3. **Lateral moment distribution.** Lateral moment distribution of a concentrated load from a critically loaded beam to adjacent parallel beams shall be calculated.

(c) **Horizontal Shear.** The maximum horizontal shear stress in a solid-sawn or glued-laminated wood beam shall not exceed that calculated by means of the formula:

$$f_v = \frac{3V}{2bd}$$

The actual unit shear stress $f_v$ shall not exceed the allowable for the species and grade as given in Table No. 25-A for solid-sawn lumber and in Tables No. 25-C and No. 25-D for glued-laminated lumber, adjusted for duration of loading, as provided in Section 2504 (c) 4.

When calculating the shear force, $V$, distribution of load to adjacent parallel beams by flooring or other members may be considered, and all loads within a distance from either support equal to the depth of the beam may be neglected for beams supported by full bearing on one surface and loads applied to the opposite surface.

(d) **Horizontal Shear in Notched Beams.** Where girders, beams or joists are notched at points of support on the tension side, they shall meet the design requirements of that section in bending and in shear. The shear at such point shall not exceed the value calculated by the following formula:

$$V = \left(\frac{2bd' F_v}{3}\right)\left(\frac{d'}{d}\right)$$

**WHERE:**

$d'$ = actual depth of beam at the notch.

$d$ = total depth of beam.



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Where girders, beams or joists are notched at points of support on the compression side, they shall meet design requirements for that net section in bending and in shear. The shear at such point shall not exceed the value calculated by the following formula:

$$V = \frac{2}{3} F_v b \left[ d - \left( \frac{d - d'}{d'} \right) e \right]$$

**WHERE:**

$d'$ = actual depth of beam at notch.
$d$ = total depth of beam.
$e$ = distance the notch extends inside the inner edge of support.

The shear for the notch on the compression side shall be further limited to the value determined for a beam of depth $d'$ if $e$ exceeds $d$.

(e) **Design of Joints in Shear.** Eccentric connector and bolted joints and beams supported by connectors or bolts shall be designed so that $f_v$ in the following formula does not exceed the allowable unit stresses in horizontal shear.

$$f_v = \frac{3V}{2bd_e}$$

**WHERE:**

$d_e$ (with connectors = the depth of the member less the distance from the unloaded edge of member to the nearest edge of the nearest connector.

$d_e$ (with bolts only) = the depth of the member less the distance from the unloaded edge of the member to the center of the nearest bolt.

Allowable unit stresses in shear for joints involving bolts or connectors loaded perpendicular to grain may be 50 percent greater than the horizontal shear values as set forth in Tables Nos. 25-A, 25-C and 25-D, provided that the joint occurs at least five times the depth of the member from its end. Where joints occur within five times the depth of the member from its end, the strength of the joint shall be evaluated not only for the bolt or connector load but also as a notched beam, considering the notch to extend from the unloaded edge of the member to the center of the nearest bolt or the nearest edge of the nearest connector.

(f) **Compression Perpendicular to Grain.** In applications where deformation is critical, the following equation shall be used to calculate the compression-perpendicular-to-grain design values:

$$F_{c\perp}' = 0.73 F_{c\perp}$$

**WHERE:**

$F_{c\perp}'$ = Critical compression-perpendicular-to-grain value.
$F_{c\perp}$ = Compression-perpendicular-to-grain values from Table No. 25-A-1.



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The duration of load modification factors given in Section 2504 (c) 4 shall not apply to compression-perpendicular-to-grain values for sawn lumber.

The allowable unit stresses for compression perpendicular to grain in Tables No. 25-A, No. 25-C and No. 25-D apply to bearings of any length at the ends of the beam and to all bearings 6 inches or more in length at any other location.

For bearings of less than 6 inches in length and not nearer than 3 inches to the end of a member, the maximum allowable load per square inch may be obtained by multiplying the allowable unit stresses in compression perpendicular to grain by the following factor:

$$\frac{l_b + .375}{l_b}$$

in which $l_b$ is the length of bearing in inches measured along the grain of the wood.

The multiplying factors for indicated lengths of bearing on such small areas as plates and washers may be:

| LENGTH OF BEARING (In Inches) | 1/2 | 1 | 1 1/2 | 2 | 3 | 4 | 6 OR MORE |
|---|---|---|---|---|---|---|---|
| Factor | 1.75 | 1.38 | 1.25 | 1.19 | 1.13 | 1.10 | 1.00 |

In using the preceding formula and table for round washers or bearing areas, use a length equal to the diameter.

In joists supported on a ribbon or ledger board and spiked to the studding, the allowable stress in compression perpendicular to grain may be increased 50 percent.

(g) **Tension Perpendicular to Grain.** Where designs that induce tension stresses perpendicular to grain cannot be avoided, mechanical reinforcement sufficient to resist such forces shall be specified.

(h) **Lateral Support.** Solid-sawn rectangular lumber beams, rafters and joists shall be supported laterally to prevent rotation or lateral displacement in accordance with the following:

If the ratio of depth to thickness, based on nominal dimensions, is:

1. Two to 1, no lateral support is required.
2. Three to 1 or 4 to 1, the ends shall be held in position, as by full-depth solid blocking, bridging, nailing or bolting to other framing members, approved hangers or other acceptable means.
3. Five to 1, one edge shall be held in line for its entire length.
4. Six to 1, bridging, full-depth solid blocking or cross bracing shall be installed at intervals not exeeeding 8 feet unless both edges are held in line.
5. Seven to 1, both edges shall be held in line for their entire length.

If a beam is subject to both flexure and compression parallel to grain, the ratio may be as much as 5 to 1 if one edge is held firmly in line. If under any



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combination of load the unbraced edge of the member is in tension, the ratio may be 6 to 1.

In lieu of providing lateral support by the methods specified in Items Nos. 2 through 5 above, the allowable stresses shall be reduced by the slenderness factor set forth in Section 2504 (c) 6.

(i) **Lateral Support of Arches, Compression Chords of Trusses and Studs.** Where roof joists or purlins are used between arches or compression chords, the largest value of *le/d*, calculated using the depth of the arch or compression chord or calculated using the breadth (least dimension) of the arch or compression chord between points of intermittent lateral support, shall be used. The roof joists or purlins shall be placed to account for shrinkage (for example, by placing the upper edges of unseasoned joists approximately 5 percent of the joist depth above the tops of the arch or chord) but also placed low enough to provide adequate lateral support.

Where roof joists or purlins are placed on top of an arch or compression chord and are securely fastened to the arch or compression chord, the largest value of *le/d*, calculated using the depth of the arch or compression chord or calculated using the breadth (least dimension) of the arch or compression chord between points of intermittent lateral support, shall be used.

Where planks are placed on top of an arch or compression chord and securely fastened to the arch or compression chord, or when sheathing is nailed properly to the top chord of trussed rafters, the depth rather than the breadth of the arch, compression chord or trussed rafter may be used as the least dimension in determining *le/d*. Where stud walls in light frame construction are adequately sheathed on at least one side, the depth rather than breadth of the stud, may be taken as the least dimension in calculating the *le/d* ratio. The sheathing shall be shown by experience to provide lateral support and shall be fastened in accordance with Table No. 25-Q.

## Column Design

**Sec. 2507.** (a) **Column Classifications.** 1. **Simple solid wood columns.** Simple columns consist of a single piece or of pieces properly glued together to form a single member.

2. **Spaced columns, connector joined.** Spaced columns are formed of two or more individual members with their longitudinal axes parallel, separated at the ends and middle points of their length by blocking and joined at the ends by timber connectors capable of developing the required shear resistance. See U.B.C. Standard No. 25-15 for design.

3. **Built-up columns.** Built-up columns, other than connector-joined spaced columns and glued-laminated columns, shall not be designed as solid columns.

(b) **Limitation on *l/d* Ratios.** For simple solid columns, *le/d* shall not exceed 50.

For individual members of a spaced column, see U.B.C. Standard No. 25-15.



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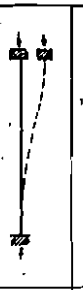
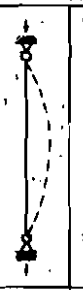
(c) **Simple Solid-column Design.** The effective column length, *le*, shall be used in design formulas given in this section. The effective column length, *le*, shall be determined in accordance with good engineering praetice. Actual column lengths, *l*, may be multiplied by the factors given in the following table to determine effeetive column length, *le*.

| | | | | | | |
|---|---|---|---|---|---|---|
| Buckling modes | | |  |  | | |
| Design buckling factor, $K_e$ when ideal conditions approximated. | 0.65 | 0.80 | 1.2 | 1.0 | 2.10 | 2.4 |
| End condition code | | Rotation fixed, translation fixed<br>Rotation free, translation fixed<br>Rotation fixed, translation free<br>Rotation free, translation free | | | | |

**Note:** $le = K_e l$

Allowable unit stresses in pounds per square ineh of cross-sectional area of square or rectangular simple solid columns shall be determined by the following formulas, but sueh unit stresses shall not exceed values for eompression, parallel to grain $F_c$ in Tables Nos. 25-A, 25-C, 25-D and 25-E adjusted in accordance with provisions of Section 2504.

Short columns (*le/d* of 11 or less):

$$F'_c = F_c$$

Intermediate columns (*le/d* greater than 11 but less than *K*):

$$K = 0.671 \sqrt{\frac{E}{F_c}}$$

$$F'_c = F_c \left[1 - \tfrac{1}{3}\left(\frac{le/d}{K}\right)^4\right]$$



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Long columns ($le/d$ of $K$ or greater):

$$F'_c = \frac{0.30E}{(le/d)^2}$$

Where machine stress-unit lumber is used as provided for in Table No. 25-A-2, stresses may be determined in accordance with the following formula:

Intermediate columns:

$$K = 0.792\sqrt{E/F_c}$$

Long columns:

$$F'_c = \frac{0.418E}{(le/d)^2}$$

Adjustments to allowable unit stresses, as provided in Section 2504 or elsewhere, shall be applied to values of $F_c$ and $E$ used in these formulas and shall not be applied to the value of $F'_c$ obtained from the formulas.

The coefficients in the long column design formulas include a $1-1.65\ C_v$ reduction for variability as defined in Section 2504 (c) 8.

Duration of load adjustment from Section 2504 (c) 4 is applied to $F_c$ but not to $E$.

(d) **Tapered Columns.** In determining the $d$ for tapered column design, the diameter of a round column or the least dimension of a column of rectangular section, tapered at one or both ends, shall be taken as the sum of the minimum diameter or least dimension and one-third the difference between the minimum and maximum diameters or lesser dimensions.

## Flexural and Axial Loading Combined

**Sec. 2508.** (a) **Flexure and Axial Tension.** Members subjected to both flexure and axial tension shall be so proportioned that

$$\frac{f_t}{F_t} + \frac{f_b}{F_b} \text{ does not exceed ONE}$$

$$\text{and } \frac{f_b - f_t}{F'_b} \text{ does not exceed ONE}$$

(b) **Flexure and Axial Compression.** Members subjected to both flexure and axial compression shall be so proportioned that

$$\frac{f_c}{F'_c} + \frac{f_b}{F'_b - Jf_c} \text{ does not exceed ONE}$$



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The value of $J$ shall be derived as:

$$J = \frac{le/d - 11}{K - 11}$$

except that $J$ shall not be less than zero nor greater than one ($0 \leq J \leq 1$). The value of $K$ shall be as specified for intermediate columns in Section 2507 (c).

$F'_c$ and $K$ shall be determined in accordance with the provisions in Section 2507 (e), except (1) when checking the design in the plane of bending the slenderness ratio, $le/d$, in the plane of bending shall be used to calculate $F'_c$ and $J$, and (2) when checking the design perpendicular to the plane of bending the slenderness ratio, $le/d$, perpendicular to the plane of bending shall be used to calculate $F'_c$ and $J$ shall be set equal to zero.

(c) **Spaced Columns.** In the case of spaced columns, this combined stress formula may be applied only if the bending is in a direction parallel to the greater $d$ of the individual member.

(d) **Truss Compression Chords.** Effects of buckling of a 2 by 4 or smaller truss compression chord having effective buckling lengths of 96 inches or less and with 3/8-inch or thicker plywood sheathing nailed to the narrow face of the chord in accordance with Table No. 25-Q shall be determined from the formula:

$$C_T = 1 + \frac{2300le}{E_{0.05}}$$

**WHERE:**

$C_T$ = buckling stiffness factor.

$le$ = effective buckling length used in design of chord for compression loading.

$E_{0.05}$ = $0.589E$ for visually graded lumber.

= $0.819E$ for machine-stress-rated lumber.

$E$ = Modulus of elasticity from tables of allowable unit stresses, psi.

The values of $C_T$ determined from this formula are for wood seasoned to a moisture content of 19 percent or less at the time the plywood is nailed to the chord. For wood that is unseasoned or partially seasoned at the time of plywood attachment, $C_T$ shall be determined from the formula:

$$C_T = 1 + \frac{1200le}{E_{0.05}}$$

For chords with an effective buckling length greater than 96 inches, $C_T$ shall be taken as the value for a chord having an effective length of 96 inches.

The buckling stiffness factor does not apply to short columns or to trusses used under wet conditions. The allowable unit compressive stress shall be modified by the buckling stiffness factor when a truss chord is subjected to combined flexure and compression and the bending moment is in the direction that induces compression stresses in the chord face to which the plywood is attached.



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The buckling stiffness factor $C_T$ shall be applied as follows:

Short columns (*le/d* of 11 or less):

$$F'_c = F_c$$

Intermediate columns (*le/d* greater than 11 but less than *K*):

$$K = 0.671\sqrt{C_T(E/F_c)}$$

$$F'_c = F_c\left[1 - 1/3\left(\frac{le/d}{K}\right)^4\right]$$

Long columns (*le/d* of *K* or greater):

$$F'_c = \frac{0.30EC_T}{(le/d)^2}$$

## Compression at Angle to Grain

**Sec. 2509.** The allowable unit stress in compression at an angle of load to grain between 0° and 90° shall be computed from the Hankinson Formula as follows:

$$F_n = \frac{F_c F_{c\perp}}{F_c \sin^2\theta + F_{c\perp}\cos^2\theta}$$

## Timber Connectors and Fasteners

**Sec. 2510.** (a) **General.** Timber connectors and fasteners may be used to transmit forces between wood members and between wood and metal members. The allowable loads and installation of timber connectors and fasteners shall be in accordance with the provisions set forth in U.B.C. Standard No. 25-17. For connectors and fasteners where the wood is wet at time of fabrication or wet in service, the allowable loads shall be modified in accordance with U.B.C. Standard No. 25-17.

Safe loads and design practices for types of connectors and fasteners not mentioned or fully covered in U.B.C. Standard No. 25-17 may be determined in a manner approved by the building official.

(b) **Bolts.** Safe loads in pounds for bolts in shear in seasoned lumber of Douglas fir-larch and southern pine shall not exceed the values set forth in Table No. 25-F. (For other species and wet conditions, see U.B.C. Standard No. 25-17.)

Allowable shear values used to connect a wood member to concrete or masonry are permitted to be determined as one half the tabulated double shear values for a wood member twice the thickness of the member attached to the concrete or masonry.

(c) **Nails and Spikes.** 1. **Safe lateral strength.** A common wire nail driven perpendicular to grain of the wood, when used to fasten wood members together,



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shall not be subjected to a greater load causing shear and bending than the safe lateral strength of the wire nail or spike as set forth in Table No. 25-G.

A wire nail driven parallel to the grain of the wood shall not be subjected to more than two thirds of the lateral load allowed when driven perpendicular to the grain. Toenails shall not be subjected to more than five sixths of the lateral load allowed for nails driven perpendicular to the grain.

2. **Safe resistance to withdrawal.** A wire nail driven perpendicular to grain of the wood shall not be subjected to a greater load, tending to cause withdrawal, than the safe resistance of the nail to withdrawal, as set forth in Table No. 25-H.

Nails driven parallel to grain of the wood shall not be allowed for resisting withdrawal forces.

3. **Spacing and penetration.** Common wire nails shall have penetration into the piece receiving the point as set forth in Table No. 25-G. Nails or spikes for which the wire gauges or lengths are not set forth in Table No. 25-G shall have a required penetration of not less than 11 diameters, and allowable loads may be interpolated. Design values shall not be increased when the penetration of nails into the member holding the point is larger than required by this item.

For wood-to-wood joints, the spacing center to center of nails in the direction of stress shall be not less than the required penetration. Edge or end distances in the direction of stress shall be not less than one half of the required penetration. All spacing and edge and end distances shall be such as to avoid splitting of the wood.

Holes for nails, where necessary to prevent splitting, shall be bored of a diameter smaller than that of the nails.

(d) **Drift Bolts or Pins, Wood Screws and Lag Screws.** Connections involving the use of drift bolts or pins, wood screws and lag screws shall be designed in accordance with the provisions set forth in U.B.C. Standard No. 25-17.

(e) **Joist Hangers and Framing Anchors.** Connections depending upon joist hangers or framing anchors, ties, and other mechanical fastenings not otherwise covered may be used where approved.

(f) **Metal Plate Connectors.** The material and workmanship during fabrication and the design of metal plate connectors employed as joint connectors for light wood trusses shall conform with the requirements of U.B.C. Standard No. 25-17.

Each truss manufacturer shall retain an approved agency having no financial interest in the plant being inspected to make nonscheduled inspections of truss fabrication and delivery and operations. The inspection shall cover all phases of truss operation, including lumber storage, handling, cutting, fixtures, presses or rollers, fabrication, bundling and banding, handling and delivery.

## Structural Glued-laminated Timber Design

**Sec. 2511.** (a) **General Provisions.** 1. **Design requirements.** Except as otherwise provided in this section, structural glued-laminated timber members shall be designed in accordance with the applicable engineering formulas used for sawn members.



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2. **Fastenings.** The pertinent provisions and allowable loads for fastenings given in this chapter shall apply to structural glued-laminated timber members.

3. **Allowable unit stresses.** The allowable unit stresses for structural glued-laminated timber shall be in accordance with Tables No. 25-C and No. 25-D and as modified by this section.

(b) **Standard Sizes.** Standard finished widths of laminated members shall be as set forth in U.B.C. Standard No. 25-10.

Depth of straight and curved members, length of all members and net dimensions shall be specified on the plans.

(c) **Specifications.** For structural glued-laminated timber, the following shall be specified on the plans:

Whether for dry or wet conditions of use.

Species and applicable standard.

Stress requirements.

If the temperature of the timber exceeds 150°F. in service.

(d) **Design Stresses.** 1. **Dry conditions of use.** Allowable stress values for dry conditions of use shall be applicable for normal loading when the moisture content in service is less than 16 percent, as in most covered structures.

2. **Wet conditions of use.** Allowable stress values for wet conditions of use shall be applicable for normal loading when the moisture content in service is 16 percent or more, as may occur in exterior and submerged construction.

3. **Curvature factor.** For the curved portion of members, the allowable unit stress in bending shall be modified by multiplication by the following curvature factor:

$$C_c = 1 - 2000\left(\frac{t}{R}\right)^2$$

in which

$t$ = thickness of lamination in inches.

$R$ = radius of curvature of inside face of lamination in inches, and $t/R$ shall not exceed $1/100$ for hardwoods and southern pine, or $1/125$ for other softwoods.

No curvature factor shall be applied to stress in the straight portion of an assembly, regardless of curvature elsewhere.

4. **Radial tension or compression.** The maximum radial stress induced in a curved member of constant rectangular cross section by a bending moment is:

$$f_r = \frac{3M}{2Rbd}$$

**WHERE:**

$f_r$ = radial stress in pounds per square inch.

$M$ = bending moment in inch pounds.



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$R$ = radius of curvature at center line of member in inches.
$b$ = width of cross section in inches.
$d$ = depth of cross section in inches.

For curved bending members having a varying cross section, the maximum radial stress induced, $f_r$, is given by:

$$f_r = K_r \frac{6M}{bd^2}$$

**WHERE:**

$M$ = bending moment at midspan in inch-pounds.
$b$ = width of cross section, inches.
$d$ = depth of cross section at the apex in inches.
$K_r$ = radial stress factor determined from the following relationship:

$$K_r = A + B\left(\frac{d}{Rm}\right) + C\left(\frac{d}{Rm}\right)^2$$

**WHERE:**

$Rm$ = radius of curvature at the center line of the member at midspan in inches.
$A$, $B$ and $C$ = constants as follow:

| $\beta$ (1) | A (2) | B (3) | C (4) |
|---|---|---|---|
| (0.0) | (0.0) | (0.2500) | (0.0) |
| 2.5 | 0.0079 | 0.1747 | 0.1284 |
| 5.0 | 0.0174 | 0.1251 | 0.1939 |
| 7.5 | 0.0279 | 0.0937 | 0.2162 |
| 10.0 | 0.0391 | 0.0754 | 0.2119 |
| 15.0 | 0.0629 | 0.0619 | 0.1722 |
| 20.0 | 0.0893 | 0.0608 | 0.1393 |
| 25.0 | 0.1214 | 0.0605 | 0.1238 |
| 30.0 | 0.1649 | 0.0603 | 0.1115 |

and $\beta$ = angle between the upper edge of the member and the horizontal in degrees.

Values of $K_r$ for intermediate values of $\beta$ may be interpolated linearly.

When $M$ is in the direction tending to decrease the curvature (increase the radius), the stress in tension across the grain ($F_{rt}$) is limited to:

A. One third the allowable unit stress in horizontal shear of all species for wind and earthquake loads.

B. Fifteen psi for Douglas fir, larch, hem-fir, western woods and other softwoods for other types of loading.



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C. One third the allowable unit stress in horizontal shear for southern pine, redwood and hardwoods for all types of loading.

These values are subject to modification for duration of load. If these values are exceeded, mechanical reinforcing sufficient to resist all radial tension stresses is required, but in no case shall the calculated radial tension stress exceed one-third the allowable unit stress in horizontal shear. When mechanical reinforcing is used, the maximum moisture content of the laminations at time of manufacture shall not exceed 12 percent for dry conditions of use.

When $M$ is in the direction tending to increase curvature (decrease the radius), the radial stress is in compression and shall be limited to the allowable stress in compression perpendicular to the grain.

When the beam is loaded with a uniform load, $K_r$ may be modified by multiplying by the reduction factor $C_r$ as calculated by the following formula:

$$C_r = A + B\left(\frac{L}{L_t}\right) + C\left(\frac{d_c}{R_m}\right) + D\left(\frac{L}{L_t}\right)^2 + E\left(\frac{d_c}{R_m}\right)^2 + F\left(\frac{d_c}{R_m}\right)\left(\frac{L}{L_t}\right) + G\left(\frac{L}{L_t}\right)^3 + H\left(\frac{d_c}{R_m}\right)^3$$

**WHERE:**

$C_r$ = reduction factor

$L$ = span of beam

$L_t$ = length of beam between tangent points.

$A, B, \ldots H$ = constants for a given $\beta$ as follows:

| $\beta$ | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 2.3° | .142 | .418 | 2.358 | .053 | — | — | .002 | — |
| 9.7° | .143 | .376 | .541 | .060 | — | — | .003 | — |
| 14.9° | .406 | .293 | .927 | .041 | — | — | .002 | — |
| 20.0° | .423 | .364 | 1.022 | .067 | — | .146 | — | — |
| 25.2° | .540 | .360 | 1.061 | .070 | — | .156 | — | — |
| 29.8° | .502 | .372 | — | .076 | 3.712 | .138 | .004 | 4.336 |

and $\beta$ = angle between the upper edge of the member and the horizontal in degrees. Values of $C_r$ for intermediate values may be interpolated linearly.



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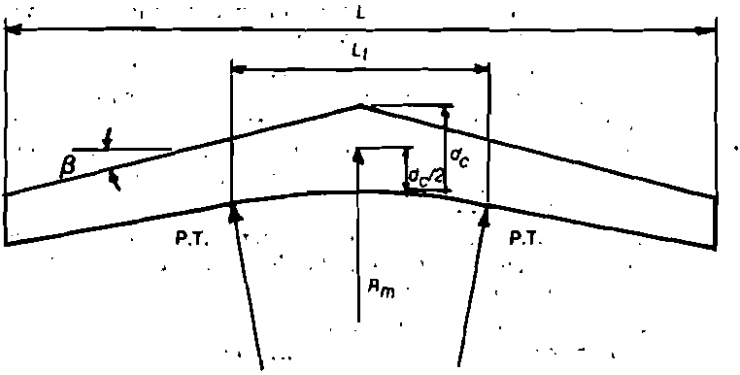


PITCHED AND TAPERED CURVED BEAM

5. **Size factor for beams.** When the depth of a rectangular glued-laminated beam is 12 inches or greater, the allowable unit stress in bending $F_b$ shall be multiplied by the size factor as determined by the formula:

$$C_F = (12/d)^{1/9}$$

**WHERE:**

$C_F$ = size factor.

$d$ = depth of beam in inches.

The values obtained from this formula are based on a uniformly loaded beam simply supported with an $l/d$ ratio of 21. Tabular values for three conditions of loading are given as follows:

| DEPTH | SIZE FACTOR $C_F$ | | |
|---|---|---|---|
| ($d$) | Uniformly Distributed Load | Single Concentrated Load | Third Point Loading |
| 12 | 1.00 | 1.08 | .97 |
| 19 | .95 | 1.02 | .92 |
| 31 | .90 | .97 | .87 |
| 52 | .85 | .92 | .82 |
| 90 | .80 | .86 | .77 |

For intermediate depths, straight line interpolation may be used. For continuous beams or beams cantilevered over a support, determine the size factor assuming the members to be equivalent to simply supported members with a



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uniformly distributed load, the length of the equivalent span being the actual distance between supports.

Values as determined above will be sufficiently accurate for most design situations. For *l/d* ratios other than 21 and other conditions of loading where greater accuracy may be desired, see U.B.C. Standard No. 25-11.

6. **Ponding.** Roof framing members shall be designed for the deflection criteria and ponding requirements specified in Sections 2305 (f) and 2307. In no case shall the roof slope provide a positive vertical displacement less than that equivalent to 1/4 inch per foot of horizontal distance between the level of the drain and the high point of the roof for drainage. Such slope shall be in addition to the camber in glued-laminated timbers of one and one-half times the calculated dead load deflection. The calculation of the required slope shall not include any vertical displacement created by short taper cuts.

Roofs having insufficient slope for drainage shall be investigated by a rational analysis to assure stability under ponding conditions, but in no case shall the deflection of such glued-laminated timbers exceed 1/2 inch for a 5-pound-per-square-foot uniform load.

(e) **Tapered Faces.** Sawn tapered cuts shall not be permitted on the tension face of any beam. Pitched or curved beams shall be so fabricated that the laminations are parallel to the tension face. Straight, pitched or curved beams may have sawn tapered cuts on the compression face.

For other members subject to bending, the slope of tapered faces, measured from the tangent to the lamination of the section under consideration, shall be not steeper than 1:24 on the tension side.

**EXCEPTIONS:** 1. This requirement shall not apply to arches.

2. Taper may be steeper at sections increased in size beyond design requirements for architectural projections.

(f) **Manufacture and Fabrication.** The manufacture and fabrication of structural glued-laminated timber shall be in accordance with U.B.C. Standard No. 25-10. All work shall be under the supervision of qualified personnel.

(g) **Exposed Structural Glued-laminated Timber.** Those portions of glued-laminated timbers which form the structural supports of a building or other structure and are exposed to weather and not properly protected by a roof, eave overhangs or similar covering shall be pressure treated with an approved preservative or be manufactured from wood of natural resistance to decay.

## Design of Glued Built-up Members

**Sec. 2512.** Plywood components shall be designed, fabricated and identified in accordance with U.B.C. Standard No. 25-18.

## Wood Shear Walls and Diaphragms

**Sec. 2513.** (a) **General.** Lumber, plywood and particleboard diaphragms may be used to resist horizontal forces in horizontal and vertical distributing or resisting elements, provided the deflection in the plane of the diaphragm, as determined by calculations, tests or analogies drawn therefrom, does not exceed



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the permissible deflection of attached distributing or resisting elements. See U.B.C. Standard No. 25-9 for a method of calculating the deflection of a blocked plywood diaphragm.

Permissible deflection shall be that deflection up to which the diaphragm and any attached distributing or resisting element will maintain its structural integrity under assumed load conditions, i.e., continue to support assumed loads without danger to occupants of the structure.

Connections and anchorages capable of resisting the design forces shall be provided between the diaphragms and the resisting elements. Openings in diaphragms which materially affect their strength shall be fully detailed on the plans and shall have their edges adequately reinforced to transfer all shearing stresses.

Size and shape of diaphragms shall be limited as set forth in Table No. 25-I.

In buildings of wood frame construction where rotation is provided for, the depth of the diaphragm normal to the open side shall not exceed 25 feet nor two-thirds the diaphragm width, whichever is the smaller depth. Straight sheathing shall not be permitted to resist shears in diaphragms acting in rotation.

**EXCEPTIONS:** 1. One-story, wood-framed structures with the depth normal to the open side not greater than 25 feet may have a depth equal to the width.

2. Where calculations show that diaphragm deflections can be tolerated, the depth normal to the open end may be increased to a depth-to-width ratio not greater than 1 1/2:1 for diagonal sheathing or 2:1 for special diagonal sheathed or plywood or particleboard diaphragms.

In masonry or concrete buildings, lumber, plywood and particleboard diaphragms shall not be considered as transmitting lateral forces by rotation.

Diaphragm sheathing nails or other approved sheathing connectors shall be driven flush but shall not fracture the surface of the sheathing.

(b) **Diagonally Sheathed Diaphragms.** 1. **Conventional construction.** Such lumber diaphragms shall be made up of 1-inch nominal sheathing boards laid at an angle of approximately 45 degrees to supports. Sheathing boards shall be directly nailed to each intermediate bearing member with not less than two 8d nails for 1-inch by 6-inch nominal boards and three 8d nails for boards 8 inches or wider; and, in addition, three 8d nails and four 8d nails shall be used for 6-inch and 8-inch boards, respectively, at the diaphragm boundaries. End joints in adjacent boards shall be separated by at least one joist or stud space, and there shall be at least two boards between joints on the same support. Boundary members at edges of diaphragms shall be designed to resist direct tensile or compressive chord stresses and shall be adequately tied together at corners.

Conventional lumber diaphragms of Douglas fir-larch or southern pine may be used to resist shear due to wind or seismic forces not exceeding 300 pounds per lineal foot of width. The allowable strength shall be adjusted by the factors 0.82 and 0.65 where nails are used with sheathing and framing of Group III or IV wood species as listed in Table No. 25-17-J of U.B.C. Standard No. 25-17.

2. **Special construction.** Special diagonally sheathed diaphragms shall conform to conventional construction and, in addition, shall have all elements designed in conformance with the provisions of this code.



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Each chord or portion thereof may be considered as a beam loaded with a uniform load per foot equal to 50 percent of the unit shear due to diaphragm action. The load shall be assumed as acting normal to the chord, in the plane of the diaphragm and either toward or away from the diaphragm. The span of the chord, or portion thereof, shall be the distance between structural members of the diaphragm, such as the joists; studs and blocking, which serve to transfer the assumed load to the sheathing.

Special diagonally sheathed diaphragms shall include conventional diaphragms sheathed with two layers of diagonal sheathing at 90 degrees to each other and on the same face of the supporting members.

Special diagonally sheathed diaphragms of Douglas fir-larch or southern pine may be used to resist shears due to wind or seismic loads; provided such shears do not stress the nails beyond their allowable safe lateral strength and do not exceed 600 pounds per lineal foot of width. The allowable strength shall be adjusted by the factors 0.82 and 0.65 where nails are used with sheathing and framing of Group III or IV wood species as listed in Table No. 25-17-J of U.B.C. Standard No. 25-17.

(c) **Plywood Diaphragms.** Horizontal and vertical diaphragms sheathed with plywood may be used to resist horizontal forces not exceeding those set forth in Table No. 25-J-1 for horizontal diaphragms and Table No. 25-K-1 for vertical diaphragms, or may be calculated by principles of mechanics without limitation by using values of nail strength and plywood shear values as specified elsewhere in this code. Plywood for horizontal diaphragms shall be as set forth in Table No. 25-S-1 and No. 25-S-2 for corresponding joist spacing and loads. Plywood in shear walls shall be at least 5/16 inch thick for studs spaced 16 inches on center and 3/8 inch thick where studs are spaced 24 inches on center.

Maximum spans for plywood subfloor underlayment shall be as set forth in Table No. 25-T-1. Plywood used for horizontal and vertical diaphragms shall conform to U.B.C. Standard No. 25-9.

All boundary members shall be proportioned and spliced where necessary to transmit direct stresses. Framing members shall be at least 2-inch nominal in the dimension to which the plywood is attached. In general, panel edges shall bear on the framing members and butt along their center lines. Nails shall be placed not less than 3/8 inch in from the panel edge, shall be spaced not more than 6 inches on center along panel edge bearings, and shall be firmly driven into the framing members. No unblocked panels less than 12 inches wide shall be used.

Where plywood is applied on both faces of a shear wall in accordance with Table No. 25-K-1, allowable shear for the wall may be taken as twice the tabulated shear for one side, except that where the shear capacities are not equal, the allowable shear shall be either the shear for the side with the higher capacity or twice the shear for the side with the lower capacity, whichever is greater.

(d) **Particleboard Diaphragms.** Horizontal and vertical diaphragms sheathed with particleboard may be used to resist horizontal forces not exceeding those set forth in Table No. 25-J-2 for horizontal diaphragms and Table No. 25-K-2 for vertical diaphragms.



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All boundary members shall be proportioned and spliced where necessary to transmit direct stresses. Framing members shall be at least 2-inch nominal in the dimension to which the particleboard is attached. In general, panel edges shall bear on the framing members and butt along their center lines. Nails shall be placed not less than 3/8 inch in from the panel edge, shall be spaced not more than 6 inches on center along panel edge bearings, and shall be firmly driven into the framing members. No unblocked panels less than 12 inches wide shall be used.

(e) **Requirements for Wood Design—Seismic Zones Nos. 3 and 4.** 1. **Wood shear walls and diaphragms.** A. **General.** Design and construction of wood shear walls and diaphragms in Seismic Zones Nos. 3 and 4 shall conform to the requirements of this section.

B. **Framing.** Collector members shall be provided to transmit tension and compression forces. Perimeter members at openings shall be provided and shall be detailed to distribute the shearing stresses. Diaphragm sheathing shall not be used to splice these members.

Diaphragm chords and ties shall be placed in, or tangent to, the plane of the diaphragm framing unless it can be demonstrated that the moments, shears and deflections and deformations resulting from other arrangements can be tolerated.

C. **Plywood.** Plywood shall be manufactured using exterior glue.

Plywood diaphragms and shear walls shall be constructed with plywood sheets not less than 4 feet by 8 feet, except at boundaries and changes in framing where minimum sheet dimension shall be 24 inches unless all edges of the undersized sheets are supported by framing members or blocking.

Framing members or blocking shall be provided at the edges of all sheets in shear walls.

Plywood sheathing may be used for splicing members, other than those noted in Section 2513 (e) 1 B, where the additional nailing required to develop the transfer of forces will not cause cross-grain bending or cross-grain tension in the nailed member.

D. **Heavy wood panels.** Diagonally sheathed panels utilizing 2-inch nominal boards may be used to resist the same permissible shears as 1-inch nominal lumber, except that 16d nails shall be used instead of 8d.

Panels utilizing straight decking overlaid with plywood may be used to resist shear forces using the same shear values as permitted for the plywood alone. Plywood joints parallel to the decking shall be located at least 1 inch offset from any parallel decking joint.

Heavy decking panels utilizing dowel pins, or vertically laminated panels connected by nailing units to one another, resist shear forces based on the permissible shear values of their connectors.

## Fiberboard Sheathing Diaphragms

**Sec. 2514.** Wood stud walls sheathed with fiberboard sheathing complying with U.B.C. Standard No. 25-24 may be used to resist horizontal forces not exceeding those set forth in Table No. 25-P. The fiberboard sheathing, 4 feet by 8 feet, shall be applied vertically to wood studs not less than 2-inch nominal in



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thickness spaced 16 inches on center. Nailing shown in Table No. 25-P shall be provided at the perimeter of the sheathing board and at intermediate studs. Blocking not less than 2-inch nominal in thickness shall be provided at horizontal joints when wall height exceeds length of sheathing panel, and sheathing shall be fastened to the blocking with nails sized as shown in Table No. 25-P spaced 3 inches on centers each side of joint. Nails shall be spaced not less than 3/8 inch from edges and ends of sheathing. Marginal studs of shear walls or shear-resisting elements shall be adequately anchored at top and bottom and designed to resist all forces. The maximum height-width ratio shall be 1 1/2:1.

## Wood Combined with Masonry or Concrete

**Sec. 2515.** (a) **Dead Load.** Wood members shall not be used to permanently support the dead load of any masonry or concrete.

**EXCEPTIONS:** 1. Masonry or concrete nonstructural floor or roof surfacing not more than 4 inches thick may be supported by wood members.

2. Any structure may rest upon wood piles constructed in accordance with the requirements of Chapter 29.

3. Masonry or concrete fireplace with a factory-built chimney conforming to Chapter 37 may be supported by wood framing.

4. Veneer of brick, concrete or stone applied as specified in Section 3006 (b) may be supported by approved treated wood foundations when the maximum height of veneer does not exceed 25 feet above the foundation. Such veneer used as an interior wall finish may also be supported on wood floors which are designed to support the additional load, and be designed to limit the deflection and shrinkage to 1/500 of the span of the supporting members.

(b) **Horizontal Force.** Wood members shall not be used to resist horizontal forces contributed by masonry or concrete construction in buildings over one story in height.

**EXCEPTIONS:** 1. Wood floor and roof members may be used in horizontal trusses and diaphragms to resist horizontal forces imposed by wind, earthquake or earth pressure, provided such forces are not resisted by rotation of the truss or diaphragm.

2. Vertical plywood-sheathed shear walls may be used to provide resistance to wind or earthquake forces in two-story buildings of masonry or concrete construction, provided the following requirements are met:

A. Story-to-story wall heights shall not exceed 12 feet.

B. Horizontal diaphragms shall not be considered to transmit lateral forces by rotation or cantilever action.

C. Deflections of horizontal and vertical diaphragms shall not permit per-story deflections of supported masonry or concrete walls to exceed .005 times each story height.

D. Plywood sheathing in horizontal diaphragms shall have all unsupported edges blocked. Plywood sheathing for both stories of vertical diaphragms shall have all unsupported edges blocked and for the lower story walls shall have a minimum thickness of 15/32 inch.

E. There shall be no out-of-plane horizontal offsets between the first and second stories of plywood shear walls.



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## General Construction Requirements

**Sec. 2516.** (a) **General.** The requirements in this section apply to all wood frame construction.

(b) **Preparation of Building Site.** All stumps and roots shall be removed from the soil to a depth of at least 12 inches below the surface of the ground in the area to be occupied by the building.

All wood forms which have been used in placing concrete, if within the ground or between foundation sills and the ground, shall be removed before a building is occupied or used for any purpose. Before completion, loose or casual wood shall be removed from direct contact with the ground under the building.

(c) **Protection Against Decay and Termites.** 1. **Wood support embedded in ground.** Wood embedded in the ground or in direct contact with the earth and used for the support of permanent structures shall be treated wood unless continuously below the groundwater line or continuously submerged in fresh water. Round or rectangular posts, poles and sawn timber columns supporting permanent structures which are embedded in concrete or masonry in direct contact with earth or embedded in concrete or masonry exposed to the weather shall be treated wood. Treatment shall conform to U.B.C. Standard No. 25-12, Tables Nos. 25-12-B through 25-12-F, for ground contact.

2. **Under-floor clearance.** When wood joists or the bottom of wood structural floors without joists are located closer than 18 inches or wood girders are located closer than 12 inches to exposed ground in crawl spaces or unexcavated areas located within the periphery of the building foundation, the floor assembly including posts, girders, joists and subfloor, shall be approved wood of natural resistance to decay as listed in Section 2516 (c) 3 or treated wood.

Accessible under-floor areas shall be provided with a minimum 18-inch by 24-inch access opening unobstructed by pipes, ducts and similar construction. All under-floor access openings shall be effectively screened or covered. Pipes, ducts and other construction shall not interfere with the accessibility to or within under-floor areas.

3. **Plates, sills and sleepers.** All foundation plates or sills and sleepers on a concrete or masonry slab, which is in direct contact with earth, and sills which rest on concrete or masonry foundations, shall be treated wood or Foundation redwood, all marked or branded by an approved agency. Foundation cedar or No. 2 Foundation redwood marked or branded by an approved agency may be used for sills in territories subject to moderate hazard, where termite damage is not frequent and when specifically approved by the building official. In territories where hazard of termite damage is slight, any species of wood permitted by this code may be used for sills when specifically approved by the building official.

4. **Columns and posts.** Columns and posts located on concrete or masonry floors or decks exposed to the weather or to water splash or in basements and which support permanent structures shall be supported by concrete piers or metal pedestals projecting above floors unless approved wood of natural resistance to decay or treated wood is used. The pedestals shall project at least 6 inches above exposed earth and at least 1 inch above such floors.



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Individual concrete or masonry piers shall project at least 8 inches above exposed ground unless the columns or posts which they support are of approved wood of natural resistance to decay or treated wood is used.

5. **Girders entering masonry or concrete walls.** Ends of wood girders entering masonry or concrete walls shall be provided with a 1/2-inch air space on tops, sides and ends unless approved wood of natural resistance to decay or treated wood is used.

6. **Foundation ventilation.** Under-floor areas shall be ventilated by an approved mechanical means or by openings in exterior foundation walls. Such openings shall have a net area of not less than 1 square foot for each 150 square feet of under-floor area. Openings shall be located as close to corners as practical and shall provide cross ventilation. The required area of such openings shall be approximately equally distributed along the length of at least two opposite sides. They shall be covered with corrosion-resistant wire mesh with mesh openings of 1/4 inch in dimension. Where moisture due to climate and groundwater conditions is not considered excessive, the building official may allow operable louvers and may allow the required net area of vent opening to be reduced to 10 percent of the above, provided the under-floor ground surface area is covered with an approved vapor barrier.

7. **Wood and earth separation.** Protection of wood against deterioration as set forth in the previous paragraphs for specified applications is required. In addition, wood used in construction of permanent structures and located nearer than 6 inches to earth shall be treated wood or wood of natural resistance to decay, as defined in Section 2502 (a). Where located on concrete slabs placed on earth, wood shall be treated wood or wood of natural resistance to decay. Where not subject to water splash or to exterior moisture and located on concrete having a minimum thickness of 3 inches with an impervious membrane installed between concrete and earth, the wood may be untreated and of any species.

Where planter boxes are installed adjacent to wood frame walls a 2-inch-wide air space shall be provided between the planter and the wall. Flashings shall be installed when the air space is less than 6 inches in width. Where flashing is used provisions shall be made to permit circulation of air in the air space. The wood frame wall shall be provided with an exterior wall covering conforming to the provisions of Subsection (g) of this section.

8. **Wood supporting roofs and floors.** Wood structural members supporting moisture permeable floors or roofs which are exposed to the weather such as concrete or masonry slabs shall be approved wood of natural resistance to decay or treated wood unless separated from such floors or roofs by an impervious moisture barrier.

9. **Moisture content of treated wood.** When wood pressure treated with a water-borne preservative is used in enclosed locations where drying in service cannot readily occur, such wood shall be at a moisture content of 19 percent or less before being covered with insulation, interior wall finish, floor covering or other material.



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10. **Retaining walls.** Wood used in retaining or crib walls shall be treated wood.

11. **Weather exposure.** In geographical areas where experience has demonstrated a specific need, approved wood of natural resistance to decay or treated wood shall be used for those portions of wood members which form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when such members are exposed to the weather without adequate protection from a roof, eave, overhang or other covering to prevent moisture or water accumulation on the surface or at joints between members. Depending on local experience, such members may include: horizontal members such as girders, joists and decking; or vertical members such as posts, poles and columns; or both horizontal and vertical members.

(d) **Wall Framing.** The framing of exterior and interior walls shall be in accordance with provisions specified in Section 2517 unless a specific design is furnished.

Wood stud walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects upon the structure nor any plumbing, electrical, mechanical systems nor other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

(e) **Floor Framing.** Wood-joisted floors shall be framed and constructed and anchored to supporting wood stud or masonry walls as specified in Chapter 23.

(f) **Fire and Draft Stops.** 1. **General.** In combustible construction, firestopping and draftstopping shall be installed to cut off all concealed draft openings (both vertical and horizontal) and shall form an effective barrier between floors, between a top story and a roof or attic space, and shall subdivide attic spaces, concealed roof spaces and floor-ceiling assemblies. The integrity of all fire and draft stops shall be maintained.

2. **Fire stops, where required.** Firestopping shall be provided in the following locations:

A. In concealed spaces of stud walls and partitions, including furred spaces, at the ceiling and floor levels and at 10-foot intervals along the length of the wall.

> **EXCEPTION:** Fire stops may be omitted at floor and ceiling levels when approved smoke-actuated fire dampers are installed at these levels.

B. At all interconnections between concealed vertical and horizontal spaces such as occur at soffits, drop ceilings and cove ceilings;

C. In concealed spaces between stair stringers at the top and bottom of the run and between studs along and in line with the run of stairs if the walls under the stairs are unfinished;

D. In openings around vents, pipes, ducts, chimneys, fireplaces and similar



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openings which afford a passage for fire at ceiling and floor levels, with noncombustible materials.

3. **Fire stop construction.** Exeept as provided in Item D above, firestopping shall eonsist of 2 inches nominal lumber or two thicknesses of 1-inch nominal lumber with broken lap joints or one thickness of 23/32-inch plywood with joints backed by 23/32-inch plywood or one thickness of 3/4-inch Type 2-M particleboard with joints backed by 3/4-inch Type 2-M particleboard.

Fire stops may also be of gypsum board, cement asbestos board, mineral fiber, glass fiber or other approved materials securely fastened in place.

Walls having parallel or staggered studs for sound-transmission control shall have fire stops of mineral fiber or glass fiber or other approved nonrigid materials.

4. **Draft stops, where required.** Draftstopping shall be provided in the following locations:

A. **Floor-ceiling assemblies.** (i) **Single-family dwellings.** When there is usable space above and below the concealed space of a floor-ceiling assembly in a single-family dwelling, draft stops shall be installed so that the area of the concealed space does not exceed 1,000 square feet. Draftstopping shall divide the concealed space into approximately equal areas.

(ii) **Two or more dwelling units and hotels.** Draft stops shall be installed in floor-ceiling assemblies of buildings having more than one dwelling unit and in hotels. Such draft stops shall be in line with walls separating tenants from each other and separating tenants from other areas.

(iii) **Other uses.** Draft stops shall be installed in floor-ceiling assemblies of buildings or portions of buildings used for other than dwelling or hotel occupancies so that the area of the concealed space does not exceed 1,000 square feet and so that the horizontal dimension between stops does not exceed 60 feet.

> **EXCEPTION:** Where approved automatic sprinklers are installed within the concealed space, the area between draft stops may be 3,000 square feet and the horizontal dimension may be 100 feet.

B. **Attics.** (i) **Single-family dwellings.** None required.

(ii) **Two or more dwelling units and hotels.** Draft stops shall be installed in the attics, mansards, overhangs, false fronts set out from walls and similar concealed spaces of buildings containing more than one dwelling unit and in hotels. Such draft stops shall be above and in line with the walls separating tenant spaces from each other and from other uses.

> **EXCEPTIONS:** 1. Draft stops may be omitted along one of the corridor walls, provided draft stops at tenant separation walls extend to the remaining corridor draft stop.
>
> 2. Where approved sprinklers are installed, draftstopping may be as specified in the exception to Item (iii) below.

(iii) **Other uses.** Draft stops shall be installed in attics, mansards, overhangs, false fronts set out from walls and similar concealed spaces of buildings having uses other than dwellings or hotels so that the area between draft stops does not exceed 3,000 square feet and the greatest horizontal dimension does not exceed 60 feet.



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**EXCEPTION:** Where approved automatic sprinklers are installed the area between draft stops may be 9,000 square feet and the greatest horizontal dimension may be 100 feet.

5. **Draft stop construction.** Draftstopping materials shall be not less than 1/2-inch gypsum board, 3/8-inch plywood, 3/8-inch Type 2-M particleboard or other approved materials adequately supported.

Openings in the partitions shall be protected by self-closing doors with automatic latches constructed as required for the partitions.

Ventilation of concealed roof spaces shall be maintained in accordance with Section 3205.

6. **Draft or fire stops in other locations.** Firestopping of veneer on noncombustible walls shall be in accordance with Item No. 2 A above.

For firestopping of wood floors on masonry or concrete floors, see Sections 1804 and 1904.

For firestopping ceilings applied against noncombustible construction, see Section 4203, Item No. 1.

For firestopping penetrations in walls required to have protected openings, see Section 4304 (e).

For firestopping penetrations through floors, see Section 4305 (a).

(g) **Exterior Wall Coverings.** 1. **General.** Exterior wood stud walls shall be covered on the outside with the materials and in the manner specified in this section or elsewhere in this code. Studs or sheathing shall be covered on the outside face with a weather-resistive barrier when required by Section 1707 (a). Exterior wall coverings of the minimum thickness specified in this section are based upon a maximum stud spacing of 16 inches unless otherwise specified.

2. **Siding.** Solid wood siding shall have an average thickness of 3/8 inch unless placed over sheathing permitted by this code.

Siding patterns known as rustic, drop siding or shiplap shall have an average thickness in place of not less than 19/32 inch and shall have a minimum thickness of not less than 3/8 inch. Bevel siding shall have a minimum thickness measured at the butt section of not less than 7/16 inch and a tip thickness of not less than 3/16 inch. Siding of lesser dimensions may be used, provided such wall covering is placed over sheathing which conforms to the provisions specified elsewhere in this code.

All weatherboarding or siding shall be securely nailed to each stud with not less than one nail, or to solid 1-inch nominal wood sheathing or 15/32-inch plywood sheathing or 1/2-inch particleboard sheathing with not less than one line of nails spaced not more than 24 inches on center in each piece of the weatherboarding or siding.

Wood board sidings applied horizontally, diagonally or vertically shall be nailed to studs, nailing strips or blocking set maximum 24 inches on center. Nails shall penetrate 1 1/2 inches into studs, studs and wood sheathing combined, or blocking.

3. **Plywood.** Where plywood is used for covering the exterior of outside walls,



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it shall be of the Exterior type not less than 3/8 inch thick. Plywood panel siding shall be installed in accordance with Table No. 25-M-1. Unless applied over 1-inch wood sheathing or 15/32-inch plywood sheathing or 1/2-inch particleboard sheathing, joints shall occur over framing members and shall be protected with a continuous wood batten, approved caulking, flashing, vertical or horizontal shiplaps; or joints shall be lapped horizontally or otherwise made waterproof.

4. **Shingles or shakes.** Wood shingles or shakes and asbestos cement shingles may be used for exterior wall covering, provided the frame of the structure is covered with building paper as specified in Section 1707 (a). All shingles or shakes attached to sheathing other than wood sheathing shall be secured with approved corrosion-resistant fasteners or on furring strips attached to the studs. Wood shingles or shakes may be applied over fiberboard shingle backer and sheathing with annular grooved nails. The thickness of wood shingles or shakes between wood nailing boards shall be not less than 3/8 inch. Wood shingles or shakes and asbestos shingles or siding may be nailed directly to approved fiberboard nailbase sheathing not less than 1/2-inch nominal thickness with annular grooved nails. Fiberboard nailbase sheathing and shingle backer shall comply with U.B.C. Standard No. 25-24.

The weather exposure of wood shingle or shake siding used on exterior walls shall not exceed maximums set forth in Table No. 25-L.

5. **Particleboard.** Where particleboard is used for covering the exterior of outside walls it shall be of the Exterior Type 2-M grades conforming to U.B.C. Standard No. 25-25. Particleboard panel siding shall be installed in accordance with Table No. 25-M-2 and Table No. 25-Q. Panels shall be gapped 1/8 inch and nails shall be spaced not less than 3/8 inch from edges and ends of sheathing. Unless applied over 5/8-inch net wood sheathing or 1/2-inch plywood sheathing or 1/2-inch particleboard sheathing, joints shall occur over framing members and shall be covered with a continuous wood batt; or joints shall be lapped horizontally or otherwise made waterproof to the satisfaction of the building official. Particleboard shall be sealed and protected with exterior quality finishes.

6. **Hardboard.** Where hardboard siding is used for covering the outside of exterior walls, it shall conform to U.B.C. Standard No. 25-26 and Table No. 25-O. Lap siding shall be installed horizontally and applied to sheathed or unsheathed walls. Corner bracing shall be installed in conformance with Section 2517 (g) 3. A weather-resistive barrier shall be installed under the lap siding as required by Section 1707 (a).

Square-edged nongrooved panels and shiplap grooved or nongrooved siding shall be applied vertically to sheathed or unsheathed walls. Siding that is grooved shall be not less than 1/4 inch thick in the groove.

Nail size and spacing shall follow Table No. 25-O and shall penetrate framing 1 1/2 inches. Lap siding shall overlap 1 inch minimum and be nailed through both courses and into framing members with nails located 1/2 inch from bottom of the overlapped course. Square-edged nongrooved panels shall be nailed 3/8 inch from the perimeter of the panel and intermediately into studs. Shiplap edge panel siding with 3/8-inch shiplap shall be nailed 3/8 inch from the edges on both sides of the



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shiplap. The 3/4-inch shiplap shall be nailed 3/8 inch from the edge and penetrate through both the overlap and underlap. Top and bottom edges of the panel shall be nailed 3/8 inch from the edge.

Shiplap and lap siding shall not be force fit. Square-edged panels shall maintain a 1/16-inch gap at joints. All joints and edges of siding shall be over framing members and shall be made resistant to weather penetration with battens, horizontal overlaps or shiplaps to the satisfaction of the building official. A 1/8-inch gap shall be provided around all openings.

7. **Nailing.** All fasteners used for the attachment of siding shall be of a corrosion-resistant type.

(h) **Structural Floor Sheathing.** Structural floor sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this subsection.

Sheathing used as subflooring shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds without failure. The concentrated load shall be applied by a loaded disc, 3 inches or smaller in diameter.

Flooring, including the finish floor, underlayment and subfloor, where used, shall meet the following requirements:

Deflection under uniform design load limited to 1/360 of the span between supporting joists or beams.

Deflection of flooring relative to joists under a 1-inch-diameter concentrated load of 200 pounds limited to 0.125 inch or less when loaded midway between supporting joists or beams not over 24 inches on center and 1/360 of the span for spans over 24 inches.

Floor sheathing conforming to the provisions of Table No. 25-R-1, No. 25-R-2, No. 25-S-1, No. 25-T-1 or No. 25-T-2 shall be deemed to meet the requirements of this subsection.

(i) **Structural Roof Sheathing.** Structural roof sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this subsection. Structural roof sheathing shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds without failure. The concentrated load shall be applied by a loaded disc, 3 inches or smaller in diameter. Structural roof sheathing shall meet the following requirement:

Deflection under uniform design live and dead load limited to 1/180 of the span between supporting rafters or beams and 1/240 under live load only.

Roof sheathing conforming to the provisions of Tables No. 25-R-1 and No. 25-R-2 or No. 25-S-1 and No. 25-S-2 or Table No. 25-S-3 shall be deemed to meet the requirements of this subsection.

Plywood roof sheathing shall be bonded by intermediate or exterior glue. Plywood roof sheathing exposed on the underside shall be bonded with exterior glue.



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(j) **Fastenings. 1. Nailing requirements.** The number and size of nails connecting wood members shall be not less than that set forth in Table No. 25-Q. Other connections shall be fastened so as to provide equivalent strength. End and edge distances and nail penetrations shall be in accordance with the applicable provisions of Section 2510. Fasteners required to be corrosion resistant shall be either zinc-coated fasteners conforming to U.B.C. Standard No. 25-17, Section 25.1717 (a), aluminum alloy wire fasteners conforming to U.B.C. Standard No. 25-17, Section 25.1716 (e), or stainless steel fasteners conforming to U.B.C. Standard No. 25-17, Section 25.1716 (h).

2. **Joist hangers and framing anchors.** Connections depending upon joist hangers or framing anchors, ties and other mechanical fastenings not otherwise covered may be used where approved.

(k) **Water Splash.** Where wood frame walls and partitions are covered on the interior with plaster, tile or similar materials and are subject to water splash, the framing shall be protected with approved waterproof paper conforming to Section 1707 (a).

(l) **Mechanically Laminated Floors and Decks.** A laminated lumber floor or deck built up of wood members set on edge, when meeting the following requirements, may be designed as a solid floor or roof deck of the same thickness, and continuous spans may be designed on the basis of the full cross section using the simple span moment coefficient.

Nail length shall be not less than two and one half times the net thickness of each lamination. When deck supports are 4 feet on center or less, side nails shall be spaced not more than 30 inches on center and staggered one third of the spacing in adjacent laminations. When supports are spaced more than 4 feet on center, side nails shall be spaced not more than 18 inches on center alternately near top and bottom edges, and also staggered one third of the spacing in adjacent laminations. Two side nails shall be used at each end of butt-jointed pieces.

Laminations shall be toenailed to supports with 20d or larger common nails. When the supports are 4 feet on center or less, alternate laminations shall be toenailed to alternate supports; when supports are spaced more than 4 feet on center, alternate laminations shall be toenailed to every support.

A single-span deck shall have all laminations full length.

A continuous deck of two spans shall have not more than every fourth lamination spliced within quarter points adjoining supports.

Joints shall be closely butted over supports or staggered across the deck but within the adjoining quarter spans.

No lamination shall be spliced more than twice in any span.

(m) **Post-beam Connections.** Where post and beam or girder construction is used, the design shall be in accordance with the provisions of this code. Positive connection shall be provided to ensure against uplift and lateral displacement.

## Conventional Construction Provisions

**Sec. 2517.** (a) **General.** The requirements contained in this section are intended for conventional, light-frame construction. Light-frame construction of



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unusual shape, size or split levels shall, when located within Seismic Zones No. 2, No. 3 and No. 4, be designed to resist lateral forces in accordance with other provisions of this code. Other methods may be used, provided a satisfactory design is submitted showing compliance with other provisions of this code.

(b) **Foundation Plates or Sills.** Foundations and footings shall be as specified in Chapter 29. Foundation plates or sills resting on concrete or masonry foundations shall be bolted as required by Section 2907 (f).

(c) **Girders.** Girders shall be designed to support the loads specified in this code. Girder end joints shall occur over supports. When a girder is spliced over a support, an adequate tie shall be provided. The end of beams or girders supported on masonry or concrete shall have not less than 3 inches of bearing.

(d) **Floor Joists.** 1. **General.** Spans for joists shall be in accordance with Table No. 25-U-J-1.

2. **Bearing.** Except where supported on a 1-inch by 4-inch ribbon strip and nailed to the adjoining stud, the ends of each joist shall have not less than 1 1/2 inches of bearing on wood or metal, nor less than 3 inches on masonry.

3. **Framing details.** Joists shall be supported laterally at the ends and at each support by solid blocking except where the ends of joists are nailed to a header, band or rim joist or to an adjoining stud or by other approved means. Solid blocking shall be not less than 2 inches in thickness and the full depth of joist.

Notches on the ends of joists shall not exceed one fourth the joist depth. Holes bored in joists shall not be within 2 inches of the top or bottom of the joist, and the diameter of any such hole shall not exceed one third the depth of the joist. Notches in the top or bottom of joists shall not exceed one sixth the depth and shall not be located in the middle third of the span.

Joist framing from opposite sides of a beam, girder or partition shall be lapped at least 3 inches or the opposing joists shall be tied together in an approved manner.

Joists framing into the side of a wood girder shall be supported by framing anchors or on ledger strips not less than 2 inches by 2 inches.

4. **Framing around openings.** Trimmer and header joists shall be doubled, or of lumber of equivalent cross section, when the span of the header exceeds 4 feet. The ends of header joists more than 6 feet long shall be supported by framing anchors or joist hangers unless bearing on a beam, partition or wall. Tail joists over 12 feet long shall be supported at header by framing anchors or on ledger strips not less than 2 inches by 2 inches.

5. **Supporting bearing partitions.** Bearing partitions perpendicular to joists shall not be offset from supporting girders, walls or partitions more than the joist depth.

Joists under and parallel to bearing partitions shall be doubled.

6. **Blocking.** Floor joists shall be blocked when required by the provisions of Sections 2506 (h) and 2517 (d) 3.

(e) **Subflooring.** 1. **Lumber subfloor.** Sheathing used as a structural subfloor shall conform to the limitations set forth in Tables No. 25-R-1 and No. 25-R-2.



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Joints in subflooring shall occur over supports unless end-matched lumber is used, in which case each piece shall bear on at least two joists.

Subflooring may be omitted when joist spacing does not exceed 16 inches and 1-inch nominal tongue-and-grooved wood strip flooring is applied perpendicular to the joists.

2. **Plywood.** Where used as structural subflooring, plywood shall be as set forth in Tables No. 25-S-1 and No. 25-S-2. Plywood combination subfloor-underlayment shall have maximum spans as set forth in Table No. 25-T-1.

When plywood floors are glued to joists with an adhesive conforming to U.B.C. Standard No. 25-19, in accordance with the adhesive manufacturer's directions, fasteners may be spaced a maximum of 12 inches on center at all supports.

3. **Plank flooring.** Plank flooring shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch tongue-and-groove planking may be used in accordance with Table No. 25-U. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support and joints are separated by at least 24 inches in adjacent pieces. One-inch nominal strip square-edged flooring, 1/2-inch tongue-and-groove flooring, 3/8-inch plywood or 3/8-inch Type 2-M particleboard shall be applied over random-length decking used as a floor. The "strip" and tongue-and-groove flooring shall be applied at right angles to the span of the planks. The 3/8-inch plywood shall be applied with the face grain at right angles to the span of the planks.

4. **Particleboard.** Where used as structural subflooring or as combined subfloor underlayment, particleboard shall be as set forth in Table No. 25-T-2.

(f) **Particleboard Underlayment.** Particleboard floor underlayment shall conform to Type 1-M or to sanded Type 2-M-W grades of U.B.C. Standard No. 25-25. Underlayment shall be not less than 1/4 inch in thickness and shall be identified by the grademark of an approved inspection agency. Underlayment shall be installed in accordance with this code and as recommended by the manufacturer.

(g) **Wall Framing.** 1. **Size, height and spacing.** The size, height and spacing of studs shall be in accordance with Table No. 25-R-3 except that Utility grade studs shall not be spaced more than 16 inches on center, nor support more than a roof and ceiling, nor exceed 8 feet in height for exterior walls and load-bearing walls or 10 feet for interior nonload-bearing walls.

2. **Framing details.** Studs shall be placed with their wide dimension perpendicular to the wall. Not less than three studs shall be installed at each corner of an exterior wall.

**EXCEPTION:** At corners a third stud may be omitted through the use of wood spacers or backup cleats of 3/8-inch-thick plywood, 3/8-inch Type 2-M particleboard, 1-inch-thick lumber or other approved devices which will serve as an adequate backing for the attachment of facing materials. Where fire-resistance ratings or shear



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values are involved, wood spacers, backup cleats or other devices shall not be used unless specifically approved for such use.

Bearing and exterior wall studs shall be capped with double top plates installed to provide overlapping at corners and at intersections with other partitions. End joints in double top plates shall be offset at least 48 inches.

**EXCEPTION:** A single top plate may be used, provided the plate is adequately tied at joints, corners and intersecting walls by at least the equivalent of 3-inch by 6-inch by 0.036-inch-thick galvanized steel that is nailed to each wall or segment of wall by six 8d nails or equivalent, provided the rafters, joists or trusses are centered over the studs with a tolerance of no more than 1 inch.

When bearing studs are spaced at 24-inch intervals and top plates are less than two 2 by 6 or two 3 by 4 members and when the floor joists, floor trusses or roof trusses which they support are spaced at more than 16-inch intervals, such joists or trusses shall bear within 5 inches of the studs beneath or a third plate shall be installed.

Interior nonbearing partitions may be capped with a single top plate installed to provide overlapping at corners and at intersections with other walls and partitions. The plate shall be continuously tied at joints by solid blocking at least 16 inches in length and equal in size to the plate or by 1/8-inch by 1 1/2-inch metal ties with spliced sections fastened with two 16d nails on each side of the joint.

Studs shall have full bearing on a plate or sill not less than 2 inches in thickness having a width not less than that of the wall studs.

3. **Bracing.** All exterior walls and main cross-stud partitions shall be effectively and thoroughly braced to resist wind and seismic forces by one of the following methods:

A. Nominal 1-inch by 4-inch continuous diagonal braces let into top and bottom plates and intervening studs, placed at an angle not more than 60 degrees nor less than 45 degrees from the horizontal, and attached to the framing in conformance with Table No. 25-Q.

B. Wood boards of 5/8-inch net minimum thickness applied diagonally on studs spaced not over 24 inches on center.

C. Plywood sheathing with a thickness not less than 5/16 inch for 16-inch stud spacing and not less than 3/8 inch for 24-inch stud spacing in accordance with Tables No. 25-M-1 and No. 25-N-1.

D. Fiberboard sheathing 4-foot by 8-foot panels not less than 1/2 inch thick applied vertically on studs spaced not over 16 inches on center when installed in accordance with Section 2514 and Table No. 25-P.

E. Gypsum board (sheathing 1/2 inch thick by 4 feet wide, wallboard or veneer base) on studs spaced not over 24 inches on center and nailed at 7 inches on center with nails as required by Table No. 47-I.

F. Particleboard wall sheathing panels shall be in accordance with Table No. 25-N-2.

G. Portland cement plaster on studs spaced 16 inches on center installed in accordance with Table No. 47-I.



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H. Hardboard panel siding when installed in accordance with Section 2516 (g) 6 and Table No. 25-O.

For methods B, C, D, E, F, G and H the braced panel must be at least 48 inches in width, covering three stud spaces where studs are spaced 16 inches apart and covering two stud spaces where studs are spaced 24 inches apart.

All vertical joints of panel sheathing shall occur over studs. Horizontal joints shall occur over blocking equal in size to the studding except where waived by the installation requirements for the specific sheathing materials.

The location, type and amount of bracing shall comply with Table No. 25-V.

4. **Cripple walls.** Foundation cripple walls shall be framed of studs not less in size than the studding above with a minimum length of 14 inches, or shall be framed of solid blocking. When exceeding 4 feet in height, such walls shall be framed of studs having the size required for an additional story.

Such walls having a stud height exceeding 14 inches shall be considered to be first-story walls for the purpose of determining the bracing required by Section 2517 (g) 3. Solid blocking or plywood sheathing may be used to brace cripple walls having a stud height of 14 inches or less.

5. **Headers.** Headers and lintels shall conform to the requirements set forth in this paragraph and together with their supporting systems shall be designed to support the loads specified in this code. All openings 4 feet wide or less in bearing walls shall be provided with headers consisting of either two pieces of 2-inch framing lumber placed on edge and securely fastened together or 4-inch lumber of equivalent cross section. All openings more than 4 feet wide shall be provided with headers or lintels. Each end of a lintel or header shall have a length of bearing of not less than 1 1/2 inches for the full width of the lintel.

6. **Pipes in walls.** Stud partitions containing plumbing, heating, or other pipes shall be so framed and the joists underneath so spaced as to give proper clearance for the piping. Where a partition containing such piping runs parallel to the floor joists, the joists underneath such partitions shall be doubled and spaced to permit the passage of such pipes and shall be bridged. Where plumbing, heating or other pipes are placed in or partly in a partition, necessitating the cutting of the soles or plates, a metal tie not less than 1/8 inch thick and 1 1/2 inches wide shall be fastened to the plate across and to each side of the opening with not less than four 16d nails.

7. **Bridging.** Unless covered by interior or exterior wall coverings or sheathing meeting the minimum requirements of this code, all stud partitions or walls with studs having a height-to-least-thickness ratio exceeding 50 shall have bridging not less than 2 inches in thickness and of the same width as the studs fitted snugly and nailed thereto to provide adequate lateral support.

8. **Cutting and notching.** In exterior walls and bearing partitions, any wood stud may be cut or notched to a depth not exceeding 25 percent of its width. Cutting or notching of studs to a depth not greater than 40 percent of the width of the stud is permitted in nonbearing partitions supporting no loads other than the weight of the partition.

9. **Bored holes.** A hole not greater in diameter than 40 percent of the stud



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width may be bored in any wood stud. Bored holes not greater than 60 percent of the width of the stud are permitted in nonbearing partitions or in any wall where each bored stud is doubled, provided not more than two such successive doubled studs are so bored.

In no case shall the edge of the bored hole be nearer than 5/8 inch to the edge of the stud. Bored holes shall not be located at the same section of stud as a cut or notch.

(h) **Roof and Ceiling Framing.** 1. **General.** The framing details required in this subsection apply to roofs having a minimum slope of 3:12 or greater. When the roof slope is less than 3:12, members supporting rafters and ceiling joists such as ridge board, hips and valleys shall be designed as beams.

2. **Spans.** Allowable spans for ceiling joists shall be in accordance with Table No. 25-U-J-6. Allowable spans for rafters shall be in accordance with Tables No. 25-U-R-1 through No. 25-U-R-14, where applicable.

3. **Framing.** Rafters shall be framed directly opposite each other at the ridge. There shall be a ridge board at least 1-inch nominal thickness at all ridges and not less in depth than the cut end of the rafter. At all valleys and hips there shall be a single valley or hip rafter not less than 2-inch nominal thickness and not less in depth than the cut end of the rafter.

4. **Rafter ties.** Rafters shall be nailed to adjacent ceiling joists to form a continuous tie between exterior walls when such joists are parallel to the rafters. Where not parallel, rafters shall be tied to 1-inch by 4-inch (nominal) minimum-size cross ties. Rafter ties shall be spaced not more than 4 feet on center.

5. **Purlins.** Purlins to support roof loads may be installed to reduce the span of rafters within allowable limits and shall be supported by struts to bearing walls. The maximum span of 2-inch by 4-inch purlins shall be 4 feet. The maximum span of the 2-inch by 6-inch purlin shall be 6 feet but in no case shall the purlin be smaller than the supported rafter. Struts shall be not smaller than 2-inch by 4-inch members. The unbraced length of struts shall not exceed 8 feet and the minimum slope of the struts shall be not less than 45 degrees from the horizontal.

6. **Blocking.** Roof rafters and ceiling joists shall be supported laterally to prevent rotation and lateral displacement when required by Section 2506 (h). Roof trusses shall be supported laterally at points of bearing by solid blocking to prevent rotation and lateral displacement.

7. **Roof sheathing.** Roof sheathing shall be in accordance with Table No. 25-S-1 and No. 25-S-2 for plywood, No. 25-R-1 and 25-R-2 for lumber or No. 25-S-3 for particleboard.

Joints in lumber sheathing shall occur over supports unless approved end-matched lumber is used, in which case each piece shall bear on at least two supports.

Plywood used for roof sheathing shall be bonded by intermediate or exterior glue. Plywood roof sheathing exposed on the underside shall be bonded with exterior glue.



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8. **Roof planking.** Planking shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch tongue-and-groove planking may be used in accordance with Table No. 25-U. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support, and joints are separated by at least 24 inches in adjacent pieces.



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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | U.B.C. STDS. UNDER WHICH GRADED |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| ASPEN (BIGTOOTH—QUAKING) (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1300 | 1500 | 775 | 60 | 265 | 850 | 1,100,000 | |
| No. 1 | 2" to 4" | 1100 | 1300 | 650 | 60 | 265 | 675 | 1,100,000 | |
| No. 2 | thick | 925 | 1050 | 525 | 60 | 265 | 550 | 1,000,000 | |
| No. 3 | 2" to 4" | 500 | 575 | 300 | 60 | 265 | 325 | 900,000 | |
| Appearance | wide | 1100 | 1300 | 650 | 60 | 265 | 825 | 1,100,000 | 25-4 |
| Stud | | 500 | 575 | 300 | 60 | 265 | 325 | 900,000 | 25-5 |
| Construction | 2" to 4" | 650 | 750 | 400 | 60 | 265 | 625 | 900,000 | and 25-8 |
| Standard | thick | 375 | 425 | 225 | 60 | 265 | 500 | 900,000 | (See footnotes |
| Utility | 4" wide | 175 | 200 | 100 | 60 | 265 | 325 | 900,000 | 2 through 8, |
| Select Structural | | 1150 | 1300 | 750 | 60 | 265 | 750 | 1,100,000 | 13, 15 and 16) |
| No. 1 | 2" to 4" | 950 | 1100 | 650 | 60 | 265 | 675 | 1,100,000 | |
| No. 2 | thick | 775 | 900 | 425 | 60 | 265 | 575 | 1,000,000 | |
| No. 3 and Stud | 5" and | 450 | 525 | 250 | 60 | 265 | 375 | 900,000 | |
| Appearance | wider | 950 | 1100 | 650 | 60 | 265 | 825 | 1,100,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **BALSAM FIR** (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" | 1750 | 2000 | 1000 | 70 | 305 | 1350 | 1,500,000 | |
| No. 1 | thick | 1450 | 1700 | 850 | 70 | 305 | 1050 | 1,500,000 | |
| No. 2 | 2" to 4" | 1200 | 1400 | 700 | 70 | 305 | 850 | 1,300,000 | |
| No. 3 | wide | 675 | 775 | 400 | 70 | 305 | 525 | 1,200,000 | |
| Appearance | | 1450 | 1700 | 850 | 70 | 305 | 1250 | 1,500,000 | 25-5 |
| Stud | | 675 | 775 | 400 | 70 | 305 | 525 | 1,200,000 | 25-8 |
| Construction | 2" to 4" | 875 | 1000 | 525 | 70 | 305 | 950 | 1,200,000 | (See footnotes |
| Standard | thick | 500 | 575 | 275 | 70 | 305 | 775 | 1,200,000 | 1 through 9) |
| Utility | 4" wide | 225 | 275 | 125 | 70 | 305 | 525 | 1,200,000 | |
| Select Structural | 2" to 4" | 1500 | 1700 | 1000 | 70 | 305 | 1200 | 1,500,000 | |
| No. 1 | thick | 1250 | 1450 | 850 | 70 | 305 | 1050 | 1,500,000 | |
| No. 2 | 5" and | 1050 | 1200 | 550 | 70 | 305 | 900 | 1,300,000 | |
| No. 3 | wider | 600 | 700 | 325 | 70 | 305 | 575 | 1,200,000 | |
| Appearance | | 1250 | 1450 | 850 | 70 | 305 | 1250 | 1,500,000 | |
| Stud | | 600 | 700 | 325 | 70 | 305 | 575 | 1,200,000 | |
| Select Structural | Beams and | 1350 | — | 900 | 65 | 305 | 950 | 1,400,000 | |
| No. 1 | Stringers | 1100 | — | 750 | 65 | 305 | 800 | 1,400,000 | |
| Select Structural | Posts and | 1250 | — | 825 | 65 | 305 | 1000 | 1,400,000 | |
| No. 1 | Timbers | 1000 | — | 575 | 65 | 305 | 875 | 1,400,000 | |
| Select | Decking | — | 1650 | — | — | — | — | 1,500,000 | 25-8 |
| Commercial | | — | 1400 | — | — | — | — | 1,300,000 | (See footnotes 1 through 9) |

(Continued)





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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| BLACK COTTONWOOD (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1000 | 1200 | 600 | 50 | 180 | 725 | 1,200,000 | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| No. 1 | | 875 | 1000 | 500 | 50 | 180 | 575 | 1,200,000 | |
| No. 2 | | 725 | 825 | 425 | 50 | 180 | 450 | 1,100,000 | |
| No. 3 | | 400 | 450 | 225 | 50 | 180 | 275 | 900,000 | |
| Appearance | | 875 | 1000 | 500 | 50 | 180 | 700 | 1,200,000 | |
| Stud | | 400 | 450 | 225 | 50 | 180 | 275 | 900,000 | |
| Construction | 2" to 4" thick 4" wide | 525 | 600 | 300 | 50 | 180 | 525 | 900,000 | |
| Standard | | 300 | 325 | 175 | 50 | 180 | 425 | 900,000 | |
| Utility | | 150 | 150 | 75 | 50 | 180 | 275 | 900,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 875 | 1000 | 600 | 50 | 180 | 650 | 1,200,000 | |
| No. 1 | | 750 | 875 | 500 | 50 | 180 | 575 | 1,200,000 | |
| No. 2 | | 625 | 700 | 325 | 50 | 180 | 475 | 1,100,000 | |
| No. 3 and Stud | | 350 | 425 | 175 | 50 | 180 | 300 | 900,000 | |
| Appearance | | 750 | 875 | 500 | 50 | 180 | 700 | 1,200,000 | |
| CALIFORNIA REDWOOD (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Clear Heart Structural | 4" & less thick, any width | 2300 | 2650 | 1500 | 145 | 650 | 2150 | 1,400,000 | 25-7 (See footnotes 2 through 7 9, 13, 15 and 16) |
| Clear Structural | | 2300 | 2650 | 1500 | 145 | 650 | 2150 | 1,400,000 | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 2050 | 2350 | 1200 | 80 | 650 | 1750 | 1,400,000 | |
| Select Structural, Open grain | | 1600 | 1850 | 950 | 80 | 425 | 1300 | 1,100,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. 1 | 2" to 4" thick 2" to 4" wide | 1700 | 1950 | 975 | 80 | 650 | 1400 | 1,400,000 | 25-7 (See footnotes 2 through 7, 9, 13, 15 and 16) |
| No. 1, Open grain | | 1350 | 1550 | 775 | 80 | 425 | 1050 | 1,100,000 | |
| No. 2 | | 1400 | 1600 | 800 | 80 | 650 | 1100 | 1,250,000 | |
| No. 2, Open grain | | 1100 | 1250 | 625 | 80 | 425 | 825 | 1,000,000 | |
| No. 3 | | 800 | 900 | 475 | 80 | 650 | 675 | 1,100,000 | |
| No. 3, Open grain | | 625 | 725 | 375 | 80 | 425 | 500 | 900,000 | |
| Stud | | 625 | 725 | 375 | 80 | 425 | 500 | 900,000 | |
| Construction | 2" to 4" thick 4" wide | 825 | 950 | 475 | 80 | 425 | 925 | 900,000 | |
| Standard | | 450 | 525 | 250 | 80 | 425 | 775 | 900,000 | |
| Utility | | 225 | 250 | 125 | 80 | 425 | 500 | 900,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1750 | 2000 | 1150 | 80 | 650 | 1550 | 1,400,000 | |
| Select Structural, Open grain | | 1400 | 1600 | 925 | 80 | 425 | 1150 | 1,100,000 | |
| No. 1 | | 1500 | 1700 | 975 | 80 | 650 | 1400 | 1,400,000 | |
| No. 1, Open grain | | 1150 | 1350 | 775 | 80 | 425 | 1050 | 1,100,000 | |
| No. 2 | | 1200 | 1400 | 650 | 80 | 650 | 1200 | 1,250,000 | |
| No. 2, Open grain | | 950 | 1100 | 500 | 80 | 425 | 875 | 1,000,000 | |
| No. 3 | | 700 | 800 | 375 | 80 | 650 | 725 | 1,100,000 | |
| No. 3, Open grain | | 550 | 650 | 350 | 80 | 425 | 525 | 900,000 | |
| Clear Heart Structural | 5" by 5" and larger | 1850 | — | 1250 | 135 | 650 | 1650 | 1,300,000 | |
| Clear Structural | | 1850 | — | 1250 | 135 | 650 | 1650 | 1,300,000 | |
| Select Structural | | 1400 | — | 950 | 95 | 650 | 1200 | 1,300,000 | |
| No. 1 | | 1200 | — | 800 | 95 | 650 | 1050 | 1,300,000 | |
| No. 2 | | 975 | — | 650 | 95 | 650 | 900 | 1,100,000 | |
| No. 3 | | 550 | — | 375 | 95 | 650 | 550 | 1,000,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Select Decking, Close grain | Decking | 1850 | 2150 | — | — | — | — | 1,400,000 | 25-7 |
| Select Decking | 2" thick | 1450 | 1700 | — | — | — | — | 1,100,000 | (See footnotes |
| Commercial Decking | 6" & wider | 1200 | 1350 | — | — | — | — | 1,000,000 | 2, 5 and 6) |
| COAST SITKA SPRUCE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1500 | 1700 | 875 | 65 | 455 | 1100 | 1,700,000 | |
| No. 1 | 2" to 4" | 1250 | 1450 | 750 | 65 | 455 | 875 | 1,700,000 | |
| No. 2 | thick | 1050 | 1200 | 625 | 65 | 455 | 700 | 1,500,000 | |
| No. 3 | 2" to 4" | 575 | 675 | 350 | 65 | 455 | 425 | 1,300,000 | |
| Appearance | wide | 1250 | 1450 | 725 | 65 | 455 | 1050 | 1,700,000 | |
| Stud | | 600 | 675 | 350 | 65 | 455 | 425 | 1,300,000 | |
| Construction | 2" to 4" | 750 | 875 | 450 | 65 | 455 | 800 | 1,300,000 | 25-2 |
| Standard | thick | 425 | 500 | 250 | 65 | 455 | 650 | 1,300,000 | (See footnotes |
| Utility | 4" wide | 200 | 225 | 125 | 65 | 455 | 425 | 1,300,000 | 2 through 9, 11, |
| Select Structural | | 1300 | 1500 | 850 | 65 | 455 | 975 | 1,700,000 | 13, 15 and 16) |
| No. 1 | 2" to 4" | 1100 | 1250 | 725 | 65 | 455 | 875 | 1,700,000 | |
| No. 2 | thick | 900 | 1050 | 475 | 65 | 455 | 750 | 1,500,000 | |
| No. 3 and Stud | 5" and | 525 | 575 | 275 | 65 | 455 | 475 | 1,300,000 | |
| Appearance | wider | 1100 | 1250 | 725 | 65 | 455 | 1050 | 1,700,000 | |
| Select Structural | Beams and | 1150 | — | 675 | 60 | 455 | 775 | 1,500,000 | |
| No. 1 | Stringers | 950 | — | 475 | 60 | 455 | 650 | 1,500,000 | |
| Select Structural | Posts and | 1100 | — | 725 | 60 | 455 | 825 | 1,500,000 | |
| No. 1 | Timbers | 875 | — | 575 | 60 | 455 | 725 | 1,500,000 | |
| Select | Decking | 1250 | 1450 | — | — | 455 | — | 1,700,000 | |
| Commercial | | 1050 | 1200 | — | — | 455 | — | 1,500,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| COAST SPECIES (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1500 | 1700 | 850 | 65 | 370 | 1100 | 1,500,000 | |
| No. 1 | 2" to 4" | 1250 | 1450 | 750 | 65 | 370 | 875 | 1,500,000 | |
| No. 2 | thick | 1050 | 1200 | 625 | 65 | 370 | 700 | 1,400,000 | |
| No. 3 | 2" to 4" | 575 | 675 | 350 | 65 | 370 | 425 | 1,200,000 | |
| Appearance | wide | 1250 | 1450 | 725 | 65 | 370 | 1050 | 1,500,000 | |
| Stud | | 575 | 675 | 350 | 65 | 370 | 425 | 1,200,000 | |
| Construction | 2" to 4" | 750 | 875 | 450 | 65 | 370 | 800 | 1,200,000 | |
| Standard | thick | 425 | 500 | 250 | 65 | 370 | 650 | 1,200,000 | |
| Utility | 4" wide | 200 | 225 | 125 | 65 | 370 | 425 | 1,200,000 | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| Select Structural | | 1300 | 1500 | 875 | 65 | 370 | 975 | 1,500,000 | |
| No. 1 | 2" to 4" | 1100 | 1250 | 725 | 65 | 370 | 875 | 1,500,000 | |
| No. 2 | thick | 900 | 1050 | 475 | 65 | 370 | 750 | 1,400,000 | |
| No. 3 and Stud | 5" and | 525 | 600 | 275 | 65 | 370 | 475 | 1,200,000 | |
| Appearance | wider | 1100 | 1250 | 725 | 65 | 370 | 1050 | 1,500,000 | |
| Select | Decking | 1250 | 1450 | — | — | 370 | — | 1,500,000 | |
| Commercial | | 1050 | 1200 | — | — | 370 | — | 1,400,000 | |
| COTTONWOOD (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Stud | 2" to 3" thick 2" to 4" wide | 525 | 600 | 300 | 65 | 320 | 350 | 1,000,000 | 25-5 (See footnotes 1 through 9) |
| Construction | 2" to 4" | 675 | 775 | 400 | 65 | 320 | 650 | 1,000,000 | |
| Standard | thick | 375 | 425 | 225 | 65 | 320 | 525 | 1,000,000 | |
| Utility | 4" wide | 175 | 200 | 100 | 65 | 320 | 350 | 1,000,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| DOUGLAS FIR – LARCH (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| DOUGLAS FIR – LARCH (North) | | | | | | | | | |
| Dense Select Structural | | 2450 | 2800 | 1400 | 95 | 730 | 1850 | 1,900,000 | |
| Select Structural | | 2100 | 2400 | 1200 | 95 | 625 | 1600 | 1,800,000 | |
| Dense No. 1 | | 2050 | 2400 | 1200 | 95 | 730 | 1450 | 1,900,000 | |
| No. 1 | 2" to 4" | 1750 | 2050 | 1050 | 95 | 625 | 1250 | 1,800,000 | |
| Dense No. 2 | thick | 1700 | 1950 | 1000 | 95 | 730 | 1150 | 1,700,000 | |
| No. 2 | 2" to 4" | 1450 | 1650 | 850 | 95 | 625 | 1000 | 1,700,000 | |
| No. 3 | wide | 800 | 925 | 475 | 95 | 625 | 600 | 1,500,000 | 25-2 |
| Appearance | | 1750 | 2050 | 1050 | 95 | 625 | 1500 | 1,800,000 | 25-3 |
| Stud | | 800 | 925 | 475 | 95 | 625 | 600 | 1,500,000 | and |
| Construction | 2" to 4" | 1050 | 1200 | 625 | 95 | 625 | 1150 | 1,500,000 | 25-4 |
| Standard | thick | 600 | 675 | 350 | 95 | 625 | 925 | 1,500,000 | (See footnotes |
| Utility | 4" wide | 275 | 325 | 175 | 95 | 625 | 600 | 1,500,000 | 2 through 9, |
| Dense Select Structural | | 2100 | 2400 | 1400 | 95 | 730 | 1650 | 1,900,000 | 11, 13, |
| Select Structural | | 1800 | 2050 | 1200 | 95 | 625 | 1400 | 1,800,000 | 15 and 16) |
| Dense No. 1 | 2" to 4" | 1800 | 2050 | 1200 | 95 | 730 | 1450 | 1,900,000 | |
| No. 1 | thick | 1500 | 1750 | 1000 | 95 | 625 | 1250 | 1,800,000 | |
| Dense No. 2 | 5" and | 1450 | 1700 | 775 | 95 | 730 | 1250 | 1,700,000 | |
| No. 2 | wider | 1250 | 1450 | 650 | 95 | 625 | 1050 | 1,700,000 | |
| No. 3 and Stud | | 725 | 850 | 375 | 95 | 625 | 675 | 1,500,000 | |
| Appearance | | 1500 | 1750 | 1000 | 95 | 625 | 1500 | 1,800,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dense Select Structural<br>Select Structural<br>Dense No. 1<br>No. 1 | Beams and Stringers [12] | 1900<br>1600<br>1550<br>1300 | —<br>—<br>—<br>— | 1100<br>950<br>775<br>675 | 85<br>85<br>85<br>85 | 730<br>625<br>730<br>625 | 1300<br>1100<br>1100<br>925 | 1,700,000<br>1,600,000<br>1,700,000<br>1,600,000 | 25-3 (See footnotes 2 through 9) |
| Dense Select Structural<br>Select Structural<br>Dense No. 1<br>No. 1 | Posts and Timbers [12] | 1750<br>1500<br>1400<br>1200 | —<br>—<br>—<br>— | 1150<br>1000<br>950<br>825 | 85<br>85<br>85<br>85 | 730<br>625<br>730<br>625 | 1350<br>1150<br>1200<br>1000 | 1,700,000<br>1,600,000<br>1,700,000<br>1,600,000 | |
| Select Dex<br>Commercial Dex | Decking | 1750<br>1450 | 2000<br>1650 | —<br>— | —<br>— | 625<br>625 | —<br>— | 1,800,000<br>1,700,000 | |
| Dense Select Structural<br>Select Structural<br>Dense No. 1<br>No. 1<br>Dense No. 2<br>No. 2 | Beams and Stringers [12] | 1850<br>1600<br>1550<br>1350<br>1000<br>875 | —<br>—<br>—<br>—<br>—<br>— | 1100<br>950<br>775<br>675<br>500<br>425 | 85<br>85<br>85<br>85<br>85<br>85 | 730<br>625<br>730<br>625<br>730<br>625 | 1300<br>1100<br>1100<br>925<br>700<br>600 | 1,700,000<br>1,600,000<br>1,700,000<br>1,600,000<br>1,400,000<br>1,300,000 | 25-4 (See footnotes 2 through 10) |
| Dense Select Structural<br>Select Structural<br>Dense No. 1<br>No. 1<br>Dense No. 2<br>No. 2 | Posts and Timbers [12] | 1750<br>1500<br>1400<br>1200<br>800<br>700 | —<br>—<br>—<br>—<br>—<br>— | 1150<br>1000<br>950<br>825<br>550<br>475 | 85<br>85<br>85<br>85<br>85<br>85 | 730<br>625<br>730<br>625<br>730<br>625 | 1350<br>1150<br>1200<br>1000<br>550<br>475 | 1,700,000<br>1,600,000<br>1,700,000<br>1,600,000<br>1,400,000<br>1,300,000 | |
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 2000<br>1650 | —<br>— | —<br>— | —<br>— | —<br>— | 1,800,000<br>1,700,000 | |
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 2150<br>1800 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,900,000<br>1,700,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ 21 | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ 21 | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Select Structural | Beams and | 1600 | — | 950 | 85 | 625 | 1100 | 1,600,000 | 25-2 (See footnotes 2 through 9 and 11) |
| No. 1 | Stringers | 1300 | — | 675 | 85 | 625 | 925 | 1,600,000 | |
| Select Structural | Posts and | 1500 | — | 1000 | 85 | 625 | 1150 | 1,600,000 | |
| No. 1 | Timbers | 1200 | — | 825 | 85 | 625 | 1000 | 1,600,000 | |
| Select | Decking | 1750 | 2000 | — | — | 625 | — | 1,800,000 | |
| Commercial | | 1450 | 1650 | — | — | 625 | — | 1,700,000 | |
| DOUGLAS FIR SOUTH (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" | 2000 | 2300 | 1150 | 90 | 520 | 1400 | 1,400,000 | |
| No. 1 & Appearance | thick | 1700 | 1950 | 975 | 90 | 520 | 1150 | 1,400,000 | |
| No. 2 | 2" to 4" | 1400 | 1600 | 825 | 90 | 520 | 900 | 1,300,000 | |
| No. 3 | wide | 775 | 875 | 450 | 90 | 520 | 550 | 1,100,000 | |
| Stud | | 775 | 875 | 450 | 90 | 520 | 550 | 1,100,000 | |
| Construction | 2" to 4" | 1000 | 1150 | 600 | 90 | 520 | 1000 | 1,100,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| Standard | thick | 550 | 650 | 325 | 90 | 520 | 850 | 1,100,000 | |
| Utility | 4" wide | 275 | 300 | 150 | 90 | 520 | 550 | 1,100,000 | |
| Select Structural | 2" to 4" | 1700 | 1950 | 1150 | 90 | 520 | 1250 | 1,400,000 | |
| No. 1 & Appearance | thick | 1450 | 1650 | 975 | 90 | 520 | 1150 | 1,400,000 | |
| No. 2 | 5" and | 1200 | 1350 | 625 | 90 | 520 | 950 | 1,300,000 | |
| No. 3 and Stud | wider | 700 | 800 | 350 | 90 | 520 | 600 | 1,100,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural<br>No. 1<br>No. 2 | Beams and Stringers | 1550<br>1300<br>825 | — | 900<br>625<br>425 | 85<br>85<br>85 | 520<br>520<br>520 | 1000<br>850<br>525 | 1,200,000<br>1,200,000<br>1,000,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| Select Structural<br>No. 1<br>No. 2 | Posts and Timbers | 1400<br>1150<br>650 | — | 950<br>775<br>400 | 85<br>85<br>85 | 520<br>520<br>520 | 1050<br>925<br>425 | 1,200,000<br>1,200,000<br>1,000,000 | |
| Selected Decking<br>Commercial Decking | Decking | — | 1900<br>1600 | — | — | — | — | 1,400,000<br>1,300,000 | |
| Selected Decking<br>Commercial Decking | Decking | — | 2050<br>1730 | (Stresses for Decking apply at 15% moisture content) | | | | 1,500,000<br>1,300,000 | |
| **EASTERN HEMLOCK** (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structrual<br>No. 1<br>No. 2<br>No. 3<br>Appearance<br>Stud | 2" to 4" thick<br>2" to 4" wide | 1750<br>1500<br>1250<br>675<br>1500<br>675 | 2050<br>1750<br>1450<br>800<br>1750<br>800 | 1050<br>875<br>725<br>400<br>875<br>400 | 85<br>85<br>85<br>85<br>85<br>85 | 550<br>550<br>550<br>550<br>550<br>550 | 1350<br>1050<br>850<br>525<br>1250<br>525 | 1,200,000<br>1,200,000<br>1,100,000<br>1,000,000<br>1,200,000<br>1,000,000 | |
| Construction<br>Standard<br>Utility | 2" to 4" thick<br>4" wide | 900<br>500<br>250 | 1050<br>575<br>275 | 525<br>300<br>150 | 85<br>85<br>85 | 550<br>550<br>550 | 950<br>800<br>525 | 1,000,000<br>1,000,000<br>1,000,000 | 25-8 (See footnotes 1 through 9) |
| Select Structural<br>No. 1<br>No. 2<br>No. 3<br>Appearance<br>Stud | 2" to 4" thick<br>5" and wider | 1550<br>1300<br>1050<br>625<br>1300<br>625 | 1750<br>1500<br>1250<br>700<br>1500<br>700 | 1000<br>875<br>550<br>325<br>875<br>325 | 85<br>85<br>85<br>85<br>85<br>85 | 550<br>550<br>550<br>550<br>550<br>550 | 1200<br>1050<br>900<br>575<br>1250<br>575 | 1,200,000<br>1,200,000<br>1,100,000<br>1,000,000<br>1,200,000<br>1,000,000 | |
| Select Structural<br>No. 1 | Beams and Stringers | 1350<br>1150 | — | 925<br>775 | 80<br>80 | 550<br>550 | 950<br>800 | 1,200,000<br>1,200,000 | |
| Select Structural<br>No. 1 | Posts and Timbers | 1250<br>1050 | — | 850<br>700 | 80<br>80 | 550<br>550 | 1000<br>875 | 1,200,000<br>1,200,000 | |

(Continued)







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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| EASTERN HEMLOCK—TAMARACK (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| EASTERN HEMLOCK—TAMARACK (NORTH) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1800 | 2050 | 1050 | 85 | 555 | 1350 | 1,300,000 | 25-2 25-5 and 25-8 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| No. 1 | | 1500 | 1750 | 900 | 85 | 555 | 1050 | 1,300,000 | |
| No. 2 | | 1250 | 1450 | 725 | 85 | 555 | 850 | 1,100,000 | |
| No. 3 | | 700 | 800 | 400 | 85 | 555 | 525 | 1,000,000 | |
| Appearance | | 1300 | 1500 | 875 | 85 | 555 | 1300 | 1,300,000 | |
| Stud | | 700 | 800 | 400 | 85 | 555 | 525 | 1,000,000 | |
| Construction | 2" to 4" thick 4" wide | 900 | 1050 | 525 | 85 | 555 | 975 | 1,000,000 | |
| Standard | | 500 | 575 | 300 | 85 | 555 | 800 | 1,000,000 | |
| Utility | | 250 | 275 | 150 | 85 | 555 | 525 | 1,000,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1550 | 1750 | 1050 | 85 | 555 | 1200 | 1,300,000 | |
| No. 1 | | 1300 | 1500 | 875 | 85 | 555 | 1050 | 1,300,000 | |
| No. 2 | | 1050 | 1200 | 575 | 85 | 555 | 900 | 1,100,000 | |
| No. 3 and Stud | | 625 | 725 | 325 | 85 | 555 | 575 | 1,000,000 | |
| Appearance | | 1300 | 1500 | 875 | 85 | 555 | 1300 | 1,300,000 | |
| Select Structural | Beams and Stringers | 1400 | — | 925 | 80 | 555 | 950 | 1,200,000 | 25-2 (See footnotes 1 through 9 and 11) |
| No. 1 | | 1150 | — | 775 | 80 | 555 | 800 | 1,200,000 | |
| Select Structural | Posts and Timbers | 1300 | — | 875 | 80 | 555 | 1000 | 1,200,000 | |
| No. 1 | | 1050 | — | 700 | 80 | 555 | 875 | 1,200,000 | |
| Select | Decking | 1500 | 1700 | — | — | — | — | 1,300,000 | |
| Commercial | | 1250 | 1450 | — | — | — | — | 1,100,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural<br>No. 1 | Beams and<br>Stringers | 1400<br>1150 | —<br>— | 925<br>775 | 80<br>80 | 555<br>555 | 950<br>800 | 1,200,000<br>1,200,000 | 25-5<br>25-8<br>(See footnotes<br>2 through 9) |
| Select Structural<br>No. 1 | Posts and<br>Timbers | 1300<br>1050 | —<br>— | 875<br>700 | 80<br>80 | 555<br>555 | 1000<br>875 | 1,200,000<br>1,200,000 | |
| Select<br>Commercial | Decking | 1500<br>1250 | 1700<br>1450 | —<br>— | —<br>— | —<br>— | —<br>— | 1,300,000<br>1,100,000 | 25-8<br>(See footnotes<br>2 through 9) |
| Select Structural<br>No. 1 | Beams and<br>Stringers | 1450<br>1200 | —<br>— | 850<br>600 | 85<br>85 | 555<br>555 | 950<br>800 | 1,300,000<br>1,300,000 | 25-2<br>(See footnotes<br>2 through 9<br>and 11) |
| Select Structural<br>No. 1 | Posts and<br>Timbers | 1300<br>1050 | —<br>— | 875<br>700 | 80<br>80 | 555<br>555 | 1000<br>875 | 1,200,000<br>1,200,000 | |
| Select<br>Commercial | Decking | 1500<br>1250 | 1700<br>1450 | —<br>— | —<br>— | 555<br>555 | —<br>— | 1,300,000<br>1,100,000 | |
| **EASTERN SOFTWOODS** (Surfaced dry or surfaced green, Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural<br>No. 1<br>No. 2<br>No. 3 | 2" to 4"<br>thick<br>2" to 4"<br>wide | 1350<br>1150<br>950<br>525 | 1550<br>1350<br>1100<br>600 | 800<br>675<br>550<br>300 | 70<br>70<br>70<br>70 | 335<br>335<br>335<br>335 | 1050<br>825<br>650<br>400 | 1,200,000<br>1,200,000<br>1,100,000<br>1,000,000 | 25-5<br>(See footnotes<br>1 through 9) |
| Stud | 2" to 4"<br>thick<br>2" to 4"<br>wide | 525 | 600 | 300 | 70 | 335 | 400 | 1,000,000 | 25-5<br>25-8<br>(See footnotes<br>1 through 8) |
| Construction<br>Standard<br>Utility | 2" to 4"<br>thick<br>4" wide | 700<br>375<br>175 | 800<br>450<br>200 | 400<br>225<br>100 | 70<br>70<br>70 | 335<br>335<br>335 | 750<br>625<br>400 | 1,000,000<br>1,000,000<br>1,000,000 | 25-5<br>(See footnotes<br>1 through 9) |
| Select Structural<br>No. 1<br>No. 2<br>No. 3<br>Appearance | 2" to 4"<br>thick<br>5" and<br>wider | 1150<br>1000<br>825<br>475<br>1000 | 1350<br>1150<br>950<br>550<br>1150 | 775<br>675<br>425<br>250<br>875 | 70<br>70<br>70<br>70<br>70 | 335<br>335<br>335<br>335<br>335 | 925<br>825<br>700<br>450<br>1000 | 1,200,000<br>1,200,000<br>1,100,000<br>1,000,000<br>1,200,000 | |
| Stud | 2" to 4"<br>thick<br>5" and<br>wider | 475 | 550 | 250 | 70 | 335 | 450 | 1,000,000 | 25-5<br>25-8<br>(See footnotes<br>1 through 9) |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| Species and commercial grade | Size classification | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | Extreme fiber in bending $F_b$ | | Tension parallel to grain $F_t$ | Horizontal shear $F_v$ | Compression perpendicular to grain $F_{c\perp}$ [21] | Compression parallel to grain $F_c$ | Modulus of elasticity $E$ [21] | |
| | | Single-member uses | Repetitive-member uses | | | | | | |
| **EASTERN SPRUCE** (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" | 1400 | 1600 | 800 | 70 | 390 | 1050 | 1,500,000 | |
| No. 1 | thick | 1200 | 1350 | 700 | 70 | 390 | 825 | 1,500,000 | |
| No. 2 | 2" to 4" | 975 | 1100 | 575 | 70 | 390 | 650 | 1,400,000 | |
| No. 3 | wide | 550 | 625 | 325 | 70 | 390 | 400 | 1,200,000 | |
| Appearance | | 1200 | 1350 | 700 | 70 | 390 | 1000 | 1,500,000 | |
| Stud | | 550 | 625 | 325 | 70 | 390 | 400 | 1,200,000 | 25-5 |
| Construction | 2" to 4" | 700 | 800 | 400 | 70 | 390 | 750 | 1,200,000 | 25-8 |
| Standard | thick | 400 | 450 | 225 | 70 | 390 | 625 | 1,200,000 | (See footnotes |
| Utility | 4" wide | 175 | 225 | 100 | 70 | 390 | 400 | 1,200,000 | 1 through 9) |
| Select Structural | 2" to 4" | 1200 | 1350 | 800 | 70 | 390 | 925 | 1,500,000 | |
| No. 1 | thick | 1000 | 1150 | 675 | 70 | 390 | 825 | 1,500,000 | |
| No. 2 | 5" and | 825 | 950 | 425 | 70 | 390 | 700 | 1,400,000 | |
| No. 3 | wider | 475 | 550 | 250 | 70 | 390 | 450 | 1,200,000 | |
| Appearance | | 1000 | 1150 | 675 | 70 | 390 | 1000 | 1,500,000 | |
| Stud | | 475 | 550 | 250 | 70 | 390 | 450 | 1,200,000 | |
| Select Structural | Beams and | 1050 | — | 725 | 65 | 390 | 750 | 1,400,000 | |
| No. 1 | Stringers | 900 | — | 600 | 65 | 390 | 625 | 1,400,000 | |
| Select Structural | Posts and | 1000 | — | 675 | 65 | 390 | 775 | 1,400,000 | |
| No. 1 | Timbers | 800 | — | 550 | 65 | 390 | 675 | 1,400,000 | |
| Select | Decking | — | 1300 | — | — | — | — | 1,500,000 | 25-8 |
| Commercial | | — | 1100 | — | — | — | — | 1,400,000 | (See footnotes 1 through 9) |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **EASTERN WHITE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.)** | | | | | | | | | |
| **EASTERN WHITE PINE (NORTH)** | | | | | | | | | |
| Select Structural | | 1350 | 1550 | 800 | 65 | 350 | 1050 | 1,200,000 | 25-2 and 25-8 (See footnotes 2 through 9, 12 and 14) |
| No. 1 | 2" to 4" | 1150 | 1350 | 675 | 65 | 350 | 850 | 1,200,000 | |
| No. 2 | thick | 950 | 1100 | 550 | 65 | 350 | 675 | 1,100,000 | |
| No. 3 | 2" to 4" | 525 | 600 | 300 | 65 | 350 | 400 | 1,000,000 | |
| Appearance | wide | 1150 | 1350 | 675 | 65 | 350 | 1000 | 1,200,000 | |
| Stud | 2" to 4" thick 2" to 4" wide | 525 | 600 | 300 | 65 | 350 | 400 | 1,000,000 | 25-2, 25-5 and 25-8 (See footnotes 2 through 9, 11, 12, 13 and 14) |
| Construction | 2" to 4" | 700 | 800 | 400 | 65 | 350 | 750 | 1,000,000 | |
| Standard | thick | 375 | 450 | 225 | 65 | 350 | 625 | 1,000,000 | |
| Utility | 4" wide | 175 | 200 | 100 | 65 | 350 | 400 | 1,000,000 | |
| Select Structural | | 1150 | 1350 | 775 | 65 | 350 | 950 | 1,200,000 | 25-2 and 25-8 (See footnotes 2 through 9, 11, 12 and 14) |
| No. 1 | 2" to 4" | 1000 | 1150 | 675 | 65 | 350 | 850 | 1,200,000 | |
| No. 2 | thick | 825 | 950 | 450 | 65 | 350 | 700 | 1,100,000 | |
| No. 3 and Stud | 5" and | 475 | 550 | 250 | 65 | 350 | 450 | 1,000,000 | |
| Appearance | wider | 1000 | 1150 | 675 | 65 | 350 | 1000 | 1,200,000 | |
| Select Structural | Beams and | 1050 | — | 700 | 65 | 350 | 675 | 1,100,000 | 25-8 (See footnotes 2 through 9) |
| No. 1 | Stringers | 875 | — | 600 | 65 | 350 | 575 | 1,100,000 | |
| Select Structural | Posts and | 975 | — | 650 | 65 | 350 | 725 | 1,100,000 | |
| No. 1 | Timbers | 800 | — | 525 | 65 | 350 | 625 | 1,100,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Select Commercial | Decking | 900<br>775 | 1050<br>875 | — | — | — | — | 1,200,000<br>1,100,000 | 25-2 and 25-8 (See footnotes 2 through 9, 11 and 12) |
| EASTERN WOODS (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" wide | 1300 | 1500 | 775 | 60 | 270 | 850 | 1,100,000 | 25-5 and 25-8 (See footnotes 2 through 9 13, 15 and 16) |
| No. 1 | | 1100 | 1300 | 650 | 60 | 270 | 675 | 1,100,000 | |
| No. 2 | | 925 | 1050 | 525 | 60 | 270 | 550 | 1,000,000 | |
| No. 3 | | 500 | 575 | 300 | 60 | 270 | 325 | 900,000 | |
| Stud | | 500 | 575 | 300 | 60 | 270 | 325 | 900,000 | |
| Construction | 2" to 4" thick 4" wide | 650 | 750 | 400 | 60 | 270 | 625 | 900,000 | |
| Standard | | 375 | 425 | 225 | 60 | 270 | 500 | 900,000 | |
| Utility | | 175 | 200 | 100 | 60 | 270 | 325 | 900,000 | |
| Appearance | 2" to 4" thick 2" to 4" wide | 1100 | 1300 | 650 | 60 | 270 | 825 | 1,100,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1150 | 1300 | 750 | 60 | 270 | 750 | 1,100,000 | 25-5 (See footnotes 2 through 9, 15 and 16) |
| No. 1 | | 950 | 1100 | 650 | 60 | 270 | 675 | 1,100,000 | |
| No. 2 | | 775 | 900 | 425 | 60 | 270 | 575 | 1,000,000 | |
| No. 3 and Stud | | 450 | 525 | 250 | 60 | 270 | 375 | 900,000 | |
| Appearance | | 950 | 1100 | 650 | 60 | 270 | 825 | 1,100,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ENGELMANN SPRUCE—ALPINE FIR (ENGELMANN SPRUCE—LODGEPOLE PINE) (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1350 | 1550 | 800 | 70 | 320 | 950 | 1,300,000 | |
| No. 1 | 2" to 4" | 1150 | 1350 | 675 | 70 | 320 | 750 | 1,300,000 | |
| No. 2 | thick | 950 | 1100 | 550 | 70 | 320 | 600 | 1,100,000 | |
| No. 3 | 2" to 4" | 525 | 600 | 300 | 70 | 320 | 375 | 1,000,000 | |
| Appearance | wide | 1150 | 1350 | 675 | 70 | 320 | 900 | 1,300,000 | |
| Stud | | 525 | 600 | 300 | 70 | 320 | 375 | 1,000,000 | |
| Construction | 2" to 4" | 700 | 800 | 400 | 70 | 320 | 675 | 1,000,000 | |
| Standard | thick | 375 | 450 | 225 | 70 | 320 | 550 | 1,000,000 | |
| Utility | 4" wide | 175 | 200 | 100 | 70 | 320 | 375 | 1,000,000 | |
| Select Structural | | 1200 | 1350 | 775 | 70 | 320 | 850 | 1,300,000 | 25-4 |
| No. 1 | 2" to 4" | 1000 | 1150 | 675 | 70 | 320 | 750 | 1,300,000 | (See footnotes |
| No. 2 | thick | 825 | 950 | 425 | 70 | 320 | 625 | 1,100,000 | 2 through 10, |
| No. 3 and Stud | 5" and | 475 | 550 | 250 | 70 | 320 | 400 | 1,000,000 | 13, 15 and 16) |
| Appearance | wider | 1000 | 1150 | 675 | 70 | 320 | 900 | 1,300,000 | |
| Select Structural | | 1050 | — | 625 | 65 | 320 | 675 | 1,100,000 | |
| No. 1 | Beams and | 875 | — | 450 | 65 | 320 | 550 | 1,100,000 | |
| No. 2 | Stringers | 575 | — | 275 | 65 | 320 | 350 | 900,000 | |
| Select Structural | | 975 | — | 650 | 65 | 320 | 700 | 1,100,000 | |
| No. 1 | Posts and | 800 | — | 525 | 65 | 320 | 625 | 1,100,000 | |
| No. 2 | Timbers | 450 | — | 300 | 65 | 320 | 275 | 900,000 | |
| Selected Decking | Decking | — | 1300 | — | — | — | — | 1,300,000 | |
| Commercial Decking | | — | 1100 | — | — | — | — | 1,100,000 | |
| Selected Decking | Decking | — | 1400 | (Surfaced at 15% max. m.c. and | | | | 1,300,000 | |
| Commercial Decking | | — | 1200 | used at 15% max. m.c.) | | | | 1,200,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| HEM-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick | 1650 | 1900 | 975 | 75 | 405 | 1300 | 1,500,000 | 25-3 and 25-4 (See footnotes 2 through 9, 11, 12, 13 15 and 16) |
| No. 1 | | 1400 | 1600 | 825 | 75 | 405 | 1050 | 1,500,000 | |
| No. 2 | | 1150 | 1350 | 675 | 75 | 405 | 825 | 1,400,000 | |
| No. 3 | 2" to 4" wide | 650 | 725 | 375 | 75 | 405 | 500 | 1,200,000 | |
| Appearance | | 1400 | 1600 | 825 | 75 | 405 | 1250 | 1,500,000 | |
| Stud | | 650 | 725 | 375 | 75 | 405 | 500 | 1,200,000 | |
| Construction | 2" to 4" thick 4" wide | 825 | 975 | 500 | 75 | 405 | 925 | 1,200,000 | |
| Standard | | 475 | 550 | 275 | 75 | 405 | 775 | 1,200,000 | |
| Utility | | 225 | 250 | 125 | 75 | 405 | 500 | 1,200,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1400 | 1650 | 950 | 75 | 405 | 1150 | 1,500,000 | |
| No. 1 | | 1200 | 1400 | 800 | 75 | 405 | 1050 | 1,500,000 | |
| No. 2 | | 1000 | 1150 | 525 | 75 | 405 | 875 | 1,400,000 | |
| No. 3 and Stud | | 575 | 675 | 300 | 75 | 405 | 550 | 1,200,000 | |
| Appearance | | 1200 | 1400 | 800 | 75 | 405 | 1250 | 1,500,000 | |
| Select Structural | Beams and Stringers | 1300 | — | 750 | 70 | 405 | 925 | 1,300,000 | 25-3 (See footnotes 2 through 9, 15 and 16) |
| No. 1 | | 1050 | — | 525 | 70 | 405 | 750 | 1,300,000 | |
| Select Structural | Posts and Timbers | 1200 | — | 800 | 70 | 405 | 975 | 1,300,000 | |
| No. 1 | | 975 | — | 650 | 70 | 405 | 850 | 1,300,000 | |
| Select Dex | Decking | 1400 | 1600 | — | — | 405 | — | 1,500,000 | |
| Commercial Dex | | 1150 | 1350 | — | — | 405 | — | 1,400,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural<br>No. 1<br>No. 2 | Beams and Stringers | 1250<br>1050<br>675 | — | 725<br>525<br>325 | 70<br>70<br>70 | 405<br>405<br>405 | 925<br>775<br>475 | 1,300,000<br>1,300,000<br>1,100,000 | 25-4 (See footnotes 2 through 9, 15 and 16) |
| Select Structural<br>No. 1<br>No. 2 | Posts and Timbers | 1200<br>950<br>525 | — | 800<br>650<br>350 | 70<br>70<br>70 | 405<br>405<br>405 | 975<br>850<br>375 | 1,300,000<br>1,300,000<br>1,100,000 | |
| Select Structural<br>No. 1 | Beams and Stringers 12 | 1250<br>1050 | — | 850<br>725 | 70<br>70 | 405<br>405 | 925<br>775 | 1,300,000<br>1,300,000 | 25-2 (See footnotes 2 through 12) |
| Select Structural<br>No. 1 | Posts and Timbers | 1200<br>950 | — | 800<br>650 | 70<br>70 | 405<br>405 | 975<br>850 | 1,300,000<br>1,300,000 | |
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 1600<br>1350 | — | — | — | — | 1,500,000<br>1,400,000 | 25-2 and 25-4 (See footnotes 2 through 12) |
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 1700<br>1450 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,600,000<br>1,400,000 | |
| Select<br>Commercial | Decking | 1350<br>1150 | 1550<br>1300 | — | — | 405<br>405 | — | 1,500,000<br>1,400,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| Species and commercial grade | Size classification | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | Extreme fiber in bending $F_b$ | | Tension parallel to grain $F_t$ | Horizontal shear $F_v$ | Compression perpendicular to grain $F_{c\perp}$ 21 | Compression parallel to grain $F_c$ | Modulus of elasticity $E$ 21 | |
| | | Single-member uses | Repetitive-member uses | | | | | | |
| **HEM-FIR (NORTH)** (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 3" | 1600 | 1800 | 925 | 75 | 370 | 1300 | 1,500,000 | |
| No. 1 | thick | 1350 | 1550 | 800 | 75 | 370 | 1050 | 1,500,000 | |
| No. 2 | 2" to 4" | 1100 | 1300 | 650 | 75 | 370 | 800 | 1,400,000 | |
| No. 3 | wide | 625 | 700 | 350 | 75 | 370 | 500 | 1,200,000 | |
| Appearance | | 1350 | 1550 | 800 | 75 | 370 | 1250 | 1,500,000 | |
| Stud | | 625 | 700 | 350 | 75 | 370 | 500 | 1,200,000 | |
| Construction | 2" to 4" | 800 | 925 | 475 | 75 | 370 | 925 | 1,200,000 | |
| Standard | thick | 450 | 525 | 275 | 75 | 370 | 775 | 1,200,000 | |
| Utility | 4" wide | 225 | 250 | 125 | 75 | 370 | 500 | 1,200,000 | 25-2 (See footnotes 1 through 9 and 11) |
| Select Structural | 2" to 4" | 1350 | 1550 | 900 | 75 | 370 | 1150 | 1,500,000 | |
| No. 1 | thick | 1150 | 1350 | 775 | 75 | 370 | 1050 | 1,500,000 | |
| No. 2 | 5" and | 950 | 1100 | 500 | 75 | 370 | 850 | 1,400,000 | |
| No. 3 | wider | 550 | 650 | 300 | 75 | 370 | 550 | 1,200,000 | |
| Appearance | | 1150 | 1350 | 775 | 75 | 370 | 1250 | 1,500,000 | |
| Stud | | 550 | 650 | 300 | 75 | 370 | 550 | 1,200,000 | |
| Select Structural | Beams and | 1250 | — | 725 | 70 | 370 | 900 | 1,300,000 | |
| No. 1 | Stringers | 1000 | — | 500 | 70 | 370 | 750 | 1,300,000 | |
| Select Structural | Posts and | 1150 | — | 775 | 70 | 370 | 950 | 1,300,000 | |
| No. 1 | Timbers | 925 | — | 625 | 70 | 370 | 850 | 1,300,000 | |
| Select | Decking | 1350 | 1500 | — | — | 370 | — | 1,500,000 | |
| Commercial | | 1100 | 1300 | — | — | 370 | — | 1,400,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| IDAHO WHITE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select structural | 2" to 4" thick 2" to 4" wide | 1350 | 1550 | 775 | 70 | 315 | 1100 | 1,400,000 | 25-4 (See footnotes 2 through 10 13, 15 and 16) |
| No. 1 | | 1150 | 1300 | 650 | 70 | 315 | 875 | 1,400,000 | |
| No. 2 | | 925 | 1050 | 550 | 70 | 315 | 675 | 1,300,000 | |
| No. 3 | | 525 | 600 | 300 | 70 | 315 | 425 | 1,200,000 | |
| Appearance | | 1150 | 1300 | 650 | 70 | 315 | 1050 | 1,400,000 | |
| Stud | | 525 | 600 | 300 | 70 | 315 | 425 | 1,200,000 | |
| Construction | 2" to 4" thick 4" wide | 675 | 775 | 400 | 70 | 315 | 775 | 1,200,000 | |
| Standard | | 375 | 425 | 225 | 70 | 315 | 650 | 1,200,000 | |
| Utility | | 175 | 200 | 100 | 70 | 315 | 425 | 1,200,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1150 | 1300 | 775 | 70 | 315 | 950 | 1,400,000 | |
| No. 1 | | 975 | 1100 | 650 | 70 | 315 | 875 | 1,400,000 | |
| No. 2 | | 800 | 925 | 425 | 70 | 315 | 725 | 1,300,000 | |
| No. 3 and Stud | | 475 | 550 | 250 | 70 | 315 | 450 | 1,200,000 | |
| Appearance | | 975 | 1100 | 650 | 70 | 315 | 1050 | 1,400,000 | |
| Select Structural | Beams and Stringers | 1000 | — | 600 | 65 | 315 | 775 | 1,300,000 | |
| No. 1 | | 850 | — | 425 | 65 | 315 | 650 | 1,300,000 | |
| No. 2 | | 550 | — | 275 | 65 | 315 | 400 | 1,100,000 | |
| Select Structural | Posts and Timbers | 950 | — | 650 | 65 | 315 | 800 | 1,300,000 | |
| No. 1 | | 775 | — | 525 | 65 | 315 | 700 | 1,300,000 | |
| No. 2 | | 450 | — | 300 | 65 | 315 | 325 | 1,100,000 | |
| Selected Decking | Decking | — | 1300 | — | — | — | — | 1,400,000 | |
| Commercial Decking | | — | 1050 | — | — | — | — | 1,300,000 | |
| Selected Decking | Decking | — | 1400 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,500,000 | |
| Commercial Decking | | — | 1150 | | | | | 1,400,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| LODGEPOLE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1500 | 1750 | 875 | 70 | 400 | 1150 | 1,300,000 | |
| No. 1 | | 1300 | 1500 | 750 | 70 | 400 | 900 | 1,300,000 | |
| No. 2 | | 1050 | 1200 | 625 | 70 | 400 | 700 | 1,200,000 | |
| No. 3 | | 600 | 675 | 350 | 70 | 400 | 425 | 1,000,000 | |
| Appearance | | 1300 | 1500 | 750 | 70 | 400 | 1050 | 1,300,000 | |
| Stud | | 600 | 675 | 350 | 70 | 400 | 425 | 1,000,000 | |
| Construction | 2" to 4" thick 4" wide | 775 | 875 | 450 | 70 | 400 | 800 | 1,000,000 | |
| Standard | | 425 | 500 | 250 | 70 | 400 | 675 | 1,000,000 | |
| Utility | | 200 | 225 | 125 | 70 | 400 | 425 | 1,000,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1300 | 1500 | 875 | 70 | 400 | 1000 | 1,300,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| No. 1 | | 1100 | 1300 | 750 | 70 | 400 | 900 | 1,300,000 | |
| No. 2 | | 925 | 1050 | 475 | 70 | 400 | 750 | 1,200,000 | |
| No. 3 and Stud | | 525 | 625 | 275 | 70 | 400 | 475 | 1,000,000 | |
| Appearance | | 1100 | 1300 | 750 | 70 | 400 | 1050 | 1,300,000 | |
| Select Structural | Beams and Stringers | 1150 | — | 700 | 65 | 400 | 800 | 1,100,000 | |
| No. 1 | | 975 | — | 500 | 65 | 400 | 675 | 1,100,000 | |
| No. 2 | | 625 | — | 325 | 65 | 400 | 425 | 900,000 | |
| Select Structural | Posts and Timbers | 1100 | — | 725 | 65 | 400 | 850 | 1,100,000 | |
| No. 1 | | 875 | — | 600 | 65 | 400 | 725 | 1,100,000 | |
| No. 2 | | 500 | — | 350 | 65 | 400 | 350 | 900,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 1450<br>1200 | —<br>— | —<br>— | —<br>— | —<br>— | 1,300,000<br>1,200,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| Selected Decking<br>Commercial Decking | Decking | —<br>— | 1550<br>1300 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,400,000<br>1,200,000 | |
| MOUNTAIN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural<br>No. 1<br>No. 2<br>No. 3<br>Appearance<br>Stud | 2" to 4" thick 2" to 4" wide | 1750<br>1450<br>1200<br>675<br>1450<br>675 | 2000<br>1700<br>1400<br>775<br>1700<br>775 | 1000<br>850<br>700<br>400<br>850<br>400 | 95<br>95<br>95<br>95<br>95<br>95 | 570<br>570<br>570<br>570<br>570<br>570 | 1250<br>1000<br>775<br>475<br>1200<br>475 | 1,300,000<br>1,300,000<br>1,100,000<br>1,000,000<br>1,300,000<br>1,000,000 | 25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16) |
| Construction<br>Standard<br>Utility | 2" to 4" thick 4" wide | 875<br>500<br>225 | 1000<br>575<br>275 | 525<br>275<br>125 | 95<br>95<br>95 | 570<br>570<br>570 | 900<br>725<br>475 | 1,000,000<br>1,000,000<br>1,000,000 | |
| Select Structural<br>No. 1<br>No. 2<br>No. 3 and Stud<br>Appearance | 2" to 4" thick 5" and wider | 1500<br>1250<br>1050<br>625<br>1250 | 1700<br>1450<br>1200<br>700<br>1450 | 1000<br>850<br>550<br>325<br>850 | 95<br>95<br>95<br>95<br>95 | 570<br>570<br>570<br>570<br>570 | 1100<br>1000<br>825<br>525<br>1200 | 1,300,000<br>1,300,000<br>1,100,000<br>1,000,000<br>1,300,000 | |
| Select Structural<br>No. 1 | Beams and Stringers | 1350<br>1100 | — | 775<br>550 | 90<br>90 | 570<br>570 | 875<br>725 | 1,100,000<br>1,100,000 | 25-3 (See footnotes 2 through 9) |
| Select Structural<br>No. 1 | Posts and Timbers | 1250<br>1000 | — | 825<br>675 | 90<br>90 | 570<br>570 | 925<br>800 | 1,100,000<br>1,100,000 | |
| Select Dex<br>Commercial Dex | Decking | 1450<br>1200 | 1650<br>1400 | —<br>— | —<br>— | 570<br>570 | —<br>— | 1,300,000<br>1,100,000 | |

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# TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY, $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Select Structural | Beams and Stringers | 1350 | — | 775 | 90 | 570 | 875 | 1,000,000 | 25-4 (See footnotes 2 through 10) |
| No. 1 | | 1100 | — | 550 | 90 | 570 | 750 | 1,100,000 | |
| No. 2 | | 725 | — | 375 | 90 | 570 | 475 | 900,000 | |
| Select Structural | Posts and Timbers | 1250 | — | 825 | 90 | 570 | 925 | 1,100,000 | |
| No. 1 | | 1000 | — | 675 | 90 | 570 | 800 | 1,100,000 | |
| No. 2 | | 575 | — | 375 | 90 | 570 | 375 | 900,000 | |
| Selected Decking | Decking | — | 1650 | — | — | — | — | 1,300,000 | |
| Commercial Decking | | — | 1400 | — | — | — | — | 1,100,000 | |
| Selected Decking | Decking | — | 1800 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,300,000 | |
| Commercial Decking | | — | 1500 | | | | | 1,200,000 | |
| MOUNTAIN HEMLOCK—HEM-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1650 | 1900 | 975 | 75 | 405 | 1250 | 1,300,000 | |
| No. 1 | | 1400 | 1600 | 825 | 75 | 405 | 1000 | 1,300,000 | |
| No. 2 | | 1150 | 1350 | 675 | 75 | 405 | 775 | 1,100,000 | |
| No. 3 | | 650 | 725 | 375 | 75 | 405 | 475 | 1,000,000 | |
| Appearance | | 1400 | 1600 | 825 | 75 | 405 | 1200 | 1,300,000 | |
| Stud | | 650 | 725 | 375 | 75 | 405 | 475 | 1,000,000 | |
| Construction | 2" to 4" thick 4" wide | 825 | 975 | 500 | 75 | 405 | 900 | 1,000,000 | |
| Standard | | 475 | 550 | 275 | 75 | 405 | 725 | 1,000,000 | |
| Utility | | 225 | 250 | 125 | 75 | 405 | 475 | 1,000,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1400 | 1650 | 950 | 75 | 405 | 1100 | 1,300,000 | |
| No. 1 | | 1200 | 1400 | 800 | 75 | 405 | 1000 | 1,300,000 | |
| No. 2 | | 1000 | 1150 | 525 | 75 | 405 | 825 | 1,100,000 | |
| No. 3 and Stud | | 575 | 675 | 300 | 75 | 405 | 525 | 1,000,000 | |
| Appearance | | 1200 | 1400 | 800 | 75 | 405 | 1200 | 1,300,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural | Beams and Stringers | 1250 | — | 725 | 70 | 405 | 875 | 1,100,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| No. 1 | | 1050 | — | 525 | 70 | 405 | 750 | 1,100,000 | |
| No. 2 | | 675 | — | 325 | 70 | 405 | 475 | 900,000 | |
| Select Structural | Posts and Timbers | 1200 | — | 800 | 70 | 405 | 925 | 1,100,000 | |
| No. 1 | | 950 | — | 650 | 70 | 405 | 800 | 1,100,000 | |
| No. 2 | | 525 | — | 350 | 70 | 405 | 375 | 900,000 | |
| Selected Decking | Decking | — | 1600 | — | — | — | — | 1,300,000 | |
| Commercial Decking | | — | 1350 | — | — | — | — | 1,100,000 | |
| Selected Decking | Decking | — | 1700 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,300,000 | |
| Commercial Decking | | — | 1450 | | | | | 1,200,000 | |
| NORTHERN ASPEN (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1300 | 1500 | 750 | 60 | 320 | 850 | 1,400,000 | 25-2 (See footnotes 2 through 9, 11, 13 15 and 16) |
| No. 1 | | 1100 | 1250 | 650 | 60 | 320 | 675 | 1,400,000 | |
| No. 2 | | 900 | 1050 | 525 | 60 | 320 | 525 | 1,200,000 | |
| No. 3 | | 500 | 575 | 275 | 60 | 320 | 325 | 1,100,000 | |
| Appearance | | 1100 | 1250 | 650 | 60 | 320 | 800 | 1,400,000 | |
| Stud | | 500 | 575 | 275 | 60 | 320 | 325 | 1,100,000 | |
| Construction | 2" to 4" thick 4" wide | 650 | 750 | 375 | 60 | 320 | 600 | 1,100,000 | |
| Standard | | 350 | 425 | 200 | 60 | 320 | 500 | 1,100,000 | |
| Utility | | 175 | 200 | 100 | 60 | 320 | 325 | 1,100,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1100 | 1250 | 750 | 60 | 320 | 750 | 1,400,000 | |
| No. 1 | | 950 | 1100 | 625 | 60 | 320 | 675 | 1,400,000 | |
| No. 2 | | 775 | 900 | 400 | 60 | 320 | 575 | 1,200,000 | |
| No. 3 and Stud | | 450 | 525 | 250 | 60 | 320 | 350 | 1,100,000 | |
| Appearance | | 950 | 1100 | 625 | 60 | 320 | 800 | 1,400,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ 21 | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ 21 | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| NORTHERN PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1650 | 1850 | 950 | 70 | 435 | 1200 | 1,400,000 | |
| No. 1 | | 1400 | 1600 | 825 | 70 | 435 | 975 | 1,400,000 | |
| No. 2 | | 1150 | 1300 | 675 | 70 | 435 | 775 | 1,300,000 | |
| No. 3 | | 625 | 725 | 375 | 70 | 435 | 475 | 1,100,000 | |
| Appearance | | 1200 | 1400 | 800 | 70 | 435 | 1150 | 1,400,000 | |
| Stud | | 625 | 725 | 375 | 70 | 435 | 475 | 1,100,000 | |
| Construction | 2" to 4" thick 4" wide | 825 | 950 | 475 | 70 | 435 | 875 | 1,100,000 | 25-5 and 25-8 (See footnotes 2 through 9, 13, 15 and 16) |
| Standard | | 450 | 525 | 275 | 70 | 435 | 725 | 1,100,000 | |
| Utility | | 225 | 250 | 125 | 70 | 435 | 475 | 1,100,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1400 | 1600 | 950 | 70 | 435 | 1100 | 1,400,000 | |
| No. 1 | | 1200 | 1400 | 800 | 70 | 435 | 975 | 1,400,000 | |
| No. 2 | | 950 | 1100 | 525 | 70 | 435 | 825 | 1,300,000 | |
| No. 3 and Stud | | 575 | 650 | 300 | 70 | 435 | 525 | 1,100,000 | |
| Appearance | | 1200 | 1400 | 800 | 70 | 435 | 1150 | 1,400,000 | |
| Select Structural | Beams and Stringers | 1250 | — | 850 | 65 | 435 | 850 | 1,300,000 | |
| No. 1 | | 1050 | — | 700 | 65 | 435 | 725 | 1,300,000 | |
| Select Structural | Posts and Timbers | 1150 | — | 800 | 65 | 435 | 900 | 1,300,000 | |
| No. 1 | | 950 | — | 650 | 65 | 435 | 800 | 1,300,000 | |
| Select | Decking | 1350 | 1550 | — | — | — | — | 1,400,000 | 25-8 (See footnotes 2 through 9) |
| Commercial | | 1150 | 1300 | — | — | — | — | 1,300,000 | |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NORTHERN SPECIES (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| Select Structural | 2" to 3" thick | 1350 | 1550 | 775 | 65 | 350 | 1050 | 1,100,000 | | |
| No. 1 | | 1150 | 1300 | 675 | 65 | 350 | 825 | 1,100,000 | | |
| No. 2 | 2" to 4" thick | 925 | 1050 | 550 | 65 | 350 | 650 | 1,000,000 | | |
| No. 3 | | 525 | 600 | 300 | 65 | 350 | 400 | 900,000 | | |
| Appearance | 2" to 4" wide | 1150 | 1300 | 675 | 65 | 350 | 975 | 1,100,000 | | |
| Stud | | 525 | 600 | 300 | 65 | 350 | 400 | 900,000 | | |
| Construction | 2" to 4" thick | 675 | 775 | 400 | 65 | 350 | 750 | 900,000 | | |
| Standard | | 375 | 425 | 225 | 65 | 350 | 600 | 900,000 | | |
| Utility | 4" wide | 175 | 200 | 100 | 65 | 350 | 400 | 900,000 | | |
| Select Structural | 2" to 4" thick | 1150 | 1300 | 775 | 65 | 350 | 900 | 1,100,000 | | |
| No. 1 | | 975 | 1150 | 650 | 65 | 350 | 825 | 1,100,000 | | |
| No. 2 | | 800 | 925 | 425 | 65 | 350 | 675 | 1,000,000 | | |
| No. 3 and Stud | 5" and wider | 475 | 550 | 250 | 65 | 350 | 425 | 900,000 | | |
| Appearance | | 975 | 1150 | 650 | 65 | 350 | 850 | 1,100,000 | | |
| Select | Decking | 900 | 1050 | — | — | 350 | — | 1,100,000 | | |
| Commercial | | 775 | 875 | — | — | 350 | — | 1,000,000 | | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| NORTHERN WHITE CEDAR (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1150 | 1350 | 700 | 65 | 370 | 875 | 800,000 | 25-8 (See footnotes 2 through 9, 13, 15 and 16) |
| No. 1 | | 1000 | 1150 | 600 | 65 | 370 | 675 | 800,000 | |
| No. 2 | | 825 | 950 | 500 | 65 | 370 | 550 | 700,000 | |
| No. 3 | | 450 | 525 | 275 | 65 | 370 | 325 | 600,000 | |
| Appearance | | 850 | 1000 | 575 | 65 | 370 | 825 | 800,000 | |
| Stud | | 450 | 525 | 275 | 65 | 370 | 325 | 600,000 | |
| Construction | 2" to 4" thick 4" wide | 600 | 675 | 350 | 65 | 370 | 625 | 600,000 | |
| Standard | | 325 | 375 | 200 | 65 | 370 | 500 | 600,000 | |
| Utility | | 150 | 175 | 100 | 65 | 370 | 325 | 600,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1000 | 1150 | 675 | 65 | 370 | 775 | 800,000 | |
| No. 1 | | 850 | 1000 | 575 | 65 | 370 | 675 | 800,000 | |
| No. 2 | | 700 | 825 | 375 | 65 | 370 | 575 | 700,000 | |
| No. 3 and Stud | | 425 | 475 | 225 | 65 | 370 | 375 | 600,000 | |
| Appearance | | 850 | 1000 | 575 | 65 | 370 | 825 | 800,000 | |
| Select Structural | Beams and Stringers | 900 | — | 600 | 60 | 370 | 600 | 700,000 | |
| No. 1 | | 750 | — | 500 | 60 | 370 | 500 | 700,000 | |
| Select Structural | Posts and Timbers | 850 | — | 575 | 60 | 370 | 650 | 700,000 | |
| No. 1 | | 675 | — | 450 | 60 | 370 | 550 | 700,000 | |
| Select | Decking | 975 | 1100 | — | — | — | — | 800,000 | |
| Commercial | | 825 | 950 | — | — | — | — | 700,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PONDEROSA PINE—SUGAR PINE (PONDEROSA PINE—LODGEPOLE PINE) (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1400 | 1650 | 825 | 70 | 375 | 1050 | 1,200,000 | 25-2 and 25-4 (See footnotes 2 through 13, 15 and 16) |
| No. 1 | | 1200 | 1400 | 700 | 70 | 375 | 850 | 1,200,000 | |
| No. 2 | | 1000 | 1150 | 575 | 70 | 375 | 675 | 1,100,000 | |
| No. 3 | | 550 | 625 | 325 | 70 | 375 | 400 | 1,000,000 | |
| Appearance | | 1200 | 1400 | 700 | 70 | 375 | 1000 | 1,200,000 | |
| Stud | | 550 | 625 | 325 | 70 | 375 | 400 | 1,000,000 | |
| Construction | 2" to 4" thick 4" wide | 725 | 825 | 425 | 70 | 375 | 775 | 1,000,000 | |
| Standard | | 400 | 450 | 225 | 70 | 375 | 625 | 1,000,000 | |
| Utility | | 200 | 225 | 100 | 70 | 375 | 400 | 1,000,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1200 | 1400 | 825 | 70 | 375 | 950 | 1,200,000 | |
| No. 1 | | 1050 | 1200 | 700 | 70 | 375 | 850 | 1,200,000 | |
| No. 2 | | 850 | 975 | 450 | 70 | 375 | 700 | 1,100,000 | |
| No. 3 and Stud | | 500 | 575 | 250 | 70 | 375 | 450 | 1,000,000 | |
| Appearance | | 1050 | 1200 | 700 | 70 | 375 | 1000 | 1,200,000 | |
| Select Structural | Beams and Stringers | 1100 | — | 650 | 65 | 375 | 750 | 1,100,000 | 25-2 and 25-4 (See footnotes 2 through 13) |
| No. 1 | | 925 | — | 450 | 65 | 375 | 625 | 1,100,000 | |
| No. 2 | | 600 | — | 300 | 65 | 375 | 400 | 900,000 | |
| Select Structural | Posts and Timbers | 1000 | — | 675 | 65 | 375 | 800 | 1,100,000 | |
| No. 1 | | 825 | — | 550 | 65 | 375 | 700 | 1,100,000 | |
| No. 2 | | 475 | — | 325 | 65 | 375 | 325 | 900,000 | |
| Selected Decking | Decking | — | 1350 | — | — | — | — | 1,200,000 | |
| Commercial Decking | | — | 1150 | — | — | — | — | 1,100,000 | |
| Selected Decking | Decking | — | 1450 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,300,000 | |
| Commercial Decking | | — | 1250 | | | | | 1,100,000 | |
| Select | Decking | 1200[20] | 1450 | — | — | 375 | — | 1,300,000 | |
| Commercial | | 1000[20] | 1250 | — | — | 375 | — | 1,100,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| RED PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 3" thick 2" to 4" wide | 1400 | 1600 | 800 | 70 | 440 | 1050 | 1,300,000 | |
| No. 1 | | 1200 | 1350 | 700 | 70 | 440 | 825 | 1,300,000 | |
| No. 2 | | 975 | 1100 | 575 | 70 | 440 | 650 | 1,200,000 | |
| No. 3 | | 525 | 625 | 325 | 70 | 440 | 400 | 1,000,000 | |
| Appearance | | 1200 | 1350 | 700 | 70 | 440 | 975 | 1,300,000 | |
| Stud | | 525 | 625 | 325 | 70 | 440 | 400 | 1,000,000 | |
| Construction | 2" to 4" thick 4" wide | 700 | 800 | 400 | 70 | 440 | 750 | 1,000,000 | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| Standard | | 400 | 450 | 225 | 70 | 440 | 600 | 1,000,000 | |
| Utility | | 175 | 225 | 100 | 70 | 440 | 400 | 1,000,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1200 | 1350 | 775 | 70 | 440 | 900 | 1,300,000 | |
| No. 1 | | 1000 | 1150 | 675 | 70 | 440 | 825 | 1,300,000 | |
| No. 2 | | 825 | 950 | 425 | 70 | 440 | 675 | 1,200,000 | |
| No. 3 and Stud | | 500 | 550 | 250 | 70 | 440 | 425 | 1,000,000 | |
| Appearance | | 1000 | 1150 | 675 | 70 | 440 | 975 | 1,300,000 | |
| Select Structural | Beams and Stringers | 1050 | — | 625 | 65 | 440 | 725 | 1,100,000 | |
| No. 1 | | 875 | — | 450 | 65 | 440 | 600 | 1,100,000 | |
| Select Structural | Posts and Timbers | 1000 | — | 675 | 65 | 440 | 775 | 1,100,000 | |
| No. 1 | | 800 | — | 550 | 65 | 440 | 675 | 1,100,000 | |
| Select | Decking | 1150 | 1350 | — | — | 440 | — | 1,300,000 | |
| Commercial | | 975 | 1100 | — | — | 440 | — | 1,200,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SITKA SPRUCE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1550 | 1800 | 925 | 75 | 435 | 1150 | 1,500,000 | |
| No. 1 | 2" to 4" | 1350 | 1550 | 775 | 75 | 435 | 925 | 1,500,000 | |
| No. 2 | thick | 1100 | 1250 | 650 | 75 | 435 | 725 | 1,300,000 | |
| No. 3 | 2" to 4" | 600 | 700 | 350 | 75 | 435 | 450 | 1,200,000 | |
| Appearance | wide | 1350 | 1500 | 750 | 75 | 435 | 1100 | 1,500,000 | |
| Stud | | 600 | 700 | 350 | 75 | 435 | 450 | 1,200,000 | |
| Construction | 2" to 4" | 800 | 925 | 475 | 75 | 435 | 825 | 1,200,000 | |
| Standard | thick | 450 | 500 | 250 | 75 | 435 | 675 | 1,200,000 | |
| Utility | 4" wide | 200 | 250 | 125 | 75 | 435 | 450 | 1,200,000 | 25-3 (See footnotes 2 through 9, 13, 15 and 16) |
| Select Structural | | 1350 | 1550 | 900 | 75 | 435 | 1000 | 1,500,000 | |
| No. 1 | 2" to 4" | 1150 | 1300 | 775 | 75 | 435 | 925 | 1,500,000 | |
| No. 2 | thick | 925 | 1050 | 500 | 75 | 435 | 775 | 1,300,000 | |
| No. 3 and Stud | 5" and | 525 | 600 | 275 | 75 | 435 | 500 | 1,200,000 | |
| Appearance | wider | 1150 | 1300 | 750 | 75 | 435 | 1100 | 1,500,000 | |
| Select Structural | Beams and | 1200 | — | 675 | 70 | 435 | 825 | 1,300,000 | |
| No. 1 | Stringers | 1000 | — | 500 | 70 | 435 | 675 | 1,300,000 | |
| Select Structural | Posts and | 1150 | — | 750 | 70 | 435 | 875 | 1,300,000 | |
| No. 1 | Timbers | 925 | — | 600 | 70 | 435 | 750 | 1,300,000 | |
| Select Dex | Decking | 1300 | 1500 | — | — | 435 | — | 1,500,000 | |
| Commercial Dex | | 1100 | 1250 | — | — | 435 | — | 1,300,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS. UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| SOUTHERN PINE (Surfaced at 15% moisture content, K.D. Used at 15% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 2150 | 2500 | 1250 | 105 | 565 | 1800 | 1,800,000 | 25-6 (See footnotes 3, 4, 9, 13, 15, 16, 18 and 19) |
| Dense Select Structural | | 2500 | 2900 | 1500 | 105 | 660 | 2100 | 1,900,000 | |
| No. 1 | | 1850 | 2100 | 1050 | 105 | 565 | 1450 | 1,800,000 | |
| No. 1 Dense | | 2150 | 2450 | 1250 | 105 | 660 | 1700 | 1,900,000 | |
| No. 2 | | 1550 | 1750 | 900 | 95 | 565 | 1150 | 1,600,000 | |
| No. 2 Dense | | 1800 | 2050 | 1050 | 95 | 660 | 1350 | 1,700,000 | |
| No. 3 | | 850 | 975 | 500 | 95 | 565 | 675 | 1,500,000 | |
| No. 3 Dense | | 1000 | 1150 | 575 | 95 | 660 | 800 | 1,500,000 | |
| Stud | | 850 | 975 | 500 | 95 | 565 | 675 | 1,500,000 | |
| Construction | 2" to 4" thick 4" wide | 1100 | 1250 | 650 | 105 | 565 | 1300 | 1,500,000 | |
| Standard | | 625 | 725 | 375 | 95 | 565 | 1050 | 1,500,000 | |
| Utility | | 275 | 300 | 175 | 95 | 565 | 675 | 1,500,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1850 | 2150 | 1200 | 95 | 565 | 1600 | 1,800,000 | |
| Dense Select Structural | | 2200 | 2500 | 1450 | 95 | 660 | 1850 | 1,900,000 | |
| No. 1 | | 1600 | 1850 | 1050 | 95 | 565 | 1450 | 1,800,000 | |
| No. 1 Dense | | 1850 | 2150 | 1250 | 95 | 660 | 1700 | 1,900,000 | |
| No. 2 | | 1300 | 1500 | 675 | 95 | 565 | 1200 | 1,600,000 | |
| No. 2 Dense | | 1550 | 1750 | 800 | 95 | 660 | 1400 | 1,700,000 | |
| No. 3 | | 750 | 875 | 400 | 95 | 565 | 725 | 1,500,000 | |
| No. 3 Dense | | 875 | 1000 | 450 | 95 | 660 | 850 | 1,500,000 | |
| Stud | | 800 | 900 | 400 | 95 | 565 | 725 | 1,500,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dense Standard Decking | 2" to 4" | 2150 | 2450 | 1250 | 105 | 660 | 1700 | 1,900,000 | |
| Select Decking | thick | 1550 | 1750 | 900 | 95 | 565 | 1150 | 1,600,000 | |
| Dense Select Decking | 2" and wider | 1800 | 2050 | 1050 | 95 | 660 | 1350 | 1,700,000 | |
| Commercial Decking | Decking | 1550 | 1750 | 900 | 95 | 565 | 1150 | 1,600,000 | 25-6 (See footnotes 4 9, 15, 16, 18 and 19) |
| Dense Commercial Decking | | 1800 | 2050 | 1050 | 95 | 660 | 1350 | 1,700,000 | |
| Dense Structural 86 | 2" to 4" | 2800 | 3250 | 1900 | 165 | 660 | 2300 | 1,900,000 | |
| Dense Structural 72 | thick | 2400 | 2750 | 1600 | 135 | 660 | 1950 | 1,900,000 | |
| Dense Structural 65 | | 2150 | 2450 | 1450 | 125 | 660 | 1750 | 1,900,000 | |
| KD-15 or MC-15 | | | | | | | | | |
| Industrial 86 KD | | 2400 | 2750 | 1600 | 160 | 415 | 1950 | 1,800,000 | |
| Dense Ind. 86 KD | | 2800 | 3250 | 1900 | 160 | 475 | 2300 | 1,900,000 | |
| Industrial 72 KD | 1" to 4" thick | 2050 | 2350 | 1350 | 135 | 415 | 1650 | 1,800,000 | |
| Dense Ind. 72 KD | | 2400 | 2750 | 1600 | 135 | 475 | 1950 | 1,900,000 | |
| Industrial 65 KD | | 1850 | 2100 | 1200 | 125 | 415 | 1500 | 1,800,000 | |
| Dense Ind. 65 KD | | 2150 | 2450 | 1400 | 125 | 475 | 1750 | 1,900,000 | |
| SOUTHERN PINE (Surfaced dry. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 2000 | 2300 | 1150 | 100 | 565 | 1550 | 1,700,000 | |
| Dense Select Structural | | 2350 | 2700 | 1350 | 100 | 660 | 1800 | 1,800,000 | |
| No. 1 | 2" to 4" | 1700 | 1950 | 1000 | 100 | 565 | 1250 | 1,700,000 | |
| No. 1 Dense | thick | 2000 | 2300 | 1150 | 100 | 660 | 1450 | 1,800,000 | |
| No. 2 | 2" to 4" | 1400 | 1650 | 825 | 90 | 565 | 975 | 1,600,000 | |
| No. 2 Dense | wide, | 1650 | 1900 | 975 | 90 | 660 | 1150 | 1,600,000 | |
| No. 3 | | 775 | 900 | 450 | 90 | 565 | 575 | 1,400,000 | 25-6 |
| No. 3 Dense | | 925 | 1050 | 525 | 90 | 660 | 675 | 1,500,000 | (See footnotes 2 4, 9, 13, 15, 16, 18 and 19) |
| Stud | | 775 | 900 | 450 | 90 | 565 | 575 | 1,400,000 | |
| Construction | 2" to 4" | 1000 | 1150 | 600 | 100 | 565 | 1100 | 1,400,000 | |
| Standard | thick | 575 | 675 | 350 | 90 | 565 | 900 | 1,400,000 | |
| Utility | 4" wide | 275 | 300 | 150 | 90 | 565 | 575 | 1,400,000 | |
| Select Structural | | 1750 | 2000 | 1150 | 90 | 565 | 1350 | 1,700,000 | |
| Dense Select Structural | | 2050 | 2350 | 1300 | 90 | 660 | 1600 | 1,800,000 | |
| No. 1 | 2" to 4" | 1450 | 1700 | 975 | 90 | 565 | 1250 | 1,700,000 | |
| No. 1 Dense | thick | 1700 | 2000 | 1150 | 90 | 660 | 1450 | 1,800,000 | |
| No. 2 | 5" and | 1200 | 1400 | 625 | 90 | 565 | 1000 | 1,600,000 | |
| No. 2 Dense | wider | 1400 | 1650 | 725 | 90 | 660 | 1200 | 1,600,000 | |
| No. 3 | | 700 | 800 | 350 | 90 | 565 | 625 | 1,400,000 | |
| No. 3 Dense | | 825 | 925 | 425 | 90 | 660 | 725 | 1,500,000 | |
| Stud | | 725 | 850 | 350 | 90 | 565 | 625 | 1,400,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504.)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS. UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression Perpendicular to Grain $F_{c\perp}$[21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$[21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Dense Standard Decking | 2" to 4" | 2000 | 2300 | 1150 | 100 | 660 | 1450 | 1,800,000 | 25-6 (See footnotes 3, 4, 9, 13, 15, 16, 17, 18 and 19) |
| Select Decking | thick | 1400 | 1650 | 825 | 90 | 565 | 975 | 1,600,000 | |
| Dense Select Decking | 2" and wider | 1650 | 1900 | 975 | 90 | 660 | 1150 | 1,600,000 | |
| Commercial Decking | Decking | 1400 | 1650 | 825 | 90 | 565 | 975 | 1,600,000 | |
| Dense Commercial Decking | Decking | 1650 | 1900 | 975 | 90 | 660 | 1150 | 1,600,000 | |
| Dense Structural 86 | 2" to 4" | 2600 | 3000 | 1750 | 155 | 660 | 2000 | 1,800,000 | |
| Dense Structural 72 | thick | 2200 | 2550 | 1450 | 130 | 660 | 1650 | 1,800,000 | |
| Dense Structural 65 | | 2000 | 2800 | 1300 | 115 | 660 | 1500 | 1,800,000 | |
| KD-19 or S-Dry | | | | | | | | | |
| Industrial 86 | | 2250 | 2600 | 1500 | 155 | 415 | 1700 | 1,700,000 | |
| Dense Ind. 86 | | 2600 | 3000 | 1750 | 155 | 475 | 2000 | 1,800,000 | |
| Industrial 72 | 1" to 4" thick | 1900 | 2200 | 1250 | 130 | 415 | 1400 | 1,700,000 | |
| Dense Ind. 72 | | 2200 | 2550 | 1450 | 130 | 475 | 1650 | 1,800,000 | |
| Industrial 65 | | 1700 | 1950 | 1100 | 115 | 415 | 1250 | 1,700,000 | |
| Dense Ind. 65 | | 2000 | 2300 | 1300 | 115 | 475 | 1500 | 1,800,000 | |
| SOUTHERN PINE (Surfaced green. Used any condition.) | | | | | | | | | |
| Select Structural | | 1600 | 1850 | 925 | 95 | 375 | 1050 | 1,500,000 | |
| Dense Select Structural | | 1850 | 2150 | 1100 | 95 | 440 | 1200 | 1,600,000 | |
| No. 1 | 2½" to 4" | 1350 | 1550 | 800 | 95 | 375 | 825 | 1,500,000 | |
| No. 1 Dense | thick | 1600 | 1800 | 925 | 95 | 440 | 950 | 1,600,000 | |
| No. 2 | 2½" to 4" | 1150 | 1300 | 675 | 85 | 375 | 650 | 1,400,000 | |
| No. 2 Dense | wide | 1350 | 1500 | 775 | 85 | 440 | 750 | 1,400,000 | |
| No. 3 | | 625 | 725 | 375 | 85 | 375 | 400 | 1,200,000 | |
| No. 3 Dense | | 725 | 850 | 425 | 85 | 440 | 450 | 1,300,000 | |
| Stud | | 625 | 725 | 375 | 85 | 375 | 400 | 1,200,000 | |
| Construction | 2½" to 4" | 825 | 925 | 475 | 95 | 375 | 725 | 1,200,000 | |
| Standard | thick | 475 | 525 | 275 | 85 | 375 | 600 | 1,200,000 | |
| Utility | 4" wide | 200 | 259 | 125 | 85 | 375 | 400 | 1,200,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural | | 1400 | 1600 | 900 | 85 | 375 | 900 | 1,500,000 | |
| Dense Select Structural | | 1600 | 1850 | 1050 | 85 | 440 | 1050 | 1,600,000 | |
| No. 1 | | 1200 | 1350 | 775 | 85 | 375 | 825 | 1,500,000 | |
| No. 1 Dense | 2½" to 4" | 1400 | 1600 | 925 | 85 | 440 | 950 | 1,600,000 | |
| No. 2 | thick | 975 | 1100 | 500 | 85 | 375 | 675 | 1,400,000 | |
| No. 2 Dense | 5" and | 1150 | 1300 | 600 | 85 | 440 | 800 | 1,400,000 | |
| No. 3 | wider | 550 | 650 | 300 | 85 | 375 | 425 | 1,200,000 | |
| No. 3 Dense | | 650 | 750 | 350 | 85 | 440 | 475 | 1,300,000 | |
| Stud | | 575 | 675 | 300 | 85 | 375 | 425 | 1,200,000 | |
| Dense Standard Decking | 2½" to 4 | 1600 | 1800 | 925 | 95 | 440 | 950 | 1,600,000 | 25-6 |
| Select Decking | thick | 1150 | 1300 | 675 | 85 | 375 | 650 | 1,400,000 | (See foot- |
| Dense Select Decking | 2" and wider | 1350 | 1500 | 775 | 85 | 440 | 750 | 1,400,000 | notes 3, |
| Commercial Decking | Decking | 1150 | 1300 | 675 | 85 | 375 | 650 | 1,400,000 | 4, 9, 13, |
| Dense Commercial Decking | | 1350 | 1500 | 775 | 85 | 440 | 750 | 1,400,000 | 15, 16, 17, 18 and 19) |
| No. 1 SR | | 1350 | — | 875 | 110 | 375 | 775 | 1,500,000 | |
| No. 1 Dense SR | 5" and | 1550 | — | 1050 | 110 | 440 | 925 | 1,600,000 | |
| No. 2 SR | thicker | 1100 | — | 725 | 95 | 375 | 625 | 1,400,000 | |
| No. 2 Dense SR | | 1250 | — | 850 | 95 | 440 | 725 | 1,400,000 | |
| Dense Structural 86 | 2½" and | 2100 | 2400 | 1400 | 145 | 440 | 1300 | 1,600,000 | |
| Dense Structural 72 | thicker | 1750 | 2050 | 1200 | 120 | 440 | 1100 | 1,600,000 | |
| Dense Structural 65 | | 1600 | 1800 | 1050 | 110 | 440 | 1000 | 1,600,000 | |
| MC over 19% | | | | | | | | | |
| Industrial 86 | | 1800 | 2050 | 1200 | 140 | 270 | 1150 | 1,500,000 | |
| Dense Ind. 86 | | 2100 | 2400 | 1400 | 140 | 315 | 1300 | 1,600,000 | |
| Industrial 72 | 2½" and | 1500 | 1750 | 1000 | 120 | 270 | 950 | 1,500,000 | |
| Dense Ind. 72 | thicker | 1750 | 2050 | 1200 | 120 | 315 | 1100 | 1,600,000 | |
| Industrial 65 | | 1350 | 1500 | 900 | 110 | 270 | 850 | 1,500,000 | |
| Dense Ind. 65 | | 1600 | 1800 | 1050 | 110 | 315 | 1000 | 1,600,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| SPRUCE—PINE—FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | | 1450 | 1650 | 850 | 70 | 425 | 1100 | 1,500,000 | |
| No. 1 | 2" to 4" | 1200 | 1400 | 725 | 70 | 425 | 875 | 1,500,000 | |
| No. 2 | thick | 1000 | 1150 | 600 | 70 | 425 | 675 | 1,300,000 | |
| No. 3 | 2" to 4" | 550 | 650 | 325 | 70 | 425 | 425 | 1,200,000 | |
| Appearance | wide | 1200 | 1400 | 700 | 70 | 425 | 1050 | 1,500,000 | |
| Stud | | 550 | 650 | 325 | 70 | 425 | 425 | 1,200,000 | |
| Construction | 2" to 4" | 725 | 850 | 425 | 70 | 425 | 775 | 1,200,000 | |
| Standard | thick | 400 | 475 | 225 | 70 | 425 | 650 | 1,200,000 | |
| Utility | 4" wide | 175 | 225 | 100 | 70 | 425 | 425 | 1,200,000 | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| Select Structural | | 1250 | 1450 | 825 | 70 | 425 | 975 | 1,500,000 | |
| No. 1 | 2" to 4" | 1050 | 1200 | 700 | 70 | 425 | 875 | 1,500,000 | |
| No. 2 | thick | 875 | 1000 | 450 | 70 | 425 | 725 | 1,300,000 | |
| No. 3 and Stud | 5" and | 500 | 575 | 275 | 70 | 425 | 450 | 1,200,000 | |
| Appearance | wider | 1050 | 1200 | 700 | 70 | 425 | 1050 | 1,500,000 | |
| Select Structural | Beams and | 1100 | — | 650 | 65 | 425 | 775 | 1,300,000 | |
| No. 1 | Stringers | 900 | — | 450 | 65 | 425 | 625 | 1,300,000 | |
| Select Structural | Posts and | 1050 | — | 700 | 65 | 425 | 800 | 1,300,000 | |
| No. 1 | Timbers | 850 | — | 550 | 65 | 425 | 700 | 1,300,000 | |
| Select | Decking | 1200 | 1400 | — | — | 425 | — | 1,500,000 | |
| Commercial | | 1000 | 1150 | — | — | 425 | — | 1,300,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WESTERN CEDARS (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| WESTERN CEDARS (NORTH) | | | | | | | | | |
| Select Structural | | 1500 | 1750 | 875 | 75 | 425 | 1200 | 1,100,000 | |
| No. 1 | 2" to 3" | 1300 | 1500 | 750 | 75 | 425 | 950 | 1,100,000 | |
| No. 2 | thick | 1050 | 1200 | 625 | 75 | 425 | 750 | 1,000,000 | |
| No. 3 | 2" to 4" | 600 | 675 | 350 | 75 | 425 | 450 | 900,000 | |
| Appearance | wide | 1300 | 1500 | 750 | 75 | 425 | 1100 | 1,100,000 | |
| Stud | | 600 | 675 | 350 | 75 | 425 | 450 | 900,000 | 25-2, 25-3 and 25-4 |
| Construction | 2" to 4" | 775 | 875 | 450 | 75 | 425 | 850 | 900,000 | (See footnotes |
| Standard | thick | 425 | 500 | 250 | 75 | 425 | 700 | 900,000 | 2 through 9, |
| Utility | 4" wide | 200 | 225 | 125 | 75 | 425 | 450 | 900,000 | 11, 12 and 13) |
| Select Structural | | 1300 | 1500 | 825 | 75 | 425 | 1050 | 1,100,000 | |
| No. 1 | 2" to 4" | 1100 | 1300 | 750 | 75 | 425 | 950 | 1,100,000 | |
| No. 2 | thick | 925 | 1050 | 475 | 75 | 425 | 800 | 1,000,000 | |
| No. 3 and Stud | 5" and | 525 | 625 | 275 | 75 | 425 | 500 | 900,000 | |
| Appearance | wider | 1100 | 1300 | 750 | 75 | 425 | 1100 | 1,100,000 | |
| Select Structural | Beams and | 1150 | — | 675 | 70 | 425 | 875 | 1,000,000 | 25-2 |
| No. 1 | Stringers | 925 | — | 475 | 70 | 425 | 725 | 1,000,000 | and 25-3 |
| Select Structural | Posts and | 1050 | — | 700 | 70 | 425 | 900 | 1,000,000 | (See footnotes |
| No. 1 | Timbers | 850 | — | 575 | 70 | 425 | 800 | 1,000,000 | 2 through 9, 11 and 12) |
| Select Dex | Decking | 1200 | 1400 | — | — | 425 | — | 1,100,000 | 25-3 |
| Commercial Dex | | 1050 | 1200 | — | — | 425 | — | 1,000,000 | (See footnotes 2 through 9) |
| Select | | 1200 | 1400 | — | — | 425 | — | 1,100,000 | 25-2 |
| Commercial | Decking | 1050 | 1200 | — | — | 425 | — | 1,000,000 | (See footnotes 2 through 9 and 11 |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
### Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
### (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| Select Structural | Beams and Stringers | 1150 | — | 700 | 70 | 425 | 875 | 1,000,000 | 25-4 (See footnotes 2 through 10) |
| No. 1 | | 975 | — | 475 | 70 | 425 | 725 | 1,000,000 | |
| No. 2 | | 625 | — | 325 | 70 | 425 | 475 | 800,000 | |
| Select Structural | Posts and Timbers | 1100 | — | 725 | 70 | 425 | 925 | 1,000,000 | |
| No. 1 | | 875 | — | 600 | 70 | 425 | 800 | 1,000,000 | |
| No. 2 | | 500 | — | 350 | 70 | 425 | 375 | 800,000 | |
| Selected Decking | Decking | — | 1450 | — | — | — | — | 1,100,000 | |
| Commercial Decking | | — | 1200 | — | — | — | — | 1,000,000 | |
| Selected Decking | Decking | — | 1550 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,100,000 | |
| Commercial Decking | | — | 1300 | | | | | 1,000,000 | |
| WESTERN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | 25-2 (See footnote 11) 25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16) |
| WESTERN HEMLOCK (NORTH) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1800 | 2100 | 1050 | 90 | 410 | 1450 | 1,600,000 | |
| No. 1 | | 1550 | 1800 | 900 | 90 | 410 | 1150 | 1,600,000 | |
| No. 2 | | 1300 | 1450 | 750 | 90 | 410 | 900 | 1,400,000 | |
| No. 3 | | 700 | 800 | 425 | 90 | 410 | 550 | 1,300,000 | |
| Appearance | | 1550 | 1800 | 900 | 90 | 410 | 1350 | 1,600,000 | |
| Stud | | 700 | 800 | 425 | 90 | 410 | 550 | 1,300,000 | |
| Construction | 2" to 4" thick 4" wide | 925 | 1050 | 550 | 90 | 410 | 1050 | 1,300,000 | |
| Standard | | 525 | 600 | 300 | 90 | 410 | 850 | 1,300,000 | |
| Utility | | 250 | 275 | 150 | 90 | 410 | 550 | 1,300,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Select Structural<br>No. 1<br>No. 2<br>No. 3 and Stud<br>Appearance | 2" to 4" thick 5" and wider | 1550<br>1350<br>1100<br>650<br>1350 | 1800<br>1550<br>1250<br>750<br>1550 | 1050<br>900<br>575<br>325<br>900 | 90<br>90<br>90<br>90<br>90 | 410<br>410<br>410<br>410<br>410 | 1300<br>1150<br>975<br>625<br>1350 | 1,600,000<br>1,600,000<br>1,400,000<br>1,300,000<br>1,600,000 | 25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16) |
| Select Structural<br>No. 1 | Beams and Stringers | 1400<br>1150 | — | 825<br>575 | 85<br>85 | 410<br>410 | 1000<br>850 | 1,400,000<br>1,400,000 | 25-3 (See footnotes 2 through 9) |
| Select Structural<br>No. 1 | Posts and Timbers | 1300<br>1050 | — | 875<br>700 | 85<br>85 | 410<br>410 | 1100<br>950 | 1,400,000<br>1,400,000 | |
| Select Dex<br>Commercial Dex | Decking | 1500<br>1300 | 1750<br>1450 | —<br>— | —<br>— | 410<br>410 | —<br>— | 1,600,000<br>1,400,000 | |
| Select Structural<br>No. 1<br>No. 2 | Beams and Stringers | 1400<br>1150<br>750 | —<br>—<br>— | 825<br>575<br>375 | 85<br>85<br>85 | 410<br>410<br>410 | 1000<br>850<br>550 | 1,400,000<br>1,400,000<br>1,100,000 | 25-4 (See footnotes 2 through 10) |
| Select Structural<br>No. 1<br>No. 2 | Posts and Timbers | 1300<br>1050<br>600 | —<br>—<br>— | 875<br>700<br>400 | 85<br>85<br>85 | 410<br>410<br>410 | 1100<br>950<br>425 | 1,400,000<br>1,400,000<br>1,100,000 | |
| Selected Decking<br>Commercial Decking | Decking | | 1750<br>1450 | | | | | 1,600,000<br>1,400,000 | |
| Selected Decking<br>Commercial Decking | Decking | | 1900<br>1600 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,700,000<br>1,500,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression perpendicular to Grain $F_{c\perp}$ [21] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [21] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| WESTERN WHITE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1350 | 1550 | 775 | 65 | 375 | 1100 | 1,400,000 | 25-2 (See footnotes 2 through 9, 11, 13, 15 and 16) |
| No. 1 | | 1150 | 1300 | 675 | 65 | 375 | 875 | 1,400,000 | |
| No. 2 | | 925 | 1050 | 550 | 65 | 375 | 675 | 1,300,000 | |
| No. 3 | | 525 | 600 | 300 | 65 | 375 | 425 | 1,200,000 | |
| Appearance | | 1150 | 1300 | 650 | 65 | 375 | 1050 | 1,400,000 | |
| Stud | | 525 | 600 | 300 | 65 | 375 | 425 | 1,200,000 | |
| Construction | 2" to 4" thick 4" wide | 675 | 775 | 400 | 65 | 375 | 775 | 1,200,000 | |
| Standard | | 375 | 425 | 225 | 65 | 375 | 650 | 1,200,000 | |
| Utility | | 175 | 200 | 100 | 65 | 375 | 425 | 1,200,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1150 | 1300 | 775 | 65 | 375 | 975 | 1,400,000 | |
| No. 1 | | 975 | 1150 | 650 | 65 | 375 | 875 | 1,400,000 | |
| No. 2 | | 800 | 925 | 425 | 65 | 375 | 725 | 1,300,000 | |
| No. 3 and Stud | | 475 | 550 | 250 | 65 | 375 | 450 | 1,200,000 | |
| Appearance | | 975 | 1150 | 650 | 65 | 375 | 1050 | 1,400,000 | |
| Select Structural | Beams and Stringers | 1050 | — | 600 | 60 | 375 | 775 | 1,300,000 | |
| No. 1 | | 850 | — | 425 | 60 | 375 | 625 | 1,300,000 | |
| Select Structural | Posts and Timbers | 975 | — | 650 | 60 | 375 | 800 | 1,300,000 | |
| No. 1 | | 775 | — | 525 | 60 | 375 | 700 | 1,300,000 | |
| Select | Decking | 1100 | 1300 | — | — | 375 | — | 1,400,000 | |
| Commercial | | 925 | 1050 | — | — | 375 | — | 1,300,000 | |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WHITE WOODS (WESTERN WOODS) (Surfaced dry or surfaced green. Used at 19% max. m.c.). (MIXED SPECIES) (WEST COAST WOODS) | | | | | | | | | |
| Select Structural | 2" to 4" thick 2" to 4" wide | 1350 | 1550 | 775 | 70 | 315 | 950 | 1,100,000 | |
| No. 1 | | 1150 | 1300 | 650 | 70 | 315 | 750 | 1,100,000 | |
| No. 2 | | 925 | 1050 | 550 | 70 | 315 | 600 | 1,000,000 | |
| No. 3 | | 525 | 600 | 300 | 70 | 315 | 375 | 900,000 | |
| Appearance | | 1150 | 1300 | 650 | 70 | 315 | 900 | 1,100,000 | |
| Stud | | 525 | 600 | 300 | 70 | 315 | 375 | 900,000 | |
| Construction | 2" to 4" thick 4" wide | 675 | 775 | 400 | 70 | 315 | 675 | 900,000 | |
| Standard | | 375 | 425 | 225 | 70 | 315 | 550 | 900,000 | |
| Utility | | 175 | 200 | 100 | 70 | 315 | 375 | 900,000 | |
| Select Structural | 2" to 4" thick 5" and wider | 1150 | 1300 | 775 | 70 | 315 | 850 | 1,100,000 | 25-4 (See footnotes 2 through 10, 13, 15 and 16) |
| No. 1 | | 975 | 1100 | 650 | 70 | 315 | 750 | 1,100,000 | |
| No. 2 | | 800 | 925 | 425 | 70 | 315 | 625 | 1,000,000 | |
| No. 3 and Stud | | 475 | 550 | 250 | 70 | 315 | 400 | 900,000 | |
| Appearance | | 975 | 1100 | 650 | 70 | 315 | 900 | 1,100,000 | |
| Select Structural | Beams and Stringers | 1000 | — | 600 | 65 | 315 | 675 | 1,000,000 | |
| No. 1 | | 850 | — | 425 | 65 | 315 | 550 | 1,000,000 | |
| No. 2 | | 550 | — | 275 | 65 | 315 | 350 | 800,000 | |
| Select Structural | Posts and Timbers | 950 | — | 650 | 65 | 315 | 700 | 1,000,000 | |
| No. 1 | | 775 | — | 525 | 65 | 315 | 625 | 1,000,000 | |
| No. 2 | | 450 | — | 300 | 65 | 315 | 275 | 800,000 | |
| Selected Decking | Decking | — | 1300 | — | — | — | — | 1,100,000 | |
| Commercial Decking | | — | 1050 | — | — | — | — | 1,000,000 | |
| Selected Decking | Decking | — | 1400 | (Surfaced at 15% max. m.c. and used at 15% max. m.c.) | | | | 1,100,000 | |
| Commercial Decking | | — | 1150 | | | | | 1,000,000 | |

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## TABLE NO. 25-A-1—ALLOWABLE UNIT STRESSES—STRUCTURAL LUMBER—(Continued)
## Allowable Unit Stresses for Structural Lumber—VISUAL GRADING
## (Normal loading. See also Section 2504.)

| SPECIES AND COMMERCIAL GRADE | SIZE CLASSIFICATION | ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH | | | | | | | U.B.C. STDS. UNDER WHICH GRADED |
|---|---|---|---|---|---|---|---|---|---|
| | | EXTREME FIBER IN BENDING $F_b$ | | Tension Parallel to Grain $F_t$ | Horizontal Shear $F_v$ | Compression Perpendicular to Grain $F_{c\perp}$[2,1] | Compression Parallel to Grain $F_c$ | MODULUS OF ELASTICITY $E$ [2,1] | |
| | | Single-member Uses | Repetitive-member Uses | | | | | | |
| YELLOW-POPLAR (Surfaced dry or surfaced green. Used at 19% max. m.c.) | | | | | | | | | |
| Select Structural | 2" to 3" | 1500 | 1700 | 875 | 80 | 420 | 1050 | 1,500,000 | |
| No. 1 | thick | 1250 | 1450 | 750 | 80 | 420 | 825 | 1,500,000 | |
| No. 2 | 2" to 4" | 1050 | 1200 | 625 | 75 | 420 | 650 | 1,300,000 | |
| No. 3 | wide | 575 | 675 | 350 | 75 | 420 | 400 | 1,200,000 | |
| Stud | | 575 | 675 | 350 | 75 | 420 | 400 | 1,200,000 | |
| Construction | 2" to 4" | 750 | 875 | 450 | 80 | 420 | 750 | 1,200,000 | 25-5 |
| Standard | thick | 425 | 500 | 250 | 75 | 420 | 625 | 1,200,000 | (See foot- |
| Utility | 4" wide | 200 | 225 | 125 | 75 | 420 | 400 | 1,200,000 | notes 1 |
| Select Structural | 2" to 4" | 1300 | 1500 | 850 | 75 | 420 | 925 | 1,500,000 | through 9 |
| No. 1 | thick | 1100 | 1250 | 725 | 75 | 420 | 825 | 1,500,000 | |
| No. 2 | 5" and | 900 | 1050 | 475 | 75 | 420 | 700 | 1,300,000 | |
| No. 3 | wider | 525 | 600 | 275 | 75 | 420 | 425 | 1,200,000 | |
| Appearance | | 1100 | 1250 | 725 | 75 | 420 | 1000 | 1,500,000 | |
| Stud | | 525 | 600 | 275 | 75 | 420 | 425 | 1,200,000 | |

[1]Where eastern spruce and balsam fir are shipped in a combination, the tabulated values for balsam fir shall apply.

[2]The design values shown in Table No. 25-A-1 are applicable to lumber that will be used under dry conditions such as in most covered structures. For 2-inch- to 4-inch-thick lumber the DRY surfaced size shall be used. In calculating design values, the natural gain in strength and stiffness that occurs as lumber dries has been taken into consideration as well as the reduction in size that occurs when unseasoned lumber shrinks. The gain in load-carrying capacity due to increased strength and stiffness resulting from drying more than offsets the design effect of size reductions due to shrinkage. For 5-inch and thicker lumber, the surfaced sizes also may be used because design values have been adjusted to compensate for any loss in size by shrinkage which may occur.



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[3]Values for $F_b$, $F_t$ and $F_c$ for the grades of Construction, Standard and Utility apply only to 4-inch widths.

[4]The values in Table No. 25-A-1 for dimension 2 inches to 4 inches are based on edgewise use. Where such lumber is used flatwise, the recommended design values for extreme fiber stress in bending may be multiplied by the following factors:

| WIDTH | THICKNESS | | |
|---|---|---|---|
| | 2" | 3" | 4" |
| 2 inches to 4 inches | 1.10 | 1.04 | 1.00 |
| 5 inches and wider | 1.22 | 1.16 | 1.11 |

Values for decking may be increased by 10 percent for 2-inch decking and 4 pereent for 3-inch decking.

[5]When 2-inch- to 4-inch-thick lumber is manufactured at a maximum moisture content of 15 percent and used in a condition where the moisture content does not exceed 15 percent, the design values shown in Table No. 25-A-1 for surfaced dry and surfaced green may be multiplied by the following factors:

| EXTREME FIBER IN BENDING $F_b$ | TENSION PARALLEL TO GRAIN $F_t$ | HORIZONTAL SHEAR $F_v$ | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ | COMPRESSION PARALLEL TO GRAIN $F_c$ | MODULUS OF ELASTICITY $E$ |
|---|---|---|---|---|---|
| 1.08 | 1.08 | 1.05 | 1.00 | 1.17* | 1.05* |

*For redwood use 1.15 for $F_c$ and 1.04 for $E$.

[6]When 2-inch- to 4-inch-thick lumber is designed for use where the moisture content will exceed 19 percent for an extended period of time, the values shown in Table No. 25-A-1 shall be multiplied by the following factors:

| EXTREME FIBER IN BENDING $F_b$ | TENSION PARALLEL TO GRAIN $F_t$ | HORIZONTAL SHEAR $F_v$ | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ | COMPRESSION PARALLEL TO GRAIN $F_c$ | MODULUS OF ELASTICITY $E$ |
|---|---|---|---|---|---|
| 0.86 | 0.84 | 0.97 | 0.67 | 0.70 | 0.97 |

*(Continued)*



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## FOOTNOTES FOR TABLE NO. 25-A-1

[7]When lumber 5 inches and thicker is designed for use where the moisture content will exceed 19 percent for an extended period of time, the values shown in Table No. 25-A-1 shall be multiplied by the following factors:

| EXTREME FIBER IN BENDING $F_b$ | TENSION PARALLEL TO GRAIN $F_t$ | HORIZONTAL SHEAR $F_v$ | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ | COMPRESSION PARALLEL TO GRAIN $F_c$ | MODULUS OF ELASTICITY $E$ |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 0.67 | 0.91 | 1.00 |

[8]Specific horizontal shear values may be established by using the following tables when the length of split or check is known:

| WHEN LENGTH OF SPLIT ON WIDE FACE IS: | MULTIPLY TABULATED $F_v$ VALUE BY: (NOMINAL 2-INCH) LUMBER) |
|---|---|
| No split | 2.00 |
| 1/2 x wide face | 1.67 |
| 3/4 x wide face | 1.50 |
| 1 x wide face | 1.33 |
| 1 1/2 x wide face or more | 1.00 |

| WHEN LENGTH OF SPLIT ON WIDE FACE IS: | MULTIPLY TABULATED $F_v$ VALUE BY: (3-INCH AND THICKER LUMBER) |
|---|---|
| No split | 2.00 |
| 1/2 x narrow face | 1.67 |
| 1 x narrow face | 1.33 |
| 1 1/2 x narrow face or more | 1.00 |

[9]Stress-rated boards of nominal 1-inch, 1 1/4-inch and 1 1/2-inch thickness, 2 inches and wider, are permitted the recommended design values shown for Select Structural, No. 1, No. 2, No. 3, Construction, Standard, Utility, Appearance, Clear Heart Structural and Clear Structural grades as shown in the 2-inch- to 4-inch-thick categories herein, where graded in accordance with the stress-rated board provisions in the applicable grading rules.



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[10]When decking is used where the moisture content will exceed 15 percent for an extended period of time, the tabulated design values shall be multiplied by the following factors: Extreme Fiber in Bending $F_b$ – 0.79; Modulus of Elasticity $E$ – 0.92.

[11]Where lumber is graded under U.B.C. Standard No. 25-2 values shown for Select Structural, No. 1, No. 2, No. 3, and Stud grades are not applicable to 3-inch x 4-inch and 4-inch x 4-inch sizes.

[12]Lumber in the beam and stringer or post and timber size classification may be assigned different working stresses for the same grade name and species based upon the grading rules of the specific agency involved. It is therefore necessary that the grading rule agency be identified to properly correlate permitted design stresses with the grade mark.

[13]Utility grades of all species may be used only under conditions specifically approved by the building official.

[14]A horizontal shear $F_v$ of 70 may be used for eastern white pine graded under U.B.C. Standards No. 25-5 and No. 25-8 (grading rules of Northern Hardwood and Pine Manufacturers, Inc. and Northeastern Lumber Manufacturers Association, Inc.).

[15]Tabulated tension parallel to grain values for species 5 inches and wider, 2 inches to 4 inches thick (and 2½ inches to 4 inches thick) size classifications apply to 5-inch and 6-inch widths only, for grades of Select Structural, No. 1, No. 2, No. 3, Appearance and Stud (including dense grades). For lumber wider than 6 inches in these grades, the tabulated $F_t$ values shall be multiplied by the following factors:

| GRADE (2 inches to 4 inches thick, 5 inches and wider) (2½ inches to 4 inches thick, 5 inches and wider) (includes "Dense" grades) | Multiply tabulated $F_t$ values by: 5 inches and 6 inches wide | 8 inches wide | 10 inches and wider |
|---|---|---|---|
| Select Structural | 1.00 | 0.90 | 0.80 |
| No. 1, No. 2, No. 3 and Appearance | 1.00 | 0.80 | 0.60 |
| Stud | 1.00 | | |

[16]Design values for all species of Stud grade in 5-inch and wider size classifications apply to 5-inch and 6-inch widths only.

[17]Repetitive member design values for extreme fiber in bending for southern pine grades of Dense Structural 86, 72 and 65 apply to 2-inch to 4-inch thicknesses only.

[18]When 2-inch- to 4-inch-thick southern pine lumber is surfaced dry or at 15 percent maximum moisture content (KD) and is designed for use where the moisture content will exceed 19 percent for an extended period of time, the design values in Table No. 25-A-1 for the corresponding grades of 2½-inch- to 4-inch-thick surfaced green southern pine lumber shall be used. The net green size may be used in such designs.

[19]When 2-inch- to 4-inch-thick southern pine lumber is surfaced dry or at 15 percent maximum moisture content (KD) and is designed for use under dry conditions, such as in most covered structures, the net DRY size shall be used in design. For other sizes and conditions of use, the net green size may be used in design.

[20]Values apply only to ponderosa pine graded under U.B.C. Standard No. 25-2.

[21]The duration of load modification factors given in Section 2504 (c) 4 shall not apply.





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## TABLE NO. 25-A-2—ALLOWABLE UNIT STRESSES FOR MACHINE STRESS RATED STRUCTURAL LUMBER

(Values listed are for normal loading conditions.[8] See also Section 2504.[8])

| Grade Designation[10] | Grading Rules U.B.C. Std. No. (See footnotes 1, 2, 3, 4) | Size Classification | Design values in pounds square inch[9] | | | | |
|---|---|---|---|---|---|---|---|
| | | | Extreme fiber in bending $F_b$[7] | | Tension parallel to grain $F_t$ | Compression parallel to grain $F_c$ | Modulus of elasticity $E$ |
| | | | Single-member uses | Repetitive-member uses | | | |
| 900f-1.0E | 3, 4 | Machine-rated lumber 2" thick or less All widths | 900 | 1050 | 350 | 725 | 1,000,000 |
| 1200f-1.2E | 1, 2, 3, 4 | | 1200 | 1400 | 600 | 950 | 1,200,000 |
| 1350f-1.3E | 2, 4 | | 1350 | 1550 | 750 | 1075[11] | 1,300,000 |
| 1450f-1.3E | 1, 3, 4 | | 1450 | 1650 | 800 | 1150 | 1,300,000 |
| 1500f-1.3E | 2 | | 1500 | 1750 | 900 | 1200 | 1,300,000 |
| 1500f-1.4E | 1, 2, 3, 4 | | 1500 | 1750 | 900 | 1200 | 1,400,000 |
| 1650f-1.4E | 2 | | 1650 | 1900 | 1020 | 1320 | 1,400,000 |
| 1650f-1.5E | 1, 2, 3, 4 | | 1650 | 1900 | 1020 | 1320 | 1,500,000 |
| 1800f-1.6E | 1, 2, 3, 4 | | 1800 | 2050 | 1175 | 1450 | 1,600,000 |
| 1950f-1.5E | 2 | | 1950 | 2250 | 1375 | 1550 | 1,500,000 |
| 1950f-1.7E | 1, 2, 4 | | 1950 | 2250 | 1375 | 1550 | 1,700,000 |
| 2100f-1.8E | 1, 2, 3, 4 | | 2100 | 2400 | 1575 | 1700 | 1,800,000 |
| 2250f-1.6E | 2 | | 2250 | 2600 | 1750 | 1800 | 1,600,000 |
| 2250f-1.9E | 1, 2, 4 | | 2250 | 2600 | 1750 | 1800 | 1,900,000 |
| 2400f-1.7E | 2 | | 2400 | 2750 | 1925 | 1925 | 1,700,000 |
| 2400f-2.0E | 1, 2, 3, 4 | | 2400 | 2750 | 1925 | 1925 | 2,000,000 |
| 2550f-2.1E | 1, 2, 4 | | 2550 | 2950 | 2050 | 2050 | 2,100,000 |
| 2700f-2.2E | 1, 2, 3, 4 | | 2700 | 3100 | 2150 | 2150 | 2,200,000 |
| 2850f-2.3E | 2 | | 2850 | 3300 | 2300 | 2300 | 2,300,000 |
| 3000f-2.4E | 1, 2 | | 3000 | 3450 | 2400 | 2400 | 2,400,000 |
| 3150f-2.5E | 2 | | 3150 | 3600 | 2500 | 2500 | 2,500,000 |
| 3300f-2.6E | 2 | | 3300 | 3800 | 2650 | 2650 | 2,600,000 |
| 900f-1.0E | 1, 2, 3 | See footnote 5 | 900 | 1050 | 350 | 725 | 1,000,000 |
| 900f-1.2E | 1, 2, 3 | | 900 | 1050 | 350 | 725 | 1,200,000 |
| 1200f-1.5E | 1, 2, 3 | | 1200 | 1400 | 600 | 950 | 1,500,000 |
| 1350f-1.8E | 1, 2 | | 1350 | 1550 | 750 | 1075 | 1,800,000 |
| 1500f-1.8E | 3 | | 1500 | 1750 | 900 | 1200 | 1,800,000 |
| 1800f-2.1E | 1, 2, 3 | | 1800 | 2050 | 1175 | 1450 | 2,100,000 |

[1]U.B.C. Standard No. 25-2.
[2]U.B.C. Standard No. 25-6.



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[3]U.B.C. Standard No. 25-3.
[4]U.B.C. Standard No. 25-4.
[5]Size classifications for these grades are:
U.B.C. Standard No. 25-2—Machine Rated Lumber; 2" thick or less, all widths.
U.B.C. Standard No. 25-6—Machine Rated Lumber; 2" thick or less, all widths.
U.B.C. Standard No. 25-3—Machine Rated Joists; 2" thick or less, 6" and wider.
[6]Stresses apply for lumber used at 19 percent maximum moisture content. Where moisture content exceeds 19 percent, the tabulated design values shall be modified as specified in Section 2504 (c) 10.
[7]Tabulated extreme fiber in bending values $F_b$ are applicable to lumber loaded on edge. When loaded flatwise, these values may be increased by multiplying by the following factors:

| Nominal width (in.) | 3" | 4" | 5" | 6" | 8" | 10" | 12" | 14" |
|---|---|---|---|---|---|---|---|---|
| Factor | 1.06 | 1.10 | 1.12 | 1.15 | 1.19 | 1.22 | 1.25 | 1.28 |

[8]Footnotes 1, 2, 9, 11 and 19 to Table No. 25-A-1 apply also to machine stress rated lumber.
[9]Design values for horizontal shear $F_v$ and compression perpendicular to grain $F_c\perp$ for lumber used under dry conditions are as follows:

| Douglas Fir-Larch | Douglas Fir-South | Hem-Fir | Western Hemlock | Lodgepole-Ponderosa-Sugar Pine | Englemann Spruce | Cedar | Southern Pine | | White Woods-Mixed Species† |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | KD | S-DRY | |
| Horizontal Shear $F_v$ | | | | | | | | | |
| 95 | 90 | 75 | 90 | 70 | 70 | 75 | 95 | 90 | 70 |
| Compression Perpendicular to Grain $F_c\perp$* | | | | | | | | | |
| 625 | 520 | 405 | 410 | 375 | 320 | 425 | 565 | 565 | 315 |

†Graded in accordance with U.B.C. Standard No. 25-3 and No. 25-4.
*The duration of load modification factors given in Section 2504 c (4) shall not apply.
For other species, use values shown in Table No. 25-A-1 for visually graded lumber, No. 2 grade, for the appropriate species.

[10]For any given value of fiber stress in bending, $F_b$, the average modulus of elasticity, $E$, may vary depending upon species, timber source and other variables. The $E$ values included in the $f$-$E$ grade designations are those usually associated with each $F_b$ level. Grade stamps may show higher or lower $E$ values (in increments of 100,000 psi) if machine rating indicates the assignment is appropriate. When an $E$ value associated with a designated $F$ level is lower or higher than those listed, the tabulated $F_b$, $F_t$, and $F_c$ values associated with the designated $f$ value are applicable. The $E$ for design shall be that associated with the $E$ value on the grade stamp.
[11]When graded under U.B.C. Standard No. 25-3 grading rules, values shall be 1100 psi.




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## TABLE NO. 25-B—ALLOWABLE UNIT STRESSES FOR CONSTRUCTION AND INDUSTRIAL SOFTWOOD PLYWOOD
(In Pounds per Square Inch—Normal Loading)
(To be used with section properties in Plywood Design Specification—See U.B.C. Standard No. 25-9)

| STRESS | SPECIES[1] GROUP OF FACE PLY | EXTERIOR A-A, A-C, C-C; STRUCTURAL I A-C, C-C (Use Group I Stresses) | | EXTERIOR A-B, B-B, B-C, C-C (PLUGGED); STRUCTURAL I C-D (Use Group 1 Stresses); STRUCTURAL II C-D (Use Group 3 Stresses); C-D SHEATHING (Exterior Glue); ALL INTERIOR GRADES WITH EXTERIOR GLUE | | ALL OTHER GRADES OF INTERIOR INCLUDING C-D SHEATHING |
|---|---|---|---|---|---|---|
| | | Wet[2] | Dry[3] | Wet[2] | Dry[3] | Dry[3] |
| 1. Extreme fiber stress in bending ($F_b$) | 1 | 1430 | 2000 | 1190 | 1650 | 1650 |
| Tension in plane of plies ($F_t$) | 2, 3 | 980 | 1400 | 820 | 1200 | 1200 |
| Face grain parallel or perpendicular to span (at 45° to face grain use 1/6 $F_t$) | 4 | 940 | 1330 | 780 | 1110 | 1110 |
| 2. Compression in plane of plies ($F_c$) | 1 | 970 | 1640 | 900 | 1540 | 1540 |
| Parallel or perpendicular to face grain | 2 | 730 | 1200 | 680 | 1100 | 1100 |
| (at 45° to face grain use 1/3 $F_c$) | 3 | 610 | 1060 | 580 | 990 | 990 |
| | 4 | 610 | 1000 | 580 | 950 | 950 |
| 3. Shear in plane perpendicular to plies $F_v$[4] | 1 | 155 | 190 | 155 | 190 | 160 |
| Parallel or perpendicular to face grain | 2, 3 | 120 | 140 | 120 | 140 | 120 |
| (at 45° to face grain use 2 $F_v$) | 4 | 110 | 130 | 110 | 130 | 115 |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 4. Shear, rolling, in the plane of plies<br>Parallel or perpendicular to face grain<br>(at 45° to face grain use 1½ $F_s$) | Marine and Structural I<br>Structural II<br>All Other[5] | 63<br>49<br>44 | 75<br>56<br>53 | 63<br>49<br>44 | 75<br>56<br>53 | 48 |
| 5. Bearing (on face)<br>Perpendicular to plane of plies | 1<br>2, 3<br>4 | 210<br>135<br>105 | 340<br>210<br>160 | 210<br>135<br>105 | 340<br>210<br>160 | 340<br>210<br>160 |
| 6. Modulus of elasticity<br>In bending in plane of plies<br>Face grain parallel or perpendicular to span | 1<br>2<br>3<br>4 | 1,500,000<br>1,300,000<br>1,100,000<br>900,000 | 1,800,000<br>1,500,000<br>1,200,000<br>1,000,000 | 1,500,000<br>1,300,000<br>1,100,000<br>900,000 | 1,800,000<br>1,500,000<br>1,200,000<br>1,000,000 | 1,800,000<br>1,500,000<br>1,200,000<br>1,000,000 |

**SPAN RATING**

| THICKNESS (inches) | C-C and C-D 12/0 | 16/0 | 20/0 | 24/0 | 32/16 | 40/20 | 48/24 | Underlayment and C-C Plugged 16 oc | 20 oc | 24 oc | 48 oc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/16 | 4 | 3 | 1 | | | | | | | | |
| 3/8 | | | 4[b] | 1 | | | | | | | |
| 11/32[a], 1/2 | | | | 4[b] | 1 | | | 1 | | | |
| 19/32, 5/8 | | | | | 4[b] | 1 | | 4[b] | 1 | | |
| 23/32, 3/4 | | | | | | 4[b] | 1 | | 4[b] | 1 | |
| 7/8 | | | | | | | 3[c] | | | 3[c] | |
| 1 1/8 | | | | | | | | | | | 1 |

a. Thickness not applicable to Underlayment and C-C Plugged.
b. Use Group 3 stresses for Structural II.
c. Use Group 4 stresses for Underlayment and C-C Plugged 24 o.c.

[1]See U.B.C. Standard No. 25-9 for plywood species groups. For C-C, C-D Underlayment, and CC Plugged, the combination of Span Rating and panel thickness determines the species group and therefore the stress permitted, as in the above table.

[2]Wet condition of use corresponds to a moisture content of 16 percent or more.

[3]Dry condition of use corresponds to a moisture content of less than 16 percent.

[4]See U.B.C. Standard No. 25-9, Section 25.921, for provisions under which $F_v$ stresses may be increased.

[5]Other (four-ply) panels over 3/8 inch thick.







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# TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]

## Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

| COMBINATION SYMBOL[19] | SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[4] | BENDING ABOUT X-X AXIS — Loaded Perpendicular to Wide Faces of Laminations | | | | | | BENDING ABOUT Y-Y AXIS — Loaded Parallel to Wide Faces of Laminations | | | | | AXIALLY LOADED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Extreme Fiber in Bending $F_{bxx}$ | | Compression Perpendicular to Grain $F_{c\perp xx}$[21] | | | | | | | | | | | |
| | | Tension Zone Stressed in Tension[5 22] psi | Compression Zone Stressed in Tension[6] psi | Tension Face psi | Compression Face psi | Horizontal Shear $F_{vxx}$ psi | Modulus of Elasticity $E_{xx}$[21] x 10⁶ psi | Extreme Fiber in Bending[5 17] $F_{byy}$ psi | Compression Perpendicular to Grain $F_{c\perp yy}$[21] psi | Horizontal Shear $F_{vyy}$ psi | Horizontal Shear $F_{vyy}$ psi (For members with multiple-piece laminations which are not edge glued)[20] | Modulus of Elasticity $E_{yy}$[21] x 10⁶ psi | Tension Parallel to Grain $F_t$ psi | Compression Parallel to Grain $F_c$ psi | Modulus of Elasticity $E$[21] x 10⁶ psi |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Visually Graded Western Species** | | | | | | | | | | | | | | | |
| 16F-V1 | DF/WW | 1600 | 800 | 560[7 8] | 560[7 8] | 140[18 23] | 1.3 | 950 | 255 | 130 | 65 | 1.1 | 675 | 975 | 1.1 |
| 16F-V2 | HF/HF | | | 500[9] | 375[9] | 155 | 1.4 | 1250 | 375 | 135 | 70 | 1.3 | 875 | 1300 | 1.3 |
| 16F-V3 | DF/DF | | | 560[7 8] | 560 | 165 | 1.5 | 1450 | 560 | 145 | 75 | 1.5 | 950 | 1550 | 1.5 |
| 16F-V8 | DFS/DFS | | | 650 | 500 | 165 | 1.2 | 1200 | 500 | 145 | 75 | 1.1 | 825 | 1350 | 1.1 |
| The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 16F-V4 | DF/N3WW | 1600 | 800 | 650 | 560[7] | 90[9 18] | 1.5[24] | 900 | 255 | 130 | 65 | 1.3[24] | 650 | 600 | 1.3 |
| 16F-V5 | DF/M3DF | | | 650 | 560[7] | 90[12] | 1.6 | 1000 | 470 | 135 | 70 | 1.5 | 750 | 875 | 1.5 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **The following two combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 16F-V6 | DF/DF | 1600 | 1600 | 560[7,8] | 560[7] | 165 | 1.5 | 1450 | 560 | 145 | 75 | 1.4 | 950 | 1550 | 1.5 |
| 16F-V7 | HF/HF | | | 375[9] | 375[9] | 155 | 1.4 | 1200 | 375 | 135 | 70 | 1.3 | 850 | 1350 | 1.3 |
| 20F-V1 | DF/WW | 2000 | 1000 | 650 | 560[7] | 140[18,23] | 1.4[24] | 1000 | 255 | 130 | 65 | 1.2[24] | 750 | 1000 | 1.2 |
| 20F-V2 | HF/HF | | | 500[9] | 375[9] | 155 | 1.5 | 1200 | 375 | 135 | 70 | 1.4 | 950 | 1350 | 1.4 |
| 20F-V3 | DF/DF | | | 650 | 560[7] | 165 | 1.6 | 1450 | 560 | 145 | 75 | 1.5 | 1000 | 1550 | 1.5 |
| 20F-V4 | DF/DF | | | 590[7,8] | 560[7] | 165 | 1.6 | 1450 | 560 | 145 | 75 | 1.6 | 1000 | 1550 | 1.6 |
| 20F-V10 | DF/HF | | | 650 | 560 | 155 | 1.5 | 1300 | 375 | 135 | 70 | 1.4 | 950 | 1500 | 1.4 |
| 20F-V11 | DFS/DFS | | | 650 | 500 | 165 | 1.3 | 1400 | 500 | 145 | 75 | 1.1 | 900 | 1400 | 1.1 |
| 20F-V12 | AC/AC | | | 560 | 560 | 190 | 1.5 | 1200 | 470 | 165 | 80 | 1.4 | 900 | 1500 | 1.4 |
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 20F-V5 | DF/N3WW | 2000 | 1000 | 650 | 560[7] | 90[11,18] | 1.6 | 1000 | 255 | 135 | 70 | 1.3 | 750 | 725 | 1.3 |
| 20F-V6 | DF/M3DF | | | 650 | 560[7] | 90[12] | 1.6 | 1000 | 470 | 135 | 70 | 1.5 | 775 | 900 | 1.5 |
| **The following three combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 20F-V7 | DF/DF | 2000 | 2000 | 650 | 650 | 165 | 1.6 | 1450 | 560 | 145 | 75 | 1.6 | 1000 | 1600 | 1.6 |
| 20F-V8 | DF/DF | | | 590[7,8] | 590[7,8] | 165 | 1.7 | 1450 | 560 | 145 | 75 | 1.6 | 1000 | 1600 | 1.6 |
| 20F-V9 | HF/HF | | | 500[9] | 500[9] | 155 | 1.5 | 1400 | 375 | 135 | 70 | 1.4 | 975 | 1400 | 1.4 |
| 22F-V1 | DF/WW | 2200 | 1100 | 650 | 560[7] | 140[18] | 1.6[24] | 1050 | 255 | 130 | 65 | 1.3[24] | 850 | 1100 | 1.3 |
| 22F-V2 | HF/HF | | | 500[9] | 500[9] | 155 | 1.5 | 1250 | 375 | 135 | 70 | 1.4 | 950 | 1350 | 1.4 |
| 22F-V3 | DF/DF | | | 650 | 560[9] | 165 | 1.7 | 1450 | 560 | 145 | 75 | 1.6 | 1050 | 1500 | 1.6 |
| 22F-V4 | DF/DF | | | 590[7,8] | 560[7] | 165 | 1.7 | 1450 | 560 | 145 | 75 | 1.6 | 1000 | 1550 | 1.6 |
| 22F-V10 | DF/DFS | | | 650 | 560[7] | 165 | 1.6 | 1600 | 500 | 145 | 75 | 1.3 | 1000 | 1400 | 1.3 |
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 22F-V5 | DF/N3WW | 2200 | 1100 | 650 | 560[7] | 90[11,18] | 1.6[24] | 1100 | 255 | 135 | 75 | 1.4[24] | 800 | 725 | 1.4 |
| 22F-V6 | DF/M3DF | | | 650 | 560[7] | 90[12] | 1.7 | 1250 | 470 | 135 | 75 | 1.6 | 900 | 925 | 1.6 |



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## TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]—(Continued)

**Mambers stressed principally in bending with load applied perpendicular to the wide faces of the laminations**

| COMBINATION SYMBOL[10] | SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[4] | BENDING ABOUT X-X AXIS — Loaded Perpendicular to Wide Faces of Laminations | | | | | | BENDING ABOUT Y-Y AXIS — Loaded Parallel to Wide Faces of Laminations | | | | | AXIALLY LOADED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Extreme Fiber in Bending $F_{bxx}$ | | Compression Perpendicular to Grain $F_{c\perp xx}$[21] | | | | | | | | | | | |
| | | Tension Zone Stressed in Tension[5 22] psi | Compression Zone Stressed in Tension[6] psi | Tension Face psi | Compression Face psi | Horizontal Shear $F_{vxx}$ psi | Modulus of Elasticity $E_{xx}$[21] x 10⁶ psi | Extreme Fiber in Bending[5 17] $F_{byy}$ psi | Compression Perpendicular to Grain $F_{c\perp yy}$[21] psi | Horizontal Shear $F_{vyy}$ psi | Horizontal Shear $F_{vyy}$ psi (For members with multiple-piece laminations which are not edge glued)[20] | Modulus of Elasticity $E_{yy}$[21] x 10⁶ psi | Tension Parallel to Grain $F_t$ psi | Compression Parallel to Grain $F_c$ psi | Modulus of Elasticity $E$[21] x 10⁶ psi |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Visually Graded Western Species—(Continued)** | | | | | | | | | | | | | | | |
| The following three combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending. | | | | | | | | | | | | | | | |
| 22F-V7 | DF/DF | 2200 | 2200 | 650 | 650 | 165 | 1.8 | 1450 | 560 | 145 | 75 | 1.6 | 1100 | 1650 | 1.6 |
| 22F-V8 | DF/DF | | | 590[7 8] | 590[7 8] | 165 | 1.7 | 1450 | 560 | 145 | 75 | 1.6 | 1050 | 1650 | 1.6 |
| 22F-V9 | HF/HF | | | 500[9] | 500[9] | 155 | 1.5 | 1250 | 375 | 135 | 70 | 1.4 | 975 | 1400 | 1.4 |
| 24F-V1 | DF/WW | 2400 | 1200 | 650 | 650 | 140[23] | 1.7[24] | 1250 | 255 | 130 | 70 | 1.4[24] | 1000 | 1300 | 1.4 |
| 24F-V2 | HF/HF | | | 500[9] | 500[9] | 155 | 1.5 | 1250 | 375 | 135 | 70 | 1.4 | 950 | 1300 | 1.4 |
| 24F-V3 | DF/DF | | | 650 | 560[7] | 165 | 1.8 | 1500 | 560 | 145 | 75 | 1.6 | 1100 | 1600 | 1.6 |
| 24F-V4 | DF/DF | | | 650 | 650 | 165 | 1.8 | 1500 | 560 | 145 | 75 | 1.6 | 1150 | 1650 | 1.6 |
| 24F-V5 | DF/HF | | | 650 | 650 | 155 | 1.7 | 1350 | 375 | 140 | 70 | 1.5 | 1100 | 1450 | 1.5 |
| 24F-V11 | DF/DFS | | | 650 | 560[7] | 165 | 1.7 | 1600 | 500 | 145 | 75 | 1.4 | 1150 | 1700 | 1.4 |



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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 24F-V6 | DF/N3WW | 2400 | 1200 | 650 | 560[7] | 90[11 18 23] | 1.7[24] | 1200 | 255 | 140 | 70 | 1.5[24] | 950 | 800 | 1.5 |
| 24F-V7 | DF/M3DF | | | 650 | 560[7] | 90[12] | 1.7 | 1250 | 470 | 135 | 70 | 1.6 | 900 | 950 | 1.6 |
| **The following three combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 24F-V8 | DF/DF | 2400 | 2400 | 650 | 650 | 165 | 1.8 | 1450 | 560 | 145 | 75 | 1.6 | 1100 | 1650 | 1.6 |
| 24F-V9 | HF/HF | | | 500[9] | 500[9] | 155 | 1.5 | 1500 | 375 | 135 | 70 | 1.4 | 1000 | 1450 | 1.4 |
| 24F-V10 | DF/HF | | | 650 | 650 | 155 | 1.8 | 1400 | 375 | 140 | 70 | 1.6 | 1150 | 1600 | 1.6 |
| Wet-use factors[2] | | 0.8 | 0.8 | 0.667 | 0.667 | 0.875 | 0.833 | 0.8 | 0.667 | 0.875 | 0.875 | 0.833 | 0.8 | 0.73 | 0.833 |
| **E-Rated Western Species** | | | | | | | | | | | | | | | |
| 16F-E1 | WW/WW | 1600 | 800 | 255[13] | 255[13] | 140[18 23] | 1.3[24] | 1050 | 255 | 125 | 65 | 1.2[24] | 725 | 925 | 1.2 |
| 16F-E2[15] | HF/HF | | | 500[14] | 500[14] | 155 | 1.4 | 1250 | 375 | 135 | 70 | 1.3 | 825 | 1200 | 1.3 |
| 16F-E3 | DF/DF | | | 650 | 650 | 165 | 1.6 | 1450 | 560 | 145 | 75 | 1.5 | 975 | 1600 | 1.5 |
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 16F-E4 | DF/N3WW | 1600 | 800 | 650 | 650 | 90[11 18 23] | 1.6[24] | 900 | 255 | 130 | 65 | 1.3[24] | 675 | 675 | 1.3 |
| 16F-E5 | DF/M3DF | | | 650 | 650 | 90[12] | 1.6 | 1050 | 470 | 135 | 70 | 1.5 | 700 | 900 | 1.5 |
| **The following two combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 16F-E6 | DF/DF | 1600 | 1600 | 650 | 650 | 165 | 1.6 | 1500 | 560 | 145 | 75 | 1.5 | 1000 | 1600 | 1.5 |
| 16F-E7[15] | HF/HF | | | 500[14] | 500[14] | 155 | 1.4 | 1250 | 375 | 135 | 70 | 1.3 | 850 | 1150 | 1.3 |
| 20F-E1 | WW/WW | 2000 | 1000 | 255[13] | 255[13] | 140[18 23] | 1.6[24] | 1100 | 255 | 125 | 65 | 1.3[24] | 800 | 1050 | 1.3 |
| 20F-E2[15] | HF/HF | | | 500[14] | 500[14] | 155 | 1.6 | 1400 | 375 | 135 | 70 | 1.4 | 925 | 1550 | 1.4 |
| 20F-E3 | DF/DF | | | 650 | 650 | 165 | 1.7 | 1550 | 560 | 145 | 75 | 1.6 | 1050 | 1650 | 1.6 |
| 20F-E8 | ES/ES | | | 450 | 450 | 145 | 1.5 | 1400 | 300 | 125 | 65 | 1.4 | 800 | 1000 | 1.4 |

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## TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]—(Continued)

### Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

| COMBINATION SYMBOL[19] | SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[4] | BENDING ABOUT X-X AXIS — Loaded Perpendicular to Wide Faces of Laminations | | | | | | BENDING ABOUT Y-Y AXIS — Loaded Parallel to Wide Faces of Laminations | | | | | AXIALLY LOADED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Extreme Fiber in Bending $F_{bxx}$ | | Compression Perpendicular to Grain $F_{c\perp xx}$[21] | | | | | | | | | | | |
| | | Tension Zone Stressed in Tension[5 22] psi | Compression Zone Stressed in Tension[6] psi | Tension Face psi | Compression Face psi | Horizontal Shear $F_{vxx}$ psi | Modulus of Elasticity $E_{xx}$[21] x 10[6] psi | Extreme Fiber in Bending[5 17] $F_{byy}$ psi | Compression Perpendicular to Grain $F_{c\perp yy}$[21] psi | Horizontal Shear $F_{vyy}$ psi | Horizontal Shear $F_{vyy}$ psi (For members with multiple-piece laminations which are not edge glued)[20] | Modulus of Elasticity $E_{yy}$[21] x 10[6] psi | Tension Parallel to Grain $F_t$ psi | Compression Parallel to Grain $F_c$ psi | Modulus of Elasticity $E$[21] x 10[6] psi |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **E-Rated Western Species—(Continued)** | | | | | | | | | | | | | | | |
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 20F-E4 | DF/N3WW | 2000 | 1000 | 650 | 650 | 90[11 16 23] | 1.6[24] | 1100 | 255 | 130 | 65 | 1.4[24] | 800 | 700 | 1.4 |
| 20F-E5 | DF/N3DF | | | 650 | 650 | 90[12] | 1.7 | 1300 | 470 | 135 | 70 | 1.6 | 825 | 975 | 1.6 |
| **The following two combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 20F-E6 | DF/DF | 2000 | 2000 | 650 | 650 | 165 | 1.7 | 1600 | 560 | 145 | 75 | 1.6 | 1150 | 1650 | 1.6 |
| 20F-E7[15] | HF/HF | | | 500[14] | 500[14] | 155 | 1.6 | 1500 | 375 | 135 | 70 | 1.4 | 1050 | 1550 | 1.4 |
| 22F-E1 | DF/DF | 2200 | 1100 | 650 | 650 | 165 | 1.7 | 1550 | 560 | 145 | 75 | 1.6 | 1050 | 1600 | 1.6 |
| 22F-E2[15] | HF/HF | | | 500[14] | 500[14] | 155 | 1.6 | 1400 | 375 | 135 | 70 | 1.4 | 950 | 1400 | 1.4 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]** | | | | | | | | | | | | | | |
| 22F-E3 | DF/N3WW | 2200 | 1100 | 650 | 650 | 9011 18 23 | 1.724 | 1250 | 255 | 135 | 70 | 1.424 | 825 | 750 | 1.4 |
| 22F-E4 | DF/N3DF | | | 650 | 650 | 9012 | 1.8 | 1350 | 470 | 135 | 70 | 1.6 | 950 | 950 | 1.6 |
| **The following two combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | |
| 22F-E5 | DF/DF | 2200 | 2200 | 650 | 650 | 165 | 1.7 | 1650 | 560 | 145 | 75 | 1.6 | 1100 | 1650 | 1.6 |
| 22F-E6[15] | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.7 | 1550 | 375 | 135 | 70 | 1.5 | 1050 | 1500 | 1.5 |
| 24F-E1 | DF/DF | 2400 | 1200 | 650 | 650 | 165 | 1.8 | 1550 | 560 | 145 | 75 | 1.6 | 1100 | 1600 | 1.6 |
| 24F-E2[15] | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.7 | 1300 | 375 | 135 | 70 | 1.5 | 850 | 1400 | 1.5 |
| 24F-E3 | DF/HF | | | 650 | 5001[4] | 155 | 1.8 | 1500 | 375 | 135 | 70 | 1.5 | 1050 | 1550 | 1.5 |
| 24F-E4 | DF/DF | | | 650 | 650 | 165 | 1.8 | 1650 | 560 | 145 | 75 | 1.7 | 1100 | 1700 | 1.7 |
| 24F-E5 | DF/DF | | | 650 | 650 | 165 | 1.8 | 1650 | 560 | 145 | 75 | 1.6 | 1100 | 1550 | 1.6 |
| 24F-E6[15] | HF/WW | | | 5001[4] | 5001[4] | 14018 23 | 1.824 | 1100 | 255 | 130 | 65 | 1.424 | 750 | 1250 | 1.4 |
| **The following three combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | |
| 24F-E14 | DF/DF | 2400 | 1200 | 650 | 650 | 165 | 1.8 | 1450 | 560 | 145 | 75 | 1.6 | 950 | 1600 | 1.6 |
| 24F-E15 | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.8 | 1300 | 375 | 135 | 70 | 1.5 | 950 | 1200 | 1.5 |
| 24F-E7 | DF/N3WW | | | 650 | 650 | 9011 18 23 | 1.924 | 1400 | 255 | 135 | 70 | 1.624 | 975 | 875 | 1.6 |
| 24F-E8 | DF/N3DF | | | 650 | 650 | 9012 | 1.9 | 1400 | 470 | 135 | 70 | 1.7 | 1000 | 1050 | 1.7 |
| 24F-E9[15] | HF/N3HF | | | 5001[4] | 5001[4] | 9011 | 1.8 | 1350 | 375 | 135 | 70 | 1.6 | 950 | 825 | 1.6 |
| **The following four combinations are balanced and are intended for members continuous or cantilevered over supports and provide equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | |
| 24F-E10 | DF/DF | 2400 | 2400 | 650 | 650 | 165 | 1.9 | 1850 | 560 | 145 | 75 | 1.7 | 1300 | 1750 | 1.7 |
| 24F-E11[15] | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.8 | 1600 | 375 | 135 | 70 | 1.5 | 1150 | 1550 | 1.5 |
| 24F-E12 | DF/HF | | | 650 | 650 | 155 | 1.9 | 1750 | 375 | 135 | 70 | 1.6 | 1200 | 1600 | 1.6 |
| 24F-E13 | DF/DF | | | 650 | 650 | 165 | 1.8 | 1950 | 560 | 145 | 75 | 1.7 | 1250 | 1700 | 1.7 |
| 24F-E16 | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.7 | 1300 | 375 | 135 | 70 | 1.5 | 850 | 1400 | 1.5 |
| 24F-E17 | HF/WW | | | 5001[4] | 5001[4] | 14018 23 | 1.824 | 1100 | 255 | 13018 | 6518 | 1.424 | 750 | 1250 | 1.4 |
| 24F-E18 | DF/DF | | | 650 | 650 | 165 | 1.8 | 1450 | 560 | 145 | 75 | 1.6 | 950 | 1600 | 1.6 |
| 24F-E19 | HF/HF | | | 5001[4] | 5001[4] | 155 | 1.8 | 1300 | 375 | 135 | 70 | 1.5 | 950 | 1200 | 1.5 |
| Wet-use factors[2] | | 0.8 | 0.8 | 0.667 | 0.667 | 0.875 | 0.833 | 0.8 | 0.667 | 0.875 | 0.875 | 0.833 | 0.8 | 0.73 | 0.833 |

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## TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]—(Continued)

### Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

| COMBINATION SYMBOL[19] | SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[4] | BENDING ABOUT X-X AXIS — Loaded Perpendicular to Wide Faces of Laminations | | | | | | BENDING ABOUT Y-Y AXIS — Loaded Parallel to Wide Faces of Laminations | | | | | AXIALLY LOADED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Extreme Fiber in Bending $F_{bxx}$ | | Compression Perpendicular to Grain $F_{c\perp xx}$[21] | | | | | | | | | | | |
| | | Tension Zone Stressed in Tension[5 22] psi | Compression Zone Stressed in Tension[6] psi | Tension Face psi | Compression Face psi | Horizontal Shear $F_{vxx}$ psi | Modulus of Elasticity $E_{xx}$[21] x 10⁶ psi | Extreme Fiber in Bending[5 17] $F_{byy}$ psi | Compression Perpendicular to Grain $F_{c\perp yy}$[21] psi | Horizontal Shear $F_{vyy}$ psi | Horizontal Shear $F_{vyy}$ psi (For members with multiple-piece laminations which are not edge glued)[20] | Modulus of Elasticity $E_{yy}$[21] x 10⁶ psi | Tension Parallel to Grain $F_t$ psi | Compression Parallel to Grain $F_c$ psi | Modulus of Elasticity $E$[21] x 10⁶ psi |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Visually Graded Southern Pine** | | | | | | | | | | | | | | | |
| 16F-V1 | SP/SP | 1600 | 800 | 560[7 8] | 560[7] | 200 | 1.4 | 1450 | 560 | 175 | 90 | 1.3 | 950 | 1450 | 1.3 |
| 16F-V2 | SP/SP | | | 500[7 8] | 500[7] | 200 | 1.4 | 1600 | 560 | 175 | 90 | 1.4 | 1000 | 1550 | 1.4 |
| 16F-V3 | SP/SP | | | 650 | 650 | 200 | 1.4 | 1450 | 560 | 175 | 90 | 1.3 | 975 | 1450 | 1.3 |
| The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 16F-V4 | SP/SP | 1600 | 800 | 560[7 8] | 560[7] | 90[16] | 1.3 | 975 | 470 | 150 | 75 | 1.2 | 650 | 950 | 1.2 |



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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending. | | | | | | | | | | | | | | | |
| 16F-V5 | SP/SP | 1600 | 1600 | 560[7,8] | 560[7,8] | 200 | 1.4 | 1600 | 560 | 175 | 85 | 1.4 | 1000 | 1550 | 1.4 |
| 20F-V1 | SP/SP | 2000 | 1000 | 650 | 560[7] | 200 | 1.5 | 1450 | 560 | 175 | 85 | 1.4 | 1000 | 1450 | 1.4 |
| 20F-V2 | SP/SP | | | 650 | 560[7] | 200 | 1.6 | 1450 | 560 | 175 | 85 | 1.4 | 1050 | 1550 | 1.4 |
| 20F-V3 | SP/SP | | | 560[7,8] | 560[7] | 200 | 1.4 | 1600 | 560 | 175 | 85 | 1.4 | 1000 | 1500 | 1.4 |
| The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 20F-V4 | SP/SP | 2000 | 1000 | 650 | 560[7] | 90[16] | 1.5 | 1100 | 470 | 150 | 75 | 1.3 | 725 | 950 | 1.3 |
| The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending. | | | | | | | | | | | | | | | |
| 20F-V5 | SP/SP | 2000 | 2000 | 650 | 560 | 200 | 1.6 | 1450 | 650 | 175 | 85 | 1.4 | 1050 | 1550 | 1.4 |
| 22F-V1 | SP/SP | 2200 | 1100 | 650 | 650 | 200 | 1.6 | 1600 | 560 | 175 | 85 | 1.5 | 1050 | 1650 | 1.5 |
| 22F-V2 | SP/SP | | | 560[7,8] | 560[7] | 200 | 1.4 | 1600 | 560 | 175 | 85 | 1.4 | 1000 | 1500 | 1.4 |
| 22F-V3 | SP/SP | | | 650 | 560[7] | 200 | 1.6 | 1500 | 560 | 175 | 85 | 1.4 | 1050 | 1500 | 1.4 |
| The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 22F-V4 | SP/SP | 2200 | 1100 | 650 | 560[7] | 90[16] | 1.6 | 1250 | 470 | 155 | 75 | 1.4 | 825 | 1000 | 1.4 |
| The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending. | | | | | | | | | | | | | | | |
| 22F-V5 | SP/SP | 2200 | 2200 | 650 | 650 | 200 | 1.6 | 1600 | 560 | 175 | 85 | 1.5 | 1050 | 1600 | 1.5 |
| 24F-V1 | SP/SP | 2400 | 1200 | 650 | 560[7] | 200 | 1.7 | 1500 | 560 | 175 | 85 | 1.5 | 1100 | 1350 | 1.5 |
| 24F-V2 | SP/SP | | | 650 | 650 | 200 | 1.7 | 1600 | 560 | 175 | 85 | 1.5 | 1100 | 1600 | 1.5 |
| 24F-V3 | SP/SP | | | 650 | 650 | 200 | 1.8 | 1600 | 560 | 175 | 85 | 1.6 | 1150 | 1700 | 1.6 |
| 24F-V6 | SP/SP | | | 650 | 650 | 200 | 1.7 | 1500 | 560 | 175 | 90 | 1.5 | 1150 | 1750 | 1.5 |
| The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 24F-V4 | SP/SP | 2400 | 1200 | 650 | 560[7] | 90[16] | 1.7 | 1250 | 470 | 155 | 75 | 1.4 | 850 | 1050 | 1.4 |

(Continued)





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## TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1,2,3]—(Continued)

### Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

| COMBINATION SYMBOL[19] | SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[4] | BENDING ABOUT X-X AXIS (Loaded Perpendicular to Wide Faces of Laminations) | | | | | | BENDING ABOUT Y-Y AXIS (Loaded Parallel to Wide Faces of Laminations) | | | | | AXIALLY LOADED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Extreme Fiber in Bending $F_{bxx}$ | | Compression Perpendicular to Grain $F_{c\perp xx}$[21] | | Horizontal Shear $F_{vxx}$ | Modulus of Elasticity $E_{xx}$[21] x 10⁶ | Extreme Fiber in Bending[5,17] $F_{byy}$ | Compression Perpendicular to Grain $F_{c\perp yy}$[21] | Horizontal Shear $F_{vyy}$ | Horizontal Shear $F_{vyy}$ (For members with multiple-piece laminations which are not edge glued)[20] | Modulus of Elasticity $E_{yy}$[21] x 10⁶ | Tension Parallel to Grain $F_t$ | Compression Parallel to Grain $F_c$ | Modulus of Elasticity $E$[21] x 10⁶ |
| | | Tension Zone Stressed in Tension[5,22] | Compression Zone Stressed in Tension[6] | Tension Face | Compression Face | | | | | | | | | | |
| | | psi | psi | psi | psi | psi | | psi | psi | psi | psi | | psi | psi | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Visually Graded Southern Pine—(Continued)** | | | | | | | | | | | | | | | |
| The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending. | | | | | | | | | | | | | | | |
| 24F-V5 | SP/SP | 2400 | 2400 | 650 | 650 | 200 | 1.7 | 1600 | 560 | 175 | 90 | 1.5 | 1150 | 1700 | 1.5 |
| Wet-use factors[2] | | 0.8 | 0.8 | 0.667 | 0.667 | 0.875 | 0.833 | 0.8 | 0.667 | 0.875 | 0.875 | 0.833 | 0.8 | 0.73 | 0.833 |
| **E-Rated Southern Pine** | | | | | | | | | | | | | | | |
| 16F-E1 | SP/SP | 1600 | 800 | 650 | 650 | 200 | 1.6 | 1550 | 560 | 175 | 90 | 1.5 | 1050 | 1600 | 1.5 |
| The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10] | | | | | | | | | | | | | | | |
| 16F-E2 | SP/SP | 1600 | 800 | 650 | 650 | 90[16] | 1.6 | 950 | 470 | 145 | 75 | 1.3 | 700 | 1050 | 1.3 |



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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 16F-E3 | SP/SP | 1600 | 1600 | 650 | 650 | 200 | 1.6 | 1700 | 560 | 175 | 90 | 1.5 | 1100 | 1650 | 1.5 |
| 20F-E1 | SP/SP | 2000 | 1000 | 650 | 650 | 200 | 1.7 | 1600 | 560 | 175 | 90 | 1.5 | 1050 | 1600 | 1.5 |
| **The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 20F-E2 | SP/SP | 2000 | 1000 | 650 | 650 | 90[15] | 1.6 | 1100 | 470 | 150 | 75 | 1.4 | 750 | 1000 | 1.4 |
| **The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 20F-E3 | SP/SP | 2000 | 2000 | 650 | 650 | 200 | 1.7 | 1800 | 560 | 175 | 90 | 1.5 | 1150 | 1700 | 1.5 |
| 22F-E1 | SP/SP | 2200 | 1100 | 650 | 650 | 200 | 1.7 | 1600 | 560 | 175 | 90 | 1.5 | 1050 | 1650 | 1.5 |
| **The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 22F-E2 | SP/SP | 2200 | 1100 | 650 | 650 | 90[15] | 1.6 | 1250 | 470 | 155 | 80 | 1.4 | 850 | 1050 | 1.4 |
| **The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 22F-E3 | SP/SP | 2200 | 2200 | 650 | 650 | 200 | 1.7 | 1750 | 560 | 175 | 90 | 1.5 | 1150 | 1650 | 1.5 |
| 24F-E1 | SP/SP | 2400 | 1200 | 650 | 650 | 200 | 1.8 | 1600 | 560 | 175 | 90 | 1.6 | 1100 | 1750 | 1.6 |
| 24F-E2 | SP/SP | | | 650 | 650 | 200 | 1.9 | 1700 | 560 | 175 | 90 | 1.6 | 1150 | 1700 | 1.6 |
| **The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[10]** | | | | | | | | | | | | | | | |
| 24F-E3 | SP/SP | 2400 | 1200 | 650 | 650 | 90[15] | 1.8 | 1300 | 470 | 155 | 80 | 1.5 | 950 | 1100 | 1.5 |
| **The following combination is balanced and intended for members continuous or cantilevered over supports and provides equal capacity in both positive and negative bending.** | | | | | | | | | | | | | | | |
| 24F-E4 | SP/SP | 2400 | 2400 | 650 | 650 | 200 | 1.8 | 2000 | 560 | 175 | 90 | 1.6 | 1250 | 1750 | 1.6 |
| Wet-use factors[2] | | 0.8 | 0.8 | 0.53 | 0.53 | 0.875 | 0.833 | 0.8 | 0.53 | 0.875 | 0.875 | 0.833 | 0.8 | 0.73 | 0.833 |

*(Continued)*





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## FOOTNOTES FOR TABLE NO. 25-C-1 PART A

[1]The combinations in this table are applicable to members consisting of four or more laminations and are intended primarily for members stressed in bending due to loads applied perpendicular to the wide faces of the laminations. Design values are tabulated, however, for loading both perpendicular and parallel to the wide faces of the laminations. For combinations and design values applicable to members loaded primarily axially or parallel to the wide faces of the laminations, see Table No. 25-C-1, Part B. For members of two or three laminations, see Table No. 25-C-1, Part B.

[2]The tabulated design values are for dry conditions of use. To obtain wet-use design values, multiply the tabulated values by the factors shown at the end of the table.

[3]The tabulated design values are for normal duration of loading. For other durations of loading, see Section 2504 (c) 4.

[4]The symbols used for species are AC = Alaska cedar, DF = Douglas fir-larch, DFS = Douglas fir south, HF = hem-fir, WW = softwood species, SP = southern pine and ES = eastern spruce. (N3 refers to No. 3 structural joists and planks or structural light framing grade.) Softwood species (WW) and eastern spruce are included in the general category of western species although eastern spruce and some softwood species are produced in other areas.

[5]The tabulated design values in bending are applicable to members 12 inches or less in depth. For members greater than 12 inches in depth, the requirements of Section 2511 (d) 5 apply.

[6]Design values in this column are for extreme fiber stress in bending when the member is loaded such that the compression zone laminations are subjected to tensile stresses. The values in this column may be increased 200 psi where end joint spacing restrictions are applied to the compression zone when stressed in tension.

[7]Where specified, this value may be increased to 650 psi by providing in the bearing area at least one dense 2-inch nominal thickness lamination of Douglas fir-larch for western species combinations, or southern pine for southern pine combinations. These dense laminations must be backed by a medium-grain lamination of the same species.

[8]For bending members greater than 15 inches in depth, the design value for compression stress perpendicular to grain is 650 psi on the tension face.

[9]Where specified, this value may be increased by providing at least two 2-inch nominal thickness Douglas fir-larch laminations in the bearing area. The compression-perpendicular-to-grain design values for Douglas fir-larch are 560 psi for medium grain and 650 psi for dense.

[10]These combinations are for dry conditions of use only because they may contain wane. They are recommended for industrial appearance grade and for straight or slightly cambered members only. If wane is omitted these restrictions do not apply.

[11]This value may be increased to 140 psi for softwood species (WW) and to 155 psi for hem-fir when the member does not contain wane on both sides; to 115 psi for softwood species (WW) and to 130 psi for hem-fir when the member does not contain wane on one side.

[12]This value may be increased to 110 psi when the member does not contain coarse-grain material; to 140 psi when the member does not contain wane on both sides or the member does not contain coarse-grain material and wane on one side; to 165 psi when the member does not contain coarse-grain material and wane on both sides.



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[13]The compression-perpendicular-to-grain design value of 255 psi is based on the lowest strength species of the western woods group. If at least one 2-inch nominal thickness lamination of E-rated hem-fir with the same E value; or E-rated Douglas fir-larch 200,000 psi higher in modulus of elasticity (E) than that specified is used in the bearing area on the face of the member subjected to the eompression-perpendieular-to-grain stress, $F_{c}\perp$ may be increased to 375 psi. If at least two 2-inch nominal thickness laminations of E-rated hem-fir with the same E-value, or E-rated Douglas fir-larch 200,000 psi higher in modulus of elasticity than that specified are used in the bearing area on the face of the member subjeeted to the compression-perpendicular-to-grain stress, $F_{c}\perp$ may be increased to 500 psi.

[14]Where specified, this value may be increased to 650 psi by providing in the bearing area at least one 2-ineh nominal thickness lamination of Douglas fir-larch for western species combinations, or one 2-inch nominal thickness lamination of southern pine for southern pine combinations having a modulus of elasticity (E) value 200,000 psi higher than the E value speeified.

[15]E-rated Douglas fir-larch 200,000 psi higher in modulus of elasticity may be substituted for the speeified E-rated hem-fir.

[16]This value may be increased to 140 psi when the member does not contain eoarse-grain material or when the member does not contain wane on both sides; to 165 psi when members do not contain coarse-grain material or wane on one side; or to 200 psi when the member does not contain both coarse-grain material and wane on both sides of the member.

[17]Footnote 5 to Table No. 25-C-1; Part B, also applies.

[18]When Douglas fir south is used in place of all of the western wood laminations required in western species eombinations 16F-V1, 16F-V4, 20F-V1, 20F-V5, 22F-V1, 22F-V5, 24F-V1, 24F-V6, 16F-E1, 16F-E4, 20F-E1, 20F-E4, 22F-E3, 24F-E6 and 24F-E7, the design value for horizontal shear is the same as for combinations using all Douglas fir-larch ($F_{vxx}$ = 165 psi and $F_{vyy}$ = 145 psi for L3; and $F_{vxx}$ = 90 psi and $F_{vyy}$ = 135 psi for N3).

[19]The combination symbols relate to a specific combination of grades and species in U.B.C. Standard No. 25-11 that will provide the design values shown for the combinations. The first two numbers in the combination symbol eorrespond to the design value in bending shown in column 3. The letter in the combination symbol (either a "V" or an "E") indicates whether the combination is made from visually graded (V) or E-rated (E) lumber in the outer zones.

[20]These values for horizontal shear, $F_{vyy}$ apply to members manufactured using multiple-pieee laminations with unbonded edge joints. For members manufactured using single-piece laminations or using multiple-piece laminations with bonded edge joints, the horizontal shear values in column 11 apply.

[21]The duration of load modification factors given in Section 2504 (c) 4 shall not apply.

[22]The design values in bending about the x-x axis ($F_{bx}$) in this column for bending members shall be multiplied by 0.75 when the member is manufactured without the required special tension laminations.

[23]The following species may be used for softwood species (WW), provided the design values in horizontal shear in column 7 ($F_{vx}$) and in Column 11 ($F_{vxy}$) are reduced by 10 psi and the design values in horizontal shear in Column 12 ($F_{vy}$) are redueed by 5 psi: Coast sitka spruce, coast species, eastern white pine (north) and western white pine.

[24]The following species may be used for softwood species (WW), provided the design values in modulus of elasticity ($E_x$ and $E_y$) in Columns 8 and 13 are reduced by 100,000 psi: Western cedars, western cedars (north), white woods (western woods) and California redwood—open grain.





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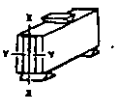
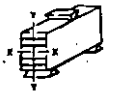
# TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1,2,3]

## Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations

| | | | | | AXIALLY LOADED | | | BENDING ABOUT Y-Y AXIS | | | | | | BENDING ABOUT X-X AXIS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Loaded Parallel to Wide Faces of Laminations  | | | | | | Loaded Perpendicular to Wide Faces of Laminations  | | |
| | | | | | Tension Parallel to Grain $F_t$ | Compression Parallel to Grain $F_c$ | | Extreme Fiber in Bending[6] $F_{bYY}$ | | | Horizontal Shear[7] $F_{vYY}$ | | | | Extreme Fiber in Bending[8] $F_{bxx}$ | | |
| COMBINATION SYMBOL 1 | SPECIES[4] 2 | GRADES 3 | MODULUS OF ELASTICITY E[14] x $10^6$ psi 4 | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi 5 | 2 or More Lams psi 6 | 4 or More Lams psi 7 | 2 or 3 Lams psi 8 | 4 or More Lams psi 9 | 3 Lams psi 10 | 2 Lams psi 11 | 4 or More Lams (For members with multiple-piece laminations.)[13] 12 | 4 or More Lams psi 13 | 3 Lams psi 14 | 2 Lams psi 15 | 2 Lams to 15 in. Deep[9] psi 16 | 4 or More Lams[10] psi 17 | Horizontal Shear $F_{vxx}$ 2 or More Lams psi 18 |
| **Visually Graded Western Species** | | | | | | | | | | | | | | | | | |
| 1 | DF | L3 | 1.5 | 560[11] | 900 | 1550 | 1200 | 1450 | 1250 | 1000 | 75 | 145 | 135 | 125 | 1250 | 1500 | 165 |
| 2 | | L2 | 1.7 | 560[11] | 1250 | 1900 | 1600 | 1800 | 1600 | 1300 | 75 | 145 | 135 | 125 | 1700 | 2000 | 165 |
| 3 | | L2D | 1.8 | 650 | 1450 | 2300 | 1850 | 2100 | 1850 | 1550 | 75 | 145 | 135 | 125 | 2000 | 2300 | 165 |
| 4 | | L1CL | 1.9 | 590[11] | 1400 | 2100 | 1900 | 2200 | 2000 | 1650 | 75 | 145 | 135 | 125 | 1900 | 2200 | 165 |
| 5 | | L1 | 2.0 | 650 | 1600 | 2400 | 2100 | 2400 | 2100 | 1800 | 75 | 145 | 135 | 125 | 2200 | 2400 | 165 |
| 6 | | N3C | 1.4 | 470 | 350 | 875 | 550 | 550 | 550 | 550 | 60 | 120 | 115 | 105 | 450 | — | 140 |
| 7 | | N3M | 1.5 | 560 | 900 | 1550 | 700 | 1450 | 1250 | 1000 | 75 | 145 | 135 | 125 | 1000 | — | 165 |
| 8 | | N2 | 1.6 | 560[11] | 1000 | 1550 | 1150 | 1600 | 1550 | 1300 | 75 | 145 | 135 | 125 | 1350 | 1600 | 165 |
| 9 | | N2D | 1.8 | 650 | 1150 | 1800 | 1350 | 1850 | 1800 | 1500 | 75 | 145 | 135 | 125 | 1600 | 1850 | 165 |
| 10 | | N1 | 1.8 | 560[11] | 1300 | 1950 | 1450 | 1950 | 1750 | 1500 | 75 | 145 | 135 | 125 | 1750 | 2100 | 165 |



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| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | DF | N1D | 2.0 | 650 | 1500 | 2300 | 1700 | 2300 | 2100 | 1750 | 75 | 145 | 135 | 125 | 2100 | 2400 | 165 |
| 12 | | SS | 1.8 | 560[11] | 1400 | 1950 | 1650 | 2100 | 1950 | 1650 | 75 | 145 | 135 | 125 | 1900 | 2200 | 165 |
| 13 | | SSD | 2.0 | 650 | 1600 | 2300 | 1950 | 2400 | 2300 | 1950 | 75 | 145 | 135 | 125 | 2200 | 2400 | 165 |
| 14 | HF | L3 | 1.3 | 375[11] | 800 | 1100 | 975 | 1200 | 1050 | 850 | 70 | 135 | 130 | 115 | 1100 | 1300 | 155 |
| 15 | | L2 | 1.4 | 375[11] | 1050 | 1350 | 1300 | 1500 | 1350 | 1100 | 70 | 135 | 130 | 115 | 1450 | 1700 | 155 |
| 16 | | L1 | 1.6 | 375[11] | 1200 | 1500 | 1450 | 1750 | 1550 | 1300 | 70 | 135 | 130 | 115 | 1600 | 1900 | 155 |
| 17 | | L1D | 1.7 | 500 | 1400 | 1750 | 1700 | 2000 | 1850 | 1550 | 70 | 135 | 130 | 115 | 1900 | 2200 | 155 |
| 18 | | N3 | 1.3 | 375 | 425 | 900 | 575 | 700 | 700 | 700 | 70 | 135 | 130 | 115 | 575 | — | 155 |
| 19 | | N2 | 1.4 | 375[11] | 850 | 1300 | 975 | 1350 | 1300 | 1100 | 70 | 135 | 130 | 115 | 1150 | 1350 | 155 |
| 20 | | N1 | 1.6 | 375[11] | 975 | 1450 | 1250 | 1550 | 1500 | 1250 | 70 | 135 | 130 | 115 | 1350 | 1550 | 155 |
| 21 | | SS | 1.6 | 375[11] | 1100 | 1450 | 1350 | 1750 | 1650 | 1400 | 70 | 135 | 130 | 115 | 1500 | 1750 | 155 |
| 22 | WW | L3 | 1.0[15] | 255 | 525 | 850 | 675 | 800 | 700 | 550 | 60[16] | 120[16] | 115[16] | 105[16] | 725 | 850 | 140[16] |
| 23 | | N3 | 1.0[15] | 255 | 275 | 625 | 450 | 450 | 450 | 450 | 60[16] | 120[16] | 115[16] | 105[16] | 400 | — | 140[16] |
| 24 | | N2 | 1.1[15] | 255 | 550 | 900 | 700 | 900 | 875 | 725 | 60[16] | 120[16] | 115[16] | 105[16] | 775 | 900 | 140[16] |
| 25 | | N1 | 1.2[15] | 255 | 650 | 1000 | 875 | 1050 | 1000 | 850 | 60[16] | 120[16] | 115[16] | 105[16] | 875 | 1050 | 140[16] |
| 26 | | SS | 1.2[15] | 255 | 750 | 1000 | 1000 | 1150 | 1100 | 925 | 60[16] | 120[16] | 115[16] | 105[16] | 1000 | 1150 | 140[16] |
| 59 | DFS | L3 | 1.1 | 500 | 800 | 1400 | 1050 | 1200 | 1050 | 850 | 75 | 145 | 135 | 125 | 1050 | 1250 | 165 |
| 60 | | L2 | 1.3 | 500 | 1050 | 1750 | 1400 | 1750 | 1550 | 1150 | 75 | 145 | 135 | 125 | 1450 | 1700 | 165 |
| 61 | | L1 | 1.5 | 650 | 1350 | 2200 | 1850 | 2000 | 1800 | 1500 | 75 | 145 | 135 | 125 | 1850 | 2200 | 165 |
| 64 | ES | D | 1.3 | 300 | 575 | 925 | 850 | 950 | 925 | 875 | 65 | 125 | 120 | 110 | 800 | 950 | 145 |
| 65 | | D4 | 1.5 | 450 | 825 | 1050 | 1050 | 1350 | 1350 | 1350 | 65 | 125 | 120 | 110 | 1150 | 1350 | 145 |
| 66 | | C4 | 1.5 | 450 | 975 | 1550 | 1200 | 1750 | 1750 | 1700 | 65 | 125 | 120 | 110 | 1400 | 1650 | 145 |
| 67 | | C6 | 1.7 | 450 | 1100 | 1850 | 1450 | 1950 | 1950 | 1900 | 65 | 125 | 120 | 110 | 1550 | 1800 | 145 |
| 68 | | B | 1.7 | 450 | 1350 | 1850 | 1800 | 2250 | 2200 | 2150 | 65 | 125 | 120 | 110 | 1900 | 2250 | 145 |
| 69 | AC | L3 | 1.3 | 470 | 700 | 1150 | 1150 | 1000 | 875 | 700 | 80 | 165 | 160 | 140 | 1000 | 1150 | 190 |
| 70 | | L2 | 1.4 | 470 | 1000 | 1450 | 1550 | 1250 | 1100 | 925 | 80 | 165 | 160 | 140 | 1350 | 1550 | 190 |
| 71 | | L1D | 1.7 | 560 | 1250 | 1900 | 2050 | 1650 | 1500 | 1250 | 80 | 165 | 160 | 140 | 1700 | 2000 | 190 |
| 72 | | L1S | 1.7 | 560 | 1250 | 1900 | 2050 | 1650 | 1500 | 1250 | 80 | 165 | 160 | 140 | 1700 | 2000 | 190 |

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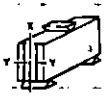
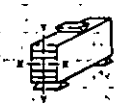
## TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1,2,3]—(Continued)

**Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations**

| | | | | | AXIALLY LOADED | | | BENDING ABOUT Y-Y AXIS | | | | | | | BENDING ABOUT X-X AXIS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Loaded Parallel to Wide Faces of Laminations  | | | | | | | Loaded Perpendicular to Wide Faces of Laminations  | | |
| | | | | | Tension Parallel to Grain $F_t$ | Compression Parallel to Grain $F_c$ | | Extreme Fiber in Bending[6] $F_{bYY}$ | | | Horizontal Shear[7] $F_{vYY}$ | | | | Extreme Fiber in Bending[8] $F_{bXX}$ | | Horizontal Shear $F_{vXX}$ |
| COMBINATION SYMBOL 1 | SPECIES[4] 2 | GRADE[5] 3 | MODULUS OF ELASTICITY $E$[14] x 10[6] psi 4 | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi 5 | 2 or More Lams psi 6 | 4 or More Lams psi 7 | 2 or 3 Lams psi 8 | 4 or More Lams psi 9 | 3 Lams psi 10 | 2 Lams psi 11 | 4 or More Lams (For members with multiple-piece laminations.)[13] 12 | 4 or More Lams psi 13 | 3 Lams psi 14 | 2 Lams psi 15 | 2 Lams to 15 in. Deep[9] psi 16 | 4 or More Lams[10] psi 17 | 2 or More Lams psi 18 |
| E-Rated Western Species | | | | | | | | | | | | | | | | | |
| 27 | DF | 1½-1.8E | 1.8 | 650 | 900 | 1750 | 1200 | 1450 | 1250 | 1000 | 75 | 145 | 135 | 125 | 1250 | 1500 | 165 |
| 28 | | 1½-2.0E | 2.0 | 650 | 1100 | 2000 | 1400 | 1450 | 1250 | 1000 | 75 | 145 | 135 | 125 | 1500 | 1750 | 165 |
| 29 | | 1½-2.2E | 2.2 | 650 | 1250 | 2300 | 1550 | 1650 | 1400 | 1150 | 75 | 145 | 135 | 125 | 1700 | 2000 | 165 |
| 30 | | 1⅜-1.8E | 1.8 | 650 | 1550 | 2100 | 1700 | 2400 | 2400 | 2100 | 75 | 145 | 135 | 125 | 1800 | 2100 | 165 |
| 31 | | 1⅜-2.0E | 2.0 | 650 | 1800 | 2400 | 1900 | 2400 | 2400 | 2400 | 75 | 145 | 135 | 125 | 2100 | 2400 | 165 |
| 32 | | 1⅜-2.2E | 2.2 | 650 | 1800 | 2400 | 2100 | 2400 | 2400 | 2400 | 75 | 145 | 135 | 125 | 2300 | 2400 | 165 |
| 62 | | 1½-2.1E | 2.1 | 650 | 1150 | 2200 | 1500 | 1550 | 1350 | 1100 | 75 | 145 | 135 | 125 | 1600 | 1900 | 165 |
| 63 | | 1⅜-2.1E | 2.1 | 650 | 1800 | 2400 | 2000 | 2400 | 2400 | 2400 | 75 | 145 | 135 | 125 | 2200 | 2400 | 165 |



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| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | HF | 1/2-1.5E | 1.5 | 500 | 800 | 1050 | 950 | 1200 | 1050 | 850 | 70 | 135 | 130 | 115 | 1100 | 1300 | 155 |
| 34 | | 1/2-1.8E | 1.8 | 500 | 900 | 1300 | 1200 | 1450 | 1250 | 1000 | 70 | 135 | 130 | 115 | 1250 | 1500 | 155 |
| 35 | | 1/2-2.0E | 2.0 | 500 | 1100 | 1550 | 1400 | 1450 | 1250 | 1000 | 70 | 135 | 130 | 115 | 1500 | 1750 | 155 |
| 36 | | 1/4-1.5E | 1.5 | 500 | 1200 | 1450 | 1300 | 2100 | 1900 | 1700 | 70 | 135 | 130 | 115 | 1400 | 1650 | 155 |
| 37 | | 1/6-1.8E | 1.8 | 500 | 1550 | 1950 | 1700 | 2400 | 2400 | 2100 | 70 | 135 | 130 | 115 | 1800 | 2100 | 155 |
| 38 | | 1/6-2.0E | 2.0 | 500 | 1800 | 2400 | 1900 | 2400 | 2400 | 2400 | 70 | 135 | 130 | 115 | 2100 | 2400 | 155 |
| 39 | WW | 1/2-1.5E | 1.5 | 255 | 800 | 1200 | 950 | 1200 | 1050 | 850 | 60[16] | 120[16] | 115[16] | 105[16] | 1100 | 1300 | 140[16] |
| 40 | | 1/2-1.8E | 1.8 | 255 | 900 | 1500 | 1200 | 1450 | 1250 | 1000 | 60[16] | 120[16] | 115[16] | 105[16] | 1250 | 1500 | 140[16] |
| 41 | | 1/2-2.0E | 2.0 | 255 | 1100 | 1750 | 1400 | 1450 | 1250 | 1000 | 60[16] | 120[16] | 115[16] | 105[16] | 1500 | 1750 | 140[16] |
| 42 | | 1/4-1.5E | 1.5 | 255 | 1200 | 1550 | 1300 | 2100 | 1900 | 1700 | 60[16] | 120[16] | 115[16] | 105[16] | 1400 | 1650 | 140[16] |
| 43 | | 1/6-1.8E | 1.8 | 255 | 1550 | 1950 | 1700 | 2400 | 2400 | 2100 | 60[16] | 120[16] | 115[16] | 105[16] | 1800 | 2100 | 140[16] |
| 44 | | 1/6-2.0E | 2.0 | 255 | 1800 | 2200 | 1900 | 2400 | 2400 | 2400 | 60[16] | 120[16] | 115[16] | 105[16] | 2100 | 2400 | 140[16] |
| **Visually Graded Southern Pine** | | | | | | | | | | | | | | | | | |
| 45 | SP | N3C | 1.1 | 470 | 325 | 850 | 550 | 550 | 550 | 550 | 60 | 120 | 115 | 105 | 450 | — | 140 |
| 46 | | N3M | 1.3 | 560 | 900 | 1500 | 675 | 1450 | 1250 | 1000 | 90 | 175 | 165 | 150 | 1000 | — | 200 |
| 47 | | N2M[12] | 1.4 | 560[11] | 1200 | 1900 | 1150 | 1750 | 1550 | 1300 | 90 | 175 | 165 | 150 | 1400 | 1600 | 200 |
| 48 | | N2D[12] | 1.7 | 650 | 1400 | 2200 | 1350 | 2000 | 1800 | 1500 | 90 | 175 | 165 | 150 | 1600 | 1900 | 200 |
| 49 | | N1M[12] | 1.7 | 560[11] | 1350 | 2100 | 1450 | 1950 | 1750 | 1500 | 90 | 175 | 165 | 150 | 1800 | 2100 | 200 |
| 50 | | N1D[12] | 1.9 | 650 | 1550 | 2300 | 1700 | 2300 | 2100 | 1750 | 90 | 175 | 165 | 150 | 2100 | 2400 | 200 |
| 51 | | SSM | 1.7 | 560[11] | 1300 | 1900 | 1600 | 2100 | 1950 | 1650 | 90 | 175 | 165 | 150 | 1750 | 2100 | 200 |
| 52 | | SSD | 1.9 | 650 | 1500 | 2200 | 1850 | 2400 | 2300 | 1950 | 90 | 175 | 165 | 150 | 2100 | 2400 | 200 |

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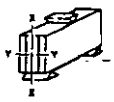
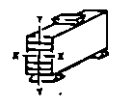
## TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1,2,3]—(Continued)

**Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations**

| | | | | | AXIALLY LOADED | | | BENDING ABOUT Y-Y AXIS | | | | | | | BENDING ABOUT X-X AXIS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Loaded Parallel to Wide Faces of Laminations  | | | | | | | Loaded Perpendicular to Wide Faces of Laminations  | | |
| | | | | | Tension Parallel to Grain $F_t$ | Compression Parallel to Grain $F_c$ | | Extreme Fiber in Bending[6] $F_{bYY}$ | | | Horizontal Shear[7] $F_{vYY}$ | | | | Extreme Fiber in Bending[8] $F_{bXX}$ | | |
| COMBINATION SYMBOL | SPECIES[4] | GRADE[5] | MODULUS OF ELASTICITY E[14] x 10[6] psi | COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi | 2 or More Lams psi | 4 or More Lams psi | 2 or 3 Lams psi | 4 or More Lams psi | 3 Lams psi | 2 Lams psi | 4 or More Lams (For members with multiple-piece laminations.)[13] psi | 4 or More Lams psi | 3 Lams psi | 2 Lams psi | 2 Lams to 15 in. Deep[9] psi | 4 or More Lams[10] psi | Horizontal Shear $F_{vXX}$ 2 or More Lams psi |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **E-Rated Southern Pine** | | | | | | | | | | | | | | | | | | | | |
| 53 | SP | 1/2-1.8E | 1.8 | 650 | 900 | 1900 | 1200 | 1450 | 1250 | 1000 | 90 | 175 | 165 | 150 | 1250 | 1500 | 200 |
| 54 | | 1/2-2.0E | 2.0 | 650 | 1100 | 2300 | 1400 | 1450 | 1250 | 1000 | 90 | 175 | 165 | 150 | 1600 | 1750 | 200 |
| 55 | | 1/2-2.2E | 2.2 | 650 | 1250 | 2400 | 1550 | 1650 | 1400 | 1150 | 90 | 175 | 165 | 150 | 1700 | 2000 | 200 |
| 56 | | 1/6-1.8E | 1.8 | 650 | 1550 | 1850 | 1700 | 2400 | 2400 | 2100 | 90 | 175 | 165 | 150 | 1800 | 2100 | 200 |
| 57 | | 1/6-2.0E | 2.0 | 650 | 1800 | 2400 | 1900 | 2400 | 2400 | 2400 | 90 | 175 | 165 | 150 | 2100 | 2400 | 200 |
| 58 | | 1/6-2.2E | 2.2 | 650 | 1800 | 2400 | 2100 | 2400 | 2400 | 2400 | 90 | 175 | 165 | 150 | 2300 | 2400 | 200 |
| Wet-use factors[2] | | — | 0.833 | 0.53 | 0.8 | 0.73 | 0.73 | 0.8 | 0.8 | 0.8 | 0.875 | 0.875 | 0.875 | 0.875 | 0.8 | 0.875 | 0.875 |



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[1]The combinations in this table are intended primarily for members loaded either axially or in bending with the loads acting parallel to the wide faces of the laminations. Design values for bending due to loading applied perpendicular to the wide faces of the laminations are also included; however, the combinations in Table No. 25-C-1, Part A, are usually better suited for this coudition of loading. The design values for bending about the x-x axis ($F_{bxx}$) shown in Column 16 are for members from two laminations to 15 inches deep without tension laminations. Design values approximately 15 percent higher for members with four or more laminations are shown in Column 17. These higher design values, however, require special tension laminations which may not be readily available.

[2]The tabulated design values are for dry conditions of use. To obtain wet-use design values, multiply the tabulated values by the factors shown at the end of the table.

[3]The tabulated design values are for normal duration of loading. For other durations of loading, see Section 2504 (c) 4.

[4]The symbols used for species are: AC = Alaska cedar, DF = Douglas fir-larch, DFS = Douglas fir south, ES = eastern spruce, HF = hem-fir, WW = softwood species, and SP = southern pine.

[5]Grade designations are as follows: Softwood species (WW) and eastern spruce are included in general category of western species although eastern spruce and some softwood species are produced in other areas.

**Visually Graded Western Species**

L1 is L1 laminating grade (dense for Douglas fir-larch and Douglas fir south).
L1D is L1 dense laminating grade for hem-fir.
L1S is a special grade of Alaska cedar, see U.B.C. Standard No. 25-11, Section 25.1110 (h).
L1CL is L1 close grain laminating grade.
L2D is L2 laminating grade (dense).
L2 is L2 laminating grade (medium grain).
L3 is L3 laminating grade (medium grain for Douglas fir-larch, Douglas fir south and hem-fir).
SSD is dense select structural, structural joists and planks, or structural light framing grade (dense).
SS is select structural, structural joists and planks, or structural light framing grade (medium grain for Douglas fir-larch).
N1D is dense No. 1 structural joists and planks, or structural light framing grade (dense).
N1 is No. 1 structural joists and planks, or structural light framing grade (medium grain for Douglas fir-larch).
N2D is dense No. 2 structural joists and planks or structural light framing grade (medium grain for Douglas fir-larch dense).
N2 is No. 2 structural joists and planks or structural light framing grade (medium grain for Douglas fir-larch).
N3M is No. 3 structural joists and planks, or structural light framing grade (medium grain).
N3C is No. 3 structural joists and planks, or structural light framing grade (coarse grain).
N3 is No. 3 structural joists and planks, or structural light framing grade.

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## FOOTNOTES FOR TABLE NO. 25-C-1—(Continued)

**Visually Graded Southern Pine**

SSD is dense select structural, structural joists and planks, or structural light framing grade (dense).
SSM is select structural, structural joists and planks, or structural light framing grade (medium grain).
N1D is No. 1 dense structural joists and planks, or structural light framing grade or No. 1 boards graded as dense.
N1M is No. 1 structural joists and planks, or structural light framing grade or No. 1 boards all with a medium grain rate of growth.
N2D is No. 2 dense structural joists and planks, or structural light framing grade or No. 2 boards graded as dense.
N2M is No. 2 structural joists and planks, or structural light framing grade or No. 2 boards all with a medium grain rate of growth.
N3M is No. 3 structural joists and planks, or structural light framing grade or No. 3 boards all with a medium grain rate of growth.
N3C is No. 3 structural joists and planks, or structural light framing grade or No. 3 boards all with coarse grain rate of growth.

**E-Rated Grades—All Species**

1/6-2.2E has 1/6 edge characteristic with 2.2E.
1/6-2.1E has 1/6 edge characteristic with 2.1E.
1/6-2.0E has 1/6 edge characteristic with 2.0E.
1/6-1.8E has 1/6 edge characteristic with 1.8E.
1/4-1.5E has 1/4 edge characteristic with 1.5E.
1/2-2.2E, 1/2-2.1E, 1/2-2.0E, 1/2-1.8E are E-rated grades with edge characteristics occupying up to one half of cross section.

[6]The values of $F_{byy}$ were calculated based on members 12 inches in depth (bending about Y-Y axis). When the depth is less than 12 inches, the values of $F_{byy}$ can be increased by multiplying by the following factors:

| DEPTH, INCHES | MULTIPLYING FACTOR |
|---|---|
| 10.75 | 1.01 |
| 8.75 | 1.04 |
| 6.75 | 1.07 |
| 5.125 | 1.10 |
| 3.125 | 1.16 |



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[7]The design values in horizontal shear contained in this table are based on members without wane.

[8]The tabulated design values in bending are applicable to members 12 inches or less in depth. For members greater than 12 inches in depth, the requirements of Section 2511 (d) 5 apply.

[9]The design values in Column 16 are for members of from two laminations to 15 inches in depth without tension laminations.

[10]The design values in Column 17 are for members of four or more laminations in depth and require special tension laminations. When these values are used in design and the member is specified by combination symbol, the designer should also specify the required design value in bending.

[11]When tension laminations are used to obtain the design value for $F_{bx}$, shown in Column 16, the compression perpendicular to grain value, $F_{c\perp}$, for the tension face may be increased to 650 psi for Douglas fir-larch and southern pine, and to 500 psi for hem-fir because the tension laminations are required to be dense.

[12]Combinations 47, 48, 49 and 50 have more restrictive slope of grain requirements than the basic slope of grain of the grades of lumber used in order to obtain higher tension-parallel-to-grain values and design values in bending when loaded perpendicular to the wide faces of the laminations. The slopes of grain used to calculate the design values in Table No. 25-C-1, Part B, were: Combination 47, 1:14; Combination 48, 1:14; Combination 49, 1:16; and Combination 50, 1:14. When design stresses are lower than the design values shown, or when a less restrictive slope of grain provides the same design value, a less restrictive slope of grain may be used. The following table gives the design values of these combinations for various

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## FOOTNOTES FOR TABLE NO. 25-C-1—(Continued)

slopes of grain: Values of $F_{bxx}$ in column 5 are for members of two laminations to 15 inches in depth without tension laminations, and values in Column 6 are for members of four or more laminations with tension laminations.

| SLOPE OF GRAIN | COMB. NO. | TENSION PARALLEL TO GRAIN ($F_t$) 2 OR MORE LAMS | COMP. PARALLEL TO GRAIN ($F_c$) 2 OR 3 LAMS | COMP. PARALLEL TO GRAIN ($F_c$) 4 OR MORE LAMS | BENDING ABOUT THE X-X AXIS $F_{bxx}$ | | BENDING ABOUT THE Y-Y AXIS $F_{byy}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 Lams to 15 in. | 4 or More Lams | 2 Lams | 3 Lams | 4 or More Lams |
| 1 | | psi 2 | psi 3 | psi 4 | psi 5 | psi 6 | psi 7 | psi 8 | psi 9 |
| 1.12 | 47 | 1200 | 1150 | 1900 | 1400 | 1600 | 1300 | 1550 | 1750 |
| | 48 | 1400 | 1350 | 2200 | 1600 | 1900 | 1500 | 1800 | 2000 |
| | 49 | 1300 | 1450 | 1900 | 1750 | 2100 | 1500 | 1750 | 1950 |
| | 50 | 1550 | 1700 | 2200 | 2100 | 2400 | 1750 | 2100 | 2300 |
| 1.10 | 47 | 1150 | 1150 | 1700 | 1400 | 1600 | 1300 | 1550 | 1750 |
| | 48 | 1350 | 1350 | 2000 | 1600 | 1900 | 1500 | 1800 | 2000 |
| | 49 | 1150 | 1450 | 1700 | 1550 | 1850 | 1500 | 1750 | 1850 |
| | 50 | 1350 | 1700 | 2000 | 1800 | 2100 | 1750 | 2100 | 2100 |
| 1.8 | 47 | 1000 | 1150 | 1500 | 1350 | 1600 | 1300 | 1550 | 1600 |
| | 48 | 1150 | 1350 | 1750 | 1600 | 1850 | 1500 | 1800 | 1850 |
| | 49 | — | — | — | — | — | — | — | — |
| | 50 | — | — | — | — | — | — | — | — |



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[13]These values for horizontal shear, $F_{vyy}$, apply to members manufactured using multiple-piece laminations with unbonded edge joints. For members using single-piece laminations or using multiple-piece laminations with bonded edge joints, the horizontal shear values tabulated in Columns 13, 14 and 15 apply.

[14]The duration of load modification factors given in Section 2504 (c) 4 shall not apply.

[15]The following species may be used for softwood species (WW), provided the modulus of elasticity, $E$, is reduced by 100,000 psi: Western cedars, western cedars (north), white woods (western woods) and California redwood—open grain.

[16]The following species may be used for softwood species (WW) provided the design values in horizontal shear in Column 12 ($F_{vy}$) are reduced by 5 psi and the design values in horizontal shear in Columns 13, 14 and 15 ($F_{vy}$) and in Column 18 ($F_{vx}$) are reduced by 10 psi: Coast sitka spruce, coast species, western white pine and eastern white pine.

[17]When special tension laminations are not used, the design values in bending about the x-x axis ($F_{bx}$) shall be multiplied by 0.75 for bending members over 15 inches deep. For bending members 15 inches and less in depth, use the design values in Column 16.





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## TABLE NO. 25-C-2 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED CALIFORNIA REDWOOD VISUALLY GRADED[1 2 3]

### Members stressed principally in axial tension or compression or in bending with load applied perpendicular to the wide faces of the laminations

| Combination Symbol | Species Outer Laminations/ Core Laminations[4] | Bending About X-X Axis | | | | | | Bending About Y-Y Axis | | | | Axially Loaded | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Loaded Parallel to Wide Faces of the Laminations | | | | | | Loaded Perpendicular to Wide Faces of Laminations | | | | | | |
| | | Extreme Fiber in Bending | | Compression Perpendicular to Grain | | | | | | | | | | |
| | | Tension Zone Stressed in Tension[5] $F_{bxx}$ psi | Compression Zone Stressed in Tension[6] $F_{bxx}$ psi | Tension Face $F_{c\perp xx}$ psi | Compression Face $F_{c\perp xx}$ psi | Horizontal Shear $F_{vxx}$ psi | Modulus of Elasticity[7] $E_{xx}$ x 10⁶ psi | Extreme Fiber in Bending[5] $F_{byy}$ psi | Compression Perpendicular to Grain Side Faces $F_{c\perp yy}$ psi | Horizontal Shear $F_{vyy}$ psi | Modulus of Elasticity[7] $E_{yy}$ x 10⁶ psi | Tension Parallel to Grain $F_t$ psi | Compression Parallel to Grain $F_c$ psi | Modulus of Elasticity[7] $E$ x 10⁶ psi |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| B-16F V1 | CR/CR | 1600 | 800 | 315 | 315 | 125 | 1.1 | 1400 | 270 | 110 | 1.1 | 900 | 1400 | 1.1 |
| Wet-use factors[2] | | 0.8 | 0.8 | 0.667 | 0.667 | 0.875 | 0.833 | 0.8 | 0.667 | 0.875 | 0.833 | 0.8 | 0.73 | 0.833 |

[1]The combinations in this table are intended primarily for members stressed in bending due to loads applied perpendicular to the wide faces of the laminations for members with four or more laminations. Stresses are tabulated, however, for loading both perpendicular and parallel to the wide faces of the laminations. For combinations and stresses applicable to members loaded primarily axially or parallel to the wide faces of the laminations, see Table No. 25-C-2, Part B. For members of two or three laminations, see Table No. 25-C-2, Part B.

[2]The tabulated design values are for dry conditions of use. To obtain wet-use design values, multiply the tabulated values by the factors shown at the end of the table.

[3]The tabulated design values are for normal duration of loading. For other durations of loading, see Section 2504 (c) 4.

[4]CR = California redwood.

[5]The tabulated design values in bending are applicable to members 12 inches or less in depth. For members greater than 12 inches in depth, the requirements of Section 2511 (d) 5 apply.

[6]Design values in this column are for extreme fiber stress in bending when the member is loaded such that the compression zone laminations are subjected to tensile stresses. The values in this column may be increased to 1200 psi when end-joint spacing restrictions are applied to the compression zone when stressed in tension.

[7]The duration of load modification factor given in Section 2504 (c) 4 shall not apply.



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## TABLE NO. 25-C-2 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED CALIFORNIA REDWOOD VISUALLY GRADED[1 2 3 7 8]

### Members stressed principally in axial tension, axial compression or in bending with load applied parallel to the wide faces of the laminations

| Combination Symbol | Species[4] | Grade[5] | Modulus of Elasticity[9] $E$ x 10[6] psi | Compression Perpendicular to Grain $F_{c\perp}$ | Axially Loaded | | | Bending About Y-Y Axis Loaded Parallel to Wide Faces of Laminations | | | | | | Bending About X-X Axis Loaded Perpendicular to Wide Faces of Laminations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Tension Parallel To Grain | Compression Parallel To Grain | | Extreme Fiber in Bending[6] | | | Horizontal Shear | | | Extreme Fiber in Bending | Horizontal Shear |
| | | | | | 2 or More Lams | 4 or More Lams | 2 or 3 Lams | 4 or More Lams | 3 Lams | 2 Lams | 4 or More Lams | 3 Lams | 2 Lams | 2 Lams to 15 in. deep | 2 or More Lams |
| | | | | | $F_t$ | $F_c$ | $F_c$ | $F_{byy}$ | $F_{byy}$ | $F_{byy}$ | $F_{vyy}$ | $F_{vyy}$ | $F_{vyy}$ | $F_{bxx}$ | $F_{vxx}$ |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| B-1 | CR | L5 | 1.0 | 315 | 875 | 1350 | 1350 | 1450 | 1300 | 1100 | 110 | 105 | 95 | 1200 | 125 |
| B-2 | CR | L4 | 1.0 | 315 | 875 | 1350 | 1350 | 1450 | 1300 | 1100 | 110 | 105 | 95 | 1200 | 125 |
| B-3 | CR | L3 | 1.2 | 315 | 1000 | 1550 | 1550 | 1450 | 1300 | 1100 | 110 | 105 | 95 | 1350 | 125 |
| B-4 | CR | L2 | 1.2 | 315 | 1000 | 1600 | 1600 | 1500 | 1350 | 1150 | 110 | 105 | 95 | 1350 | 125 |
| B-5 | CR | L1 | 1.2 | 315 | 1000 | 1600 | 1600 | 1600 | 1500 | 1250 | 110 | 105 | 95 | 1350 | 125 |
| Wet-use factors[2] | | | 0.833 | 0.667 | 0.8 | 0.73 | 0.73 | 0.8 | 0.8 | 0.8 | 0.875 | 0.875 | 0.875 | 0.8 | 0.875 |

[1]The tabulated combinations in this table are intended primarily for members loaded either axially or in bending with the loads acting parallel to the wide faces of the laminations. Design values for bending due to loading applied perpendicular to the wide faces of the laminations are also included; however, the combination in Table No. 25-C-2, Part A, is usually better suited for this condition of loading for members with four or more laminations.

[2]The tabulated design values are for dry conditions of use. To obtain wet-use design values, multiply the tabulated values by the factors shown at the end of the table.

[3]The tabulated values are for normal duration of loading. For other durations of loading, see Section 2504 (c) 4.

[4]CR = California redwood.

*(Continued)*





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## FOOTNOTES FOR TABLE NO. 25-C-2—(Continued)

[5]Grade designations are as follows:
Visually Graded—California redwood
L1 is L1 laminating grade (close grain).
L2 is L2 laminating grade (close grain).
L3 is L3 laminating grade (close grain).
L4 is L4 laminating grade (close grain).
L5 is L5 laminating grade (close grain).

[6]The values of $F_{byy}$ were calculated based on members 12 inches in depth (bending about Y-Y axis). When the depth is less than 12 inches, the values of $F_{byy}$ can be increased by multiplying by the following factors:

| DEPTH, INCHES | MULTIPLYING FACTOR |
|---|---|
| 10.75 | 1.01 |
| 8.75 | 1.04 |
| 6.75 | 1.07 |
| 5.125 | 1.10 |
| 3.125 | 1.16 |

[7]The tabulated design values for bending are applicable to members 12 inches or less in depth. For members greater than 12 inches in depth the requirements of Section 2511 (d) 5 apply.

[8]The combinations in this table are not intended for deep bending members when loaded perpendicular to the wide faces of the laminations. However, if members over 15 inches in depth are necessary, AITC 302-24 tension laminations are required and the designer must specify that the member is for use in bending about the x-x axis, in which case, the design value $F_{bxx}$ is 1400 psi for combinations B-1 and B-2 and 1600 psi for B-3, B-4 and B-5.

[9]The duration of load modification factors given in Section 2504 (c) 4 shall not apply.



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## TABLE NO. 25-D—PART A—ALLOWABLE UNIT STRESSES FOR HARDWOOD GLUED LAMINATED TIMBER[1] FOR NORMAL LOADING DURATION—DRY CONDITIONS OF USE[2]

| SPECIES | MULTIPLY THE APPROPRIATE STRESS MODULE IN PART B BY THE FACTORS BELOW TO DETERMINE ALLOWABLE STRESS FOR: | | | ALLOWABLE UNIT STRESS (Pounds per Square inch) | |
|---|---|---|---|---|---|
| | Extreme Fiber in Bending ($F_b$) or Tension Parallel to Grain ($F_t$) | Compression Parallel to Grain ($F_c$) | Modulus of Elasticity ($E$)[6] | Horizontal Shear ($F_v$) | Compression Perpendicular to Grain ($F_{c\perp}$) |
| 1. Hickory, true and pecan | 3.85 | 3.05 | 1.80 | 260 | 730 |
| 2. Beech, American | 3.05 | 2.45 | 1.70 | 230 | 610 |
| 3. Birch, sweet and yellow | 3.05 | 2.45 | 1.90 | 230 | 610 |
| 4. Elm, rock | 3.05 | 2.45 | 1.40 | 230 | 610 |
| 5. Maple, black and sugar (hard maple) | 3.05 | 2.45 | 1.70 | 230 | 610 |
| 6. Ash, commercial white | 2.80 | 2.20 | 1.70 | 230 | 610 |
| 7. Oak, commercial red and white | 2.80 | 2.05 | 1.60 | 230 | 610 |
| 8. Elm, American and slippery (white or soft elm) | 2.20 | 1.60 | 1.40 | 190 | 310 |
| 9. Sweet gum (red or sap gum) | 2.20 | 1.60 | 1.40 | 190 | 370 |
| 10. Tupelo, black (black gum) | 2.20 | 1.60 | 1.20 | 190 | 370 |
| 11. Tupelo, water | 2.20 | 1.60 | 1.30 | 190 | 370 |
| 12. Ash, black | 2.00 | 1.30 | 1.30 | 170 | 370 |
| 13. Poplar, yellow | 2.00 | 1.45 | 1.50 | 150 | 270 |
| 14. Cottonwood, eastern | 1.55 | 1.20 | 1.20 | 110 | 180 |

*(Footnotes on following page.)*





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## TABLE NO. 25-D—PART B—VALUES FOR USE IN COMPUTING WORKING STRESSES WITH FACTORS OF PART A TOGETHER WITH LIMITATIONS REQUIRED TO PERMIT THE USE OF SUCH STRESSES[3]

| COMBINATION SYMBOL | RATIO OF SIZE OF MAXIMUM PERMITTED KNOT TO FINISHED WIDTH OF LAMINATION[4] | NUMBER OF LAMINATIONS[5] | EXTREME FIBER IN BENDING | | TENSION PARALLEL TO GRAIN | | COMPRESSION PARALLEL TO GRAIN | | MODULUS OF ELASTICITY ($E$)[6] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Stress Module | Steepest Grain Slope | Stress Module | Steepest Grain Slope | Stress Module | Steepest Grain Slope | Stress Module |
| A | 0.1 | 4 to 14<br>15 or more | 800<br>800 | 1:16<br>1:16 | 500<br>500 | 1:16<br>1:16 | 970<br>970 | 1:15<br>1:15 | 1,000,000 |
| B | .2 | 4 to 14<br>15 or more | 770<br>800 | 1:16<br>1:16 | 500<br>500 | 1:16<br>1:16 | 920<br>930 | 1:15<br>1:15 | 1,000,000 |
| C | .3 | 4 to 14<br>15 or more | 600<br>660 | 1:12<br>1:12 | 450<br>450 | 1:15<br>1:16 | 860<br>870 | 1:14<br>1:14 | 900,000 |
| D | .4 | 4 to 14<br>15 or more | 450<br>520 | 1:8<br>1:8 | 350<br>350 | 1:10<br>1:12 | 780<br>810 | 1:12<br>1:12 | 800,000 |
| E | .5 | 4 to 14<br>15 or more | 300<br>380 | 1:8<br>1:8 | 300<br>300 | 1:8<br>1:8 | 690<br>730 | 1:10<br>1:10 | 800,000 |

[1]The allowable unit stresses in bending obtained from Table No. 25-D apply when the wide faces of the laminations are normal to the direction of the load.

[2]Allowable stresses for dry conditions of use shall be applicable when the moisture content in service is 16 percent or less as in most covered structures. For wet conditions of use the following maximum percentage of the dry-use stresses shall be permitted:

$F_b$ (bending) and $F_t$ (tension) 80 percent

$F_v$ (horizontal shear 88 percent)

$F_c$ (compression parallel to grain) 70 percent

$F_{c\perp}$ (compression perpendicular to grain) 67 percent

$E$ (modulus of elasticity) 83 percent

[3]For modification of allowable unit stresses for structural glued-laminated lumber, see Section 2504.

[4]Factors for knot sizes of 0.1 and 0.2 are identical in case of extreme fiber in bending and in tension parallel to grain because slope of grain of 1:16 is a greater limitation than knot size. The smaller knot size may be specified for reasons other than strength.

[5]When laminations of different thicknesses are used, divide the depth of the member by the thickest lamination used and then assume the quotient to be the number of laminations in the member for use in determining the allowable stress.

[6]The duration of load modification factors given in Section 2504 (c) 4 shall not apply.



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## TABLE NO. 25-E—ALLOWABLE UNIT STRESSES FOR TREATED ROUND TIMBER POLES AND PILES[6]

(Values for normal load duration and wet conditions of use, pounds per square inch)

| Species | Compression Parallel to Grain[7] $F_c$ | Extreme Fiber in Bending[7] $F_b$ | Horizontal Shear $F_v$ | Compression Perpendicular to Grain $F_{c\perp}$ | Modulus of Elasticity $E$ |
|---|---|---|---|---|---|
| 1. Pacific Coast Douglas Fir[1,2] | 1250 | 2450 | 115 | 230 | 1,500,000 |
| 2. Southern Pine[1,3] | 1200 | 2400 | 110 | 250 | 1,500,000 |
| 3. Red Oak[4] | 1100 | 2450 | 135 | 350 | 1,250,000 |
| 4. Red Pine[5] | 900 | 1900 | 85 | 155 | 1,280,000 |

[1]Design values in compression parallel to the grain for Pacific Coast Douglas fir and southern pine may be increased 0.20 percent for each foot of length from the tip of the pile to the critical section. The increase shall not exceed 10 percent for any single pile; however, the increase is cumulative with the increase in section properties due to taper from the pile tip to the critical section.

[2]Pacific Coast Douglas fir includes Douglas fir from west of the crest of the Cascade Mountains in Oregon, Washington and Northern California and west of the crest of the Sierra Nevada Mountains in the rest of California. For fastener design, use Douglas fir-larch design values.

[3]Southern pine values apply to longleaf, slash, loblolly and shortleaf pines.

[4]Red oak values apply to northern and southern red oak.

[5]Red pine values apply to red pine grown in the United States. For fastener design, use northern pine design values.

[6]The form factor of Section 2504 (c) 7 for bending members of circular cross section is incorporated in the allowable unit stresses for extreme fiber in bending as listed within the table.

[7]The allowable values listed in Table No. 25-E for compression parallel to grain and extreme fiber in bending are based on load-sharing principles such as occur in a pile cluster. For piles which support their own specific load, an additional safety factor of 1.25 shall be used with compression parallel to grain values and an additional safety factor of 1.30 shall be used with extreme fiber in bending values.



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## TABLE NO. 25-F—HOLDING POWER OF BOLTS[1,2,4] FOR DOUGLAS FIR-LARCH, CALIFORNIA REDWOOD (CLOSE GRAIN) AND SOUTHERN PINE

**(See U.B.C. Standard No. 25-17 where members are not of equal size and for values in other species.)**

$p$ = Safe loads parallel to grain in pounds
$q$ = Safe loads perpendicular to grain in pounds

| Length of Bolt in Main Wood Member[3] (In Inches) | | DIAMETER OF BOLT (IN INCHES) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ⅜ | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ | 1½ |
| 1½ | Single $p$ | 325 | 470 | 590 | 710 | 830 | 945 | | | |
| | Shear $q$ | 185 | 215 | 245 | 270 | 300 | 325 | | | |
| | Double $p$ | 650 | 940 | 1180 | 1420 | 1660 | 1890 | | | |
| | Shear $q$ | 370 | 430 | 490 | 540 | 600 | 650 | | | |
| 2½ | Single $p$ | | 630 | 910 | 1155 | 1370 | 1575 | | | |
| | Shear $q$ | | 360 | 405 | 450 | 495 | 540 | | | |
| | Double $p$ | 710 | 1260 | 1820 | 2310 | 2740 | 3150 | | | |
| | Shear $q$ | 620 | 720 | 810 | 900 | 990 | 1080 | | | |
| 3½ | Single $p$ | | | 990 | 1400 | 1790 | 2135 | 2455 | 2740 | 3305 |
| | Shear $q$ | | | 565 | 630 | 695 | 760 | 825 | 895 | 1020 |
| | Double $p$ | 710 | 1270 | 1980 | 2800 | 3580 | 4270 | 4910 | 5480 | 6610 |
| | Shear $q$ | 640 | 980 | 1130 | 1260 | 1390 | 1520 | 1650 | 1780 | 2040 |
| 5½ | Single $p$ | | | | | 1950 | 2535 | 3190 | 3820 | 4975 |
| | Shear $q$ | | | | | 1090 | 1190 | 1300 | 1395 | 1605 |
| | Double $p$ | | 1270 | 1990 | 2860 | 3900 | 5070 | 6380 | 7640 | 9950 |
| | Shear $q$ | | 930 | 1410 | 1880 | 2180 | 2380 | 2600 | 2790 | 3210 |



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$p$ = Safe loads parallel to grain in pounds
$q$ = Safe loads perpendicular to grain in pounds

| Length of Bolt in Main Wood Member[3] (In Inches) | | DIAMETER OF BOLT (IN INCHES) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ⅜ | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ | 1½ |
| 7½ | Single $p$ | | | | | | | | 3975 | 5680 |
| | Shear $q$ | | | | | | | | 1900 | 2185 |
| | Double $p$ | | | 1990 | 2860 | 3890 | 5080 | 6440 | 7950 | 11,360 |
| | Shear $q$ | | | 1260 | 1820 | 2430 | 3030 | 3500 | 3800 | 4370 |
| 9½ | Single $p$ | | | | | | | | | 5730 |
| | Shear $q$ | | | | | | | | | 2765 |
| | Double $p$ | | | | 2860 | 3900 | 5080 | 6440 | 7950 | 11,460 |
| | Shear $q$ | | | | 1640 | 2270 | 2960 | 3710 | 4450 | 5530 |
| 11½ | Single $p$ | | | | | | | | | |
| | Shear $q$ | | | | | | | | | |
| | Double $p$ | | | | | 3900 | 5080 | 6440 | 7950 | 11,450 |
| | Shear $q$ | | | | | 2050 | 2770 | 3540 | 4360 | 6150 |
| 13½ | Single $p$ | | | | | | | | | |
| | Shear $q$ | | | | | | | | | |
| | Double $p$ | | | | | | 5100 | 6440 | 7960 | 11,450 |
| | Shear $q$ | | | | | | 2530 | 3310 | 4160 | 6040 |

[1]Tabulated values are on a normal load-duration basis and apply to joints made of seasoned lumber used in dry locations. See U.B.C. Standard No. 25-17 for other service conditions.

[2]Double shear values are for joints consisting of three wood members in which the side members are one half the thickness of the main member. Single shear values are for joints consisting of two wood members having a minimum thickness not less than that specified.

[3]The length specified is the length of the bolt in the main member of double shear joints or the length of the bolt in the thinner member of single shear joints.

[4]See U.B.C. Standard No. 25-17 for wood-to-metal bolted joints.





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## TABLE NO. 25-G—SAFE LATERAL STRENGTH AND REQUIRED PENETRATION OF BOX AND COMMON WIRE NAILS DRIVEN PERPENDICULAR TO GRAIN OF WOOD

| SIZE OF NAIL | STANDARD LENGTH (Inches) | WIRE GAUGE | PENETRATION REQUIRED (Inches) | LOADS (Pounds)[1 2 3] | |
|---|---|---|---|---|---|
| | | | | Douglas Fir Larch or Southern Pine | Other Species |
| **BOX NAILS** | | | | | |
| 6d | 2 | 12½ | 1⅛ | 51 | See U.B.C. Standard No. 25-17 |
| 8d | 2½ | 11½ | 1¼ | 63 | |
| 10d | 3 | 10½ | 1½ | 76 | |
| 12d | 3¼ | 10½ | 1½ | 76 | |
| 16d | 3½ | 10 | 1½ | 82 | |
| 20d | 4 | 9 | 1⅝ | 94 | |
| 30d | 4½ | 9 | 1⅝ | 94 | |
| 40d | 5 | 8 | 1¾ | 108 | |
| **COMMON NAILS** | | | | | |
| 6d | 2 | 11½ | 1¼ | 63 | See U.B.C. Standard No. 25-17 |
| 8d | 2½ | 10¼ | 1½ | 78 | |
| 10d | 3 | 9 | 1⅝ | 94 | |
| 12d | 3¼ | 9 | 1⅝ | 94 | |
| 16d | 3½ | 8 | 1¾ | 108 | |
| 20d | 4 | 6 | 2⅛ | 139 | |
| 30d | 4½ | 5 | 2¼ | 155 | |
| 40d | 5 | 4 | 2½ | 176 | |
| 50d | 5½ | 3 | 2¾ | 199 | |
| 60d | 6 | 2 | 2⅞ | 223 | |

[1]The safe lateral strength values may be increased 25 percent where metal side plates are used.

[2]For wood diaphragm calculations these values may be increased 30 percent. (See U.B.C. Standard No. 25-17.)

[3]Tabulated values are on a normal load-duration basis and apply to joints made of seasoned lumber used in dry locations. See U.B.C. Standard No. 25-17 for other service conditions.



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## TABLE NO. 25-H—SAFE RESISTANCE TO WITHDRAWAL OF COMMON WIRE NAILS

**Inserted Perpendicular to Grain of the Wood, In Pounds per Linear Inch of Penetration Into the Main Member**

| KIND OF WOOD | SIZE OF NAIL | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 6d | 8d | 10d | 12d | 16d | 20d | 30d | 40d | 50d | 60d |
| 1. Douglas Fir, Larch | 29 | 34 | 38 | 38 | 42 | 49 | 53 | 58 | 63 | 67 |
| 2. Southern Pine | 35 | 41 | 46 | 46 | 50 | 59 | 64 | 70 | 76 | 81 |
| 3. Other Species | See U.B.C. Standard No. 25-17. | | | | | | | | | |

## TABLE NO. 25-I—MAXIMUM DIAPHRAGM DIMENSION RATIOS

| MATERIAL | HORIZONTAL DIAPHRAGMS | VERTICAL DIAPHRAGMS |
|---|---|---|
| | Maximum Span-Width Ratios | Maximum Height-Width Ratios |
| 1. Diagonal sheathing, conventional | 3:1 | 2:1 |
| 2. Diagonal sheathing, special | 4:1 | 3½:1 |
| 3. Plywood and particleboard, nailed all edges | 4:1 | 3½:1 |
| 4. Plywood and particleboard, blocking omitted at intermediate joints | 4:1 | 2:1 |



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## TABLE NO. 25-J-1—ALLOWABLE SHEAR IN POUNDS PER FOOT FOR HORIZONTAL PLYWOOD DIAPHRAGMS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1]

| PLYWOOD GRADE | Common Nail Size | Minimum Nominal Penetration in Framing (In inches) | Minimum Nominal Plywood Thickness (In inches) | Minimum Nominal Width of Framing Member (In inches) | BLOCKED DIAPHRAGMS: Nail spacing at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 and 4) and at all panel edges (Cases 5 and 6) — 6 | 4 | 2½/2 | 2 | BLOCKED DIAPHRAGMS: Nail spacing at other plywood panel edges — 6 | 6 | 4 | 3 | UNBLOCKED DIAPHRAGM: Nails spaced 6" max. at supported end — Load perpendicular to unblocked edges and continuous panel joints (Case 1) | Other configurations (Cases 2, 3 and 4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRUCTURAL I | 6d | 1¼ | 5/16 | 2 | 185 | 250 | 375 | 420 | | | | | 165 | 125 |
| | | | | 3 | 210 | 280 | 420 | 475 | | | | | 185 | 140 |
| | 8d | 1½ | 3/8 | 2 | 270 | 360 | 530 | 600 | | | | | 240 | 180 |
| | | | | 3 | 300 | 400 | 600 | 675 | | | | | 265 | 200 |
| | 10d[3] | 1⅝ | 15/32 | 2 | 320 | 425 | 640 | 730 | | | | | 285 | 215 |
| | | | | 3 | 360 | 480 | 720 | 820 | | | | | 320 | 240 |
| C-D, C-C, STRUCTURAL II and other grades covered in U.B.C. Standard No. 25-9 | 6d | 1¼ | 5/16 | 2 | 170 | 225 | 335 | 380 | | | | | 150 | 110 |
| | | | | 3 | 190 | 250 | 380 | 430 | | | | | 170 | 125 |
| | | | 3/8 | 2 | 185 | 250 | 375 | 420 | | | | | 165 | 125 |
| | | | | 3 | 210 | 280 | 420 | 475 | | | | | 185 | 140 |
| | 8d | 1½ | 3/8 | 2 | 240 | 320 | 480 | 545 | | | | | 215 | 160 |
| | | | | 3 | 270 | 360 | 540 | 610 | | | | | 240 | 180 |
| | | | 15/32 | 2 | 270 | 360 | 530 | 600 | | | | | 240 | 180 |
| | | | | 3 | 300 | 400 | 600 | 675 | | | | | 265 | 200 |
| | 10d[3] | 1⅝ | 15/32 | 2 | 290 | 385 | 575 | 655 | | | | | 255 | 190 |
| | | | | 3 | 325 | 430 | 650 | 735 | | | | | 290 | 215 |
| | | | 19/32 | 2 | 320 | 425 | 640 | 730 | | | | | 285 | 215 |
| | | | | 3 | 360 | 480 | 720 | 820 | | | | | 320 | 240 |



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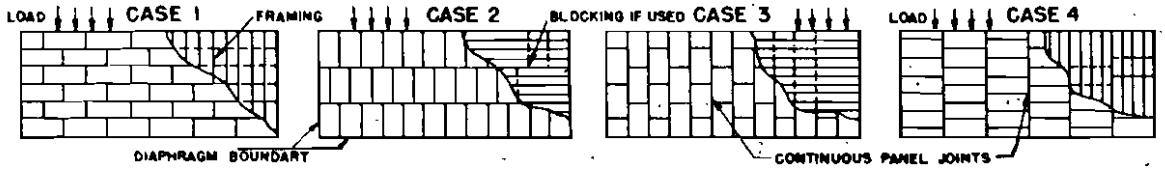
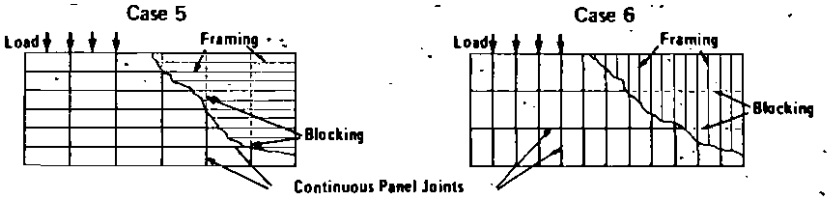
[1]These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading. Space nails 10 inches on center for floors and 12 inches on center for roofs along intermediate framing members.

Allowable shear values for nails in framing members of other species set forth in Table No. 25-17-J of U.B.C. Standards shall be calculated for all grades by multiplying the values for nails in STRUCTURAL I by the following factors: Group III, 0.82 and Group IV, 0.65.

[2]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches or 2½ inches on center.

[3]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than 1⅝ inches are spaced 3 inches or less on center.




**Note:** Framing may be located in either direction for blocked diaphragms.





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## TABLE NO. 25-J-2—ALLOWABLE SHEAR IN POUNDS PER FOOT FOR HORIZONTAL PARTICLEBOARD DIAPHRAGMS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1]

| PANEL GRADE | COMMON NAIL SIZE | MINIMUM NAIL PENETRATION IN FRAMING (Inches) | MINIMUM NOMINAL PANEL THICKNESS (Inch) | MINIMUM NOMINAL WIDTH OF FRAMING MEMBER (Inches) | BLOCKED DIAPHRAGMS | | | | UNBLOCKED DIAPHRAGMS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nail Spacing (In.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6) | | | | Nails Spaced 6" max. at Supported Edges | |
| | | | | | 6 | 4 | 2½[2] | 2[2] | Case 1 (No unblocked edges or continuous joints parallel to load) | All other configurations (Cases 2, 3 4, 5 & 6) |
| | | | | | Nail Spacing (In.) at other panel edges (Cases 1, 2, 3 & 4) | | | | | |
| | | | | | 6 | 6 | 4 | 3 | | |
| 2-M-W | 6d | 1¼ | 5/16 | 2 | 170 | 225 | 335 | 380 | 150 | 110 |
| | | | | 3 | 190 | 250 | 380 | 430 | 170 | 125 |
| | | | 3/8 | 2 | 185 | 250 | 375 | 420 | 165 | 125 |
| | | | | 3 | 210 | 280 | 420 | 475 | 185 | 140 |
| | 8d | 1½ | 3/8 | 2 | 240 | 320 | 480 | 545 | 215 | 160 |
| | | | | 3 | 270 | 360 | 540 | 610 | 240 | 180 |
| | | | 7/16 | 2 | 255 | 340 | 505 | 575 | 230 | 170 |
| | | | | 3 | 285 | 380 | 570 | 645 | 255 | 190 |
| | | | ½ | 2 | 270 | 360 | 530 | 600 | 240 | 180 |
| | | | | 3 | 300 | 400 | 600 | 675 | 265 | 200 |
| | 10d[3] | 1⅝ | ½ | 2 | 290 | 385 | 575 | 655 | 255 | 190 |
| | | | | 3 | 325 | 430 | 650 | 735 | 290 | 215 |
| | | | 5/8 | 2 | 320 | 425 | 640 | 730 | 285 | 215 |
| | | | | 3 | 360 | 480 | 720 | 820 | 320 | 240 |
| 2-M-3 | 10d[3] | 1⅝ | ¾ | 2 | 320 | 425 | 640 | 730 | 285 | 215 |
| | | | | 3 | 360 | 480 | 720 | 820 | 320 | 240 |



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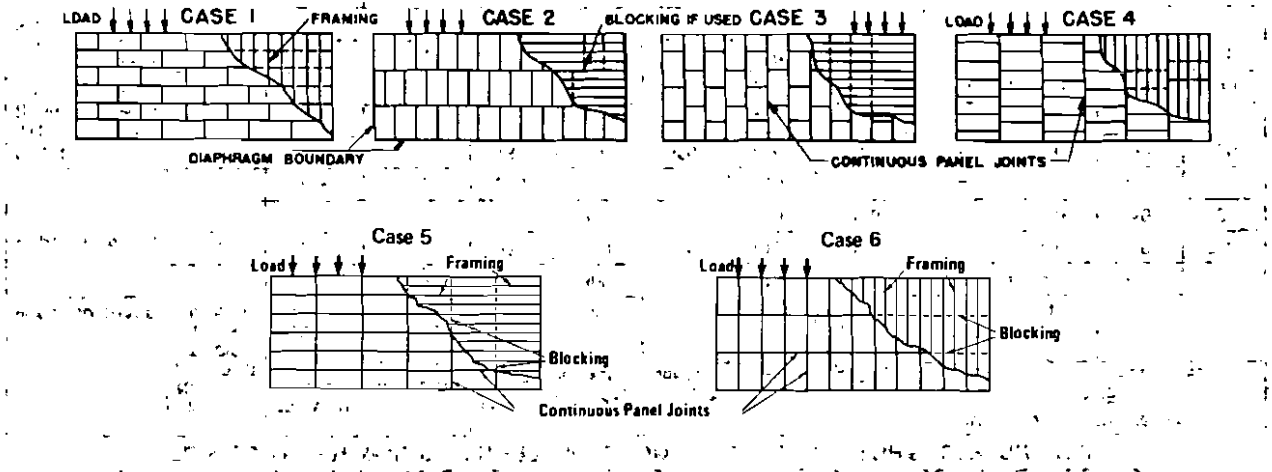
[1]These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading. Space nails 10 inches on center for floors and 12 inches on center for roofs along intermediate framing members.

Allowable shear values for nails in framing members of other species set forth in Table No. 25-17-J of U.B.C. Standards shall be calculated for all grades by multiplying the values for nails by the following factors: Group III, 0.82 and Group IV, 0.65.

[2]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches or 2½ inches on center.

[3]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than 1⅝ inches are spaced 3 inches or less on center.




Note: Framing may be located in either direction for blocked diaphragms.





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## TABLE NO. 25-K-1—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES IN POUNDS PER FOOT FOR PLYWOOD SHEAR WALLS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1,4]

| PLYWOOD GRADE | MINIMUM NOMINAL PLYWOOD THICKNESS (Inches) | MINIMUM NAIL PENETRATION IN FRAMING (Inches) | NAIL SIZE (Common or Galvanized Box) | PLYWOOD APPLIED DIRECT TO FRAMING — Nail Spacing at Plywood Panel Edges | | | | NAIL SIZE (Common or Galvanized Box) | PLYWOOD APPLIED OVER 1/2-INCH GYPSUM SHEATHING — Nail Spacing at Plywood Panel Edges | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 6 | 4 | 3 | 2[2] | | 6 | 4 | 3 | 2[2] |
| STRUCTURAL I | 5/16 | 1 1/4 | 6d | 200 | 300 | 390 | 510 | 8d | 200 | 300 | 390 | 510 |
| | 3/8 | 1 1/2 | 8d | 230[3] | 360[3] | 460[3] | 610[3] | 10d[5] | 280 | 430 | 550 | 730[2] |
| | 15/32 | 1 1/2 | 8d | 280 | 430 | 550 | 730 | 10d[5] | 280 | 430 | 550 | 730 |
| | 15/32 | 1 5/8 | 10d[5] | 340 | 510 | 665 | 870 | — | — | — | — | — |
| C-D, C-C STRUCTURAL II, plywood panel siding and other grades covered in U.B.C. Standard No. 25-9. | 5/16 | 1 1/4 | 6d | 180 | 270 | 350 | 450 | 8d | 180 | 270 | 350 | 450 |
| | 3/8 | 1 1/4 | 6d | 200 | 300 | 390 | 510 | 8d | 200 | 300 | 390 | 510 |
| | 3/8 | 1 1/2 | 8d | 220[3] | 320[3] | 410[3] | 530[3] | 10d[5] | 260 | 380 | 490 | 640 |
| | 15/32 | 1 1/2 | 8d | 260 | 380 | 490 | 640 | 10d[5] | 260 | 380 | 490 | 640 |
| | 15/32 | 1 5/8 | 10d[5] | 310 | 460 | 600 | 770 | — | — | — | — | — |
| | 19/32 | 1 5/8 | 10d[5] | 340 | 510 | 665 | 870 | — | — | — | — | — |
| | | | NAIL SIZE (Galvanized Casing) | | | | | NAIL SIZE (Galvanized Casing) | | | | |
| Plywood panel siding in grades covered in U.B.C. Standard No. 25-9 | 5/16 | 1 1/4 | 6d | 140 | 210 | 275 | 360 | 8d | 140 | 210 | 275 | 360 |
| | 3/8 | 1 1/2 | 8d | 130[3] | 200[3] | 260[3] | 340[3] | 10d[5] | 160 | 240 | 310 | 410 |



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[1]All panel edges backed with 2-inch nominal or wider framing. Plywood installed either horizontally or vertically. Space nails at 6 inches on center along intermediate framing members for 3/8-inch plywood installed with face grain parallel to studs spaced 24 inches on center and 12 inches on center for other conditions and plywood thicknesses. These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading.

Allowable shear values for nails in framing members of other species set forth in Table No. 25-17-J of U.B.C. Standards shall be calculated for all grades by multiplying the values for common and galvanized box nails in STRUCTURAL I and galvanized casing nails in other grades by the following factors: Group III, 0.82 and Group IV, 0.65.

[2]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches on center.

[3]The values for 3/8-inch-thick plywood applied direct to framing may be increased 20 percent, provided studs are spaced a maximum of 16 inches on center or plywood is applied with face grain across studs.

[4]Where plywood is applied on both faces of a wall and nail spacing is less than 6 inches on center on either side, panel joints shall be offset to fall on different framing members or framing shall be 3-inch nominal or thicker and nails on each side shall be staggered.

[5]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than 1 5/8 inches are spaced 3 inches or less on center.





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## TABLE NO. 25-K-2—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES IN POUNDS PER FOOT FOR PARTICLEBOARD SHEAR WALLS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1,4]

| PANEL GRADE | MINIMUM NOMINAL PANEL THICKNESS (In.) | MINIMUM NAIL PENETRATION IN FRAMING (In.) | PANELS APPLIED DIRECT TO FRAMING | | | | | PANELS APPLIED OVER 1/2" GYPSUM SHEATHING | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nail Size (Common or galvanized box) | Nail Spacing at Panel Edges (In.) | | | | Nail Size (Common or galvanized box) | Nail Spacing at Panel Edges (In.) | | | |
| | | | | 6 | 4 | 3 | 2[2] | | 6 | 4 | 3 | 2[2] |
| 2-M-W | 5/16 | 1 1/4 | 6d | 180 | 270 | 350 | 450 | 8d | 180 | 270 | 350 | 450 |
| | 3/8 | | | 200 | 300 | 390 | 510 | | 200 | 300 | 390 | 510 |
| | 3/8 | 1 1/2 | 8d | 220[3] | 320[3] | 410[3] | 530[3] | 10d[5] | 260 | 380 | 490 | 640 |
| | 7/16 | | | 240[3] | 350[3] | 450[3] | 585[3] | | | | | |
| | 1/2 | | | 260 | 380 | 490 | 640 | | | | | |
| | 1/2 | 1 5/8 | 10d[5] | 310 | 460 | 600 | 770 | — | — | — | — | — |
| | 5/8 | | | 340 | 510 | 665 | 870 | — | — | — | — | — |

[1]All panel edges backed with 2-inch nominal or wider framing. Panels installed either horizontally or vertically. Space nails at 6 inches on center along intermediate framing members for 3/8-inch panel installed with the long dimension parallel to studs spaced 24 inches on center and 12 inches on center for other conditions and panel thicknesses. These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading.

Allowable shear values for nails in framing members of other species set forth in Table No. 25-17-J of U.B.C. Standards shall be calculated for all grades by multiplying the values for common and galvanized box nails by the following factors: Group III, 0.82 and Group IV, 0.65.

[2]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches on center.

[3]The allowable shear values may be increased to the values shown for 1/2-inch-thick sheathing with the same nailing, provided:

(a) The studs are spaced a maximum of 16 inches on center, or

(b) The panels are applied with the long dimension perpendicular to studs.

[4]Where particleboard is applied on both faces of a wall and nail spacing is less than 6 inches on center on either side, panel joints shall be offset to fall on different framing members, or framing shall be 3-inch nominal or thicker and nails on each side shall be staggered.

[5]Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than 1 5/8 inches are spaced 3 inches or less on center.



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## TABLE NO. 25-L—WOOD SHINGLE AND SHAKE SIDEWALL EXPOSURES

| SHINGLE OR SHAKE | MAXIMUM WEATHER EXPOSURES | | | |
|---|---|---|---|---|
| | Single-Coursing | | Double-Coursing | |
| Length and Type | No. 1 | No. 2 | No. 1 | No. 2 |
| 1. 16-inch Shingles | 7½" | 7½" | 12" | 10" |
| 2. 18-inch Shingles | 8½" | 8½" | 14" | 11" |
| 3. 24-inch Shingles | 11½" | 11½" | 16" | 14" |
| 4. 18-inch Resawn Shakes | 8½" | — | 14" | — |
| 5. 18-inch Straight-Split Shakes | 8½" | — | 16" | — |
| 6. 24-inch Resawn Shakes | 11½" | — | 20" | — |

## TABLE NO. 25-M-1—EXPOSED PLYWOOD PANEL SIDING

| MINIMUM THICKNESS[1] | MINIMUM NO. OF PLIES | STUD SPACING (INCHES) PLYWOOD SIDING APPLIED DIRECT TO STUDS OR OVER SHEATHING |
|---|---|---|
| 1. 3/8" | 3 | 16[2] |
| 2. ½" | 4 | 24 |

[1]Thickness of grooved panels is measured at bottom of grooves.

[2]May be 24 inches if plywood siding applied with face grain perpendicular to studs or over one of the following: (a) 1-inch board sheathing, (b) ½-inch plywood sheathing, (c) 3/8-inch plywood sheathing with face grain of sheathing perpendicular to studs.

## TABLE NO. 25-M-2—ALLOWABLE SPANS FOR EXPOSED PARTICLEBOARD PANEL SIDING

| GRADE | STUD SPACING (Inches) | MINIMUM THICKNESS (Inches) | | |
|---|---|---|---|---|
| | | Siding | | Exterior Ceilings and Soffits |
| | | Direct to Studs | Continuous Support | Direct to Supports |
| 2-M-W and 2-M-F | 16 | 3/8 | 5/16 | 5/16 |
| | 24 | 1/2 | 5/16 | 3/8 |
| 2-M-1 2-M-2 2-M-3 | 16 | 5/8 | 3/8 | |
| | 24 | 3/4 | 3/8 | |



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## TABLE NO. 25-N-1—PLYWOOD WALL SHEATHING[1] (Not Exposed to the Weather, Face Grain Parallel or Perpendicular to Studs)

| MINIMUM THICKNESS AND CONSTRUCTION | PANEL SPAN RATING | STUD SPACING (Inches) | | |
|---|---|---|---|---|
| | | Siding Nailed to Studs | Sheathing Under Coverings Specified in Section 2517 (g) 3 | |
| | | | Sheathing Parallel to Studs | Sheathing Perpendicular to Studs |
| 1. 5/16" | 12/0, 16/0, 20/0 | 16 | — | 16 |
| 2. 3/8", 15/32", 1/2"—3 ply | 16/0, 20/0, 24/0, 32/16 | 24 | 16 | 24 |
| 3. 15/32", 1/2"—4 and 5 ply | 24/0, 32/16 | 24 | 24 | 24 |

[1]In reference to Section 2517 (g) 3, blocking of horizontal joints is not required.

## TABLE NO. 25-N-2—ALLOWABLE SPANS FOR PARTICLEBOARD WALL SHEATHING[1] (Not exposed to the weather, long dimension of the panel parallel or perpendicular to studs)

| GRADE | THICKNESS (Inches) | STUD SPACING (Inches) | |
|---|---|---|---|
| | | Siding Nailed to Studs | Sheathing Under Coverings Specified in Section 2517 (g) 3 Parallel or Perpendicular to Studs |
| 2-M-W | 5/16 | 16 | — |
| 2-M-F | 3/8 | 24 | 16 |
| | 7/16 | 24 | 24 |
| 2-M-1 | 3/8 | 16 | — |
| 2-M-2 | | | |
| 2-M-3 | 1/2 | 16 | 16 |

[1]In reference to Section 2517 (g) 3, blocking of horizontal joints is not required.



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## TABLE NO. 25-O—HARDBOARD SIDING

| SIDING | MINIMUM NOMINAL THICKNESS | FRAMING (2"x4") MAXIMUM SPACING | NAIL SIZE[1] | NAIL SPACING | |
|---|---|---|---|---|---|
| | | | | GENERAL | BRACING PANELS[3] |
| **1. LAP SIDING** | | | | | |
| Direct to studs | ⅜" | 16" o.c. | 8d[1] | 16" o.c. | Not applicable |
| Over sheathing | ⅜" | 16" o.c. | 10d[1] | 16" o.c. | Not applicable |
| **2. SQUARE EDGE PANEL SIDING** | | | | | |
| Direct to studs | ⅜" | 24" o.c. | 6d[2] | 6" o.c. edges; 12" o.c. at intermed. supports | 4" o.c. edges; 8" o.c. intermed. supports |
| Over sheathing | ⅜" | 24" o.c. | 8d[2] | 6" o.c. edges; 12" o.c. at intermed. supports | 4" o.c. edges; 8" o.c. intermed. supports |
| **3. SHIPLAP EDGE PANEL SIDING** | | | | | |
| Direct to studs | ⅜" | 16" o.c. | 6d[2] | 6" o.c. edges; 12" o.c. at intermed. supports | 4" o.c. edges; 8" o.c. intermed. supports |
| Over sheathing | ⅜" | 16" o.c. | 8d[2] | 6" o.c. edges; 12" o.c. at intermed. supports | 4" o.c. edges; 8" o.c. intermed. supports |

[1]Siding nail.
[2]Corrosion-resistant box nail.
[3]When used to comply with Section 2517 (g) 3.



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## TABLE NO. 25-P—ALLOWABLE SHEARS FOR WIND OR SEISMIC LOADING ON VERTICAL DIAPHRAGMS OF FIBERBOARD SHEATHING BOARD CONSTRUCTION FOR TYPE V CONSTRUCTION ONLY[1]

| SIZE AND APPLICATION | NAIL SIZE | SHEAR VALUE 3-INCH NAIL SPACING AROUND PERIMETER AND 6-INCH AT INTERMEDIATE POINTS |
|---|---|---|
| 1. ½" x 4' x 8' | No. 11 gauge galvanized roofing nail 1½" long, 7/16" head | 125[2] |
| 2. 25/32" x 4' x 8' | No. 11 gauge galvanized roofing nail 1¾" long, 7/16" head | 175 |

[1]Fiberboard sheathing diaphragms shall not be used to brace concrete or masonry walls.
[2]The shear value may be 175 for ½-inch x 4-foot x 8-foot fiberboard nail-base sheathing.

## TABLE NO. 25-Q—NAILING SCHEDULE

| CONNECTION | NAILING[1] |
|---|---|
| 1. Joist to sill or girder, toenail | 3-8d |
| 2. Bridging to joist, toenail each end | 2-8d |
| 3. 1" x 6" subfloor or less to each joist, face nail | 2-8d |
| 4. Wider than 1" x 6" subfloor to each joist, face nail | 3-8d |
| 5. 2" subfloor to joist or girder, blind and face nail | 2-16d |
| 6. Sole plate to joist or blocking, face nail | 16d at 16" o.c. |
| 7. Top plate to stud, end nail | 2-16d |
| 8. Stud to sole plate | 4-8, toenail or 2-16d, end nail |
| 9. Double studs, face nail | 16d at 24" o.c. |
| 10. Doubled top plates, face nail | 16d at 16" o.c. |
| 11. Top plates, laps and intersections, face nail | 2-16d |
| 12. Continuous header, two pieces | 16d at 16" o.c. along each edge |
| 13. Ceiling joists to plate, toenail | 3-8d |
| 14. Continuous header to stud, toenail | 4-8d |
| 15. Ceiling joists, laps over partitions, face nail | 3-16d |
| 16. Ceiling joists to parallel rafters, face nail | 3-16d |
| 17. Rafter to plate, toenail | 3-8d |
| 18. 1" brace to each stud and plate, face nail | 2-8d |
| 19. 1" x 8" sheathing or less to each bearing, face nail | 2-8d |
| 20. Wider than 1" x 8" sheathing to each bearing, face nail | 3-8d |
| 21. Built-up corner studs | 16d at 24" o.c. |
| 22. Built-up girder and beams | 20d at 32" o.c. at top and bottom and staggered 2-20d at ends and at each splice |

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| CONNECTION | NAILING[1] |
|---|---|
| 23. 2" planks | 2-16d at each bearing |
| 24. **Plywood and particleboard:**[5] | |
| **Subfloor, roof and wall sheathing (to framing):** | |
| 1/2" and less | 6d[2] |
| 19/32"-3/4" | 8d[3] or 6d[4] |
| 7/8"-1" | 8d[2] |
| 1 1/8"-1 1/4" | 10d[3] or 8d[4] |
| **Combination Subfloor-underlayment (to framing):** | |
| 3/4" and less | 6d[4] |
| 7/8"-1" | 8d[4] |
| 1 1/8"-1 1/4" | 10d[3] or 8d[4] |
| 25. **Panel Siding (to framing):** | |
| 1/2" or less | 6d[6] |
| 5/8" | 8d[6] |
| 26. **Fiberboard Sheathing:**[7] | |
| 1/2" | No. 11 ga.[8]<br>6d[3]<br>No. 16 ga.[9] |
| 25/32" | No. 11 ga.[8]<br>8d[3]<br>No. 16 ga.[9] |

[1]Common or box nails may be used except where otherwise stated.

[2]Common or deformed shank.

[3]Common.

[4]Deformed shank.

[5]Nails spaced at 6 inches on center at edges, 12 inches at intermediate supports (10 inches at intermediate supports for floors), except 6 inches at all supports where spans are 48 inches, or more. For nailing of plywood and particleboard diaphragms and shear walls, refer to Section 2513 (c). Nails for wall sheathing may be common, box or casing.

[6]Corrosion-resistant siding or casing nails conforming to the requirements of Section 2516 (j) 1.

[7]Fasteners spaced 3 inches on center at exterior edges and 6 inches on center at intermediate supports.

[8]Corrosion-resistant roofing nails with 7/16-inch-diameter head and 1 1/2-inch length for 1/2-inch sheathing and 1 3/4-inch length for 25/32-inch sheathing conforming to the requirements of Section 2516 (j) 1.

[9]Corrosion-resistant staples with nominal 7/16-inch crown and 1 1/8-inch length for 1/2-inch sheathing and 1 1/2-inch length for 25/32-inch sheathing conforming to the requirements of Section 2516 (j) 1.



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## TABLE NO. 25-R-1—ALLOWABLE SPANS FOR LUMBER FLOOR AND ROOF SHEATHING[1] [3]

| SPAN (Inches) | MINIMUM NET THICKNESS (Inches) OF LUMBER PLACED | | | |
|---|---|---|---|---|
| | PERPENDICULAR TO SUPPORTS | | DIAGONALLY TO SUPPORTS | |
| | Surfaced Dry[2] | Surfaced Unseasoned | Surfaced Dry[2] | Surfaced Unseasoned |
| | FLOORS | | | |
| 1. 24 | 3/4 | 25/32 | 3/4 | 25/32 |
| 2. 16 | 5/8 | 11/16 | 5/8 | 11/16 |
| | ROOFS | | | |
| 3. 24 | 5/8 | 11/16 | 3/4 | 25/32 |

[1]Installation details shall conform to Sections 2517 (e) 1 and 2517 (h) 7 for floor and roof sheathing, respectively.

[2]Maximum 19 percent moisture content.

[3]Floor or roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.

## TABLE NO. 25-R-2—SHEATHING LUMBER SHALL MEET THE FOLLOWING MINIMUM GRADE REQUIREMENTS: BOARD GRADE

| SOLID FLOOR OR ROOF SHEATHING | SPACED ROOF SHEATHING | U.B.C. STANDARD NUMBER |
|---|---|---|
| 1. Utility | Standard | 25-2, 25-3 or 25-4 |
| 2. 4 Common or Utility | 3 Common or Standard | 25-2, 25-3, 25-4 25-5 or 25-8 |
| 3. No. 3 | No. 2 | 25-6 |
| 4. Merchantable | Construction Common | 25-7 |

## TABLE NO. 25-R-3—SIZE, HEIGHT AND SPACING OF WOOD STUDS[1]

| STUD SIZE (Inches) | BEARING WALLS | | | | NONBEARING WALLS | |
|---|---|---|---|---|---|---|
| | LATERALLY UNSUPPORTED STUD HEIGHT[3] (Feet) | SUPPORTING ROOF AND CEILING ONLY | SUPPORTING ONE FLOOR, ROOF AND CEILING | SUPPORTING TWO FLOORS, ROOF AND CEILING | LATERALLY UNSUPPORTED STUD HEIGHT[3] (Feet) | SPACING (Inches) |
| | | SPACING (Inches) | | | | |
| 1. 2 x 3[2] | — | — | — | — | 10 | 16 |
| 2. 2 x 4 | 10 | 24 | 16 | — | 14 | 24 |
| 3. 3 x 4 | 10 | 24 | 24 | 16 | 14 | 24 |
| 4. 2 x 5 | 10 | 24 | 24 | — | 16 | 24 |
| 5. 2 x 6 | 10 | 24 | 24 | 16 | 20 | 24 |

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[1]Utility grade studs shall not be spaced more than 16 inches on center, nor support more than a roof and ceiling, nor exceed 8 feet in height for exterior walls and load bearing or 10 feet for interior nonload-bearing walls.

[2]Shall not be used in exterior walls.

[3]Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Increases in supported height are permitted where justified by an analysis.

## TABLE NO. 25-S-1—ALLOWABLE SPANS FOR PLYWOOD SUBFLOOR AND ROOF SHEATHING CONTINUOUS OVER TWO OR MORE SPANS AND FACE GRAIN PERPENDICULAR TO SUPPORTS[1 8]

| PANEL SPAN RATING[3] | PLYWOOD THICKNESS (Inch) | ROOF[2] Maximum Span (In Inches) | | Load (In Pounds per Square Foot) | | FLOOR MAXIMUM SPAN[4] (In Inches) |
|---|---|---|---|---|---|---|
| | | Edges Blocked | Edges Unblocked | Total Load | Live Load | |
| 1. 12/0 | 5/16 | 12 | | 135 | 130 | 0 |
| 2. 16/0 | 5/16, 3/8 | 16 | | 80 | 65 | 0 |
| 3. 20/0 | 5/16, 3/8 | 20 | | 70 | 55 | 0 |
| 4. 24/0 | 3/8 | 24 | 16 | 60 | 45 | 0 |
| 5. 24/0 | 15/32, 1/2 | 24 | 24 | 60 | 45 | 0 |
| 6. 32/16 | 15/32, 1/2, 19/32, 5/8 | 32 | 28 | 55 | 35[5] | 16[6] |
| 7. 40/20 | 19/32, 5/8, 23/32, 3/4, 7/8 | 40 | 32 | 40[5] | 35[5] | 20[6 7] |
| 8. 48/24 | 23/32, 3/4, 7/8 | 48 | 36 | 40[5] | 35[5] | 24 |

[1]These values apply for C-C, C-D, Structural I and II grades only. Spans shall be limited to values shown because of possible effect of concentrated loads.

[2]Uniform load deflection limitations 1/180 of the span under live load plus dead load. 1/240 under live load only. Edges may be blocked with lumber or other approved type of edge support.

[3]Span rating appears on all panels in the construction grades listed in Footnote No. 1.

[4]Plywood edges shall have approved tongue-and-groove joints or shall be supported with blocking unless 1/4-inch minimum thickness underlayment, or 1 1/2 inches of approved cellular or lightweight concrete is placed over the subfloor, or finish floor is 25/32-inch wood strip. Allowable uniform load based on deflection of 1/360 of span is 165 pounds per square foot.

[5]For roof live load of 40 pounds per square foot or total load of 55 pounds per square foot, decrease spans by 13 percent or use panel with next greater span rating.

[6]May be 24 inches if 25/32-inch wood strip flooring is installed at right angles to joists.

[7]May be 24 inches where a minimum of 1 1/2 inches of approved cellular or lightweight concrete is placed over the subfloor and the plywood sheathing is manufactured with exterior glue.

[8]Floor or roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.



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## TABLE NO. 25-S-2—ALLOWABLE LOADS FOR PLYWOOD ROOF SHEATHING CONTINUOUS OVER TWO OR MORE SPANS AND FACE GRAIN PARALLEL TO SUPPORTS[1,2]

| | THICKNESS | NO. OF PLIES | SPAN | TOTAL LOAD | LIVE LOAD |
|---|---|---|---|---|---|
| STRUCTURAL I | 15/32 | 4 | 24 | 30 | 20 |
| | | 5 | 24 | 45 | 35 |
| | 1/2 | 4 | 24 | 35 | 25 |
| | | 5 | 24 | 55 | 40 |
| Other grades covered in U.B.C. Standard No. 25-9 | 15/32 | 5 | 24 | 25 | 20 |
| | 1/2 | 5 | 24 | 30 | 25 |
| | 19/32 | 4 | 24 | 35 | 25 |
| | | 5 | 24 | 50 | 40 |
| | 5/8 | 4 | 24 | 40 | 30 |
| | | 5 | 24 | 55 | 45 |

[1]Uniform load deflection limitations: 1/180 of span under live load plus dead load, 1/240 under live load only. Edges shall be blocked with lumber or other approved type of edge supports.

[2]Roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.

## TABLE NO. 25-S-3—ALLOWABLE LOADS FOR PARTICLEBOARD ROOF SHEATHING[1,2,4]

| GRADE | THICKNESS (Inches) | MAXIMUM ON-CENTER SPACING OF SUPPORTS (Inches) | LIVE LOAD (Pounds Per Square Foot) | TOTAL LOAD (Pounds Per Square Foot) |
|---|---|---|---|---|
| 2-M-W and 2-M-F | 3/8[3] | 16 | 45 | 65 |
| | 7/16 | 16 | 105 | 105 |
| | 7/16[3] | 24 | 30 | 40 |
| | 1/2 | 16 | 110 | 150 |
| | 1/2 | 24 | 40 | 55 |

[1]Panels are continuous over two or more spans.

[2]Uniform load deflection limitation: 1/180 of the span under live load plus dead load and 1/240 of the span under live load only.

[3]Edges shall be tongue-and-groove or supported with blocking or edge clips.

[4]Roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.



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## TABLE NO. 25-T-1—ALLOWABLE SPAN FOR PLYWOOD COMBINATION SUBFLOOR-UNDERLAYMENT[1 2]

### Plywood Continuous over Two or More Spans and Face Grain Perpendicular to Supports

| IDENTIFICATION | SPACING OF JOISTS (Inches) | | | |
|---|---|---|---|---|
| | 16 | 20 | 24 | 48 |
| Species Group[3] | Thickness in inches | | | |
| 1 | 1/2 | 5/8 | 3/4 | — |
| 2, 3 | 5/8 | 3/4 | 7/8 | — |
| 4 | 3/4 | 7/8 | 1 | — |
| Span Rating[4] | 16 o.c. | 20 o.c. | 24 o.c. | 48 o.c. |

[1]Spans limited to value shown because of possible effect of concentrated loads. Allowable uniform load based on deflection of 1/360 of span is 125 pounds per square foot, except allowable total uniform load for 1 1/8-inch plywood over joists spaced 48 inches on center is 65 pounds per square foot. Plywood edges shall have approved tongue-and-groove joints or shall be supported with blocking, unless 1/4-inch minimum thickness underlayment is installed, or finish floor is 25/32-inch wood strip.

If wood strips are perpendicular to supports, thicknesses shown for 16-inch and 20-inch spans may be used on 24-inch span.

[2]Floor panels conforming with this table shall be deemed to meet the design criteria of Section 2516.

[3]Applicable to all grades of sanded exterior-type plywood. See U.B.C. Standard No. 25-9 for plywood species groups.

[4]Applicable to underlayment grade and C-C (plugged).

## TABLE NO. 25-T-2—ALLOWABLE SPANS FOR PARTICLEBOARD SUBFLOOR AND COMBINED SUBFLOOR-UNDERLAYMENT[1 5]

| GRADE | THICKNESS (Inches) | MAXIMUM SPACING OF SUPPORTS[2] | |
|---|---|---|---|
| | | Subfloor | Combined Subfloor-Underlayment[3 4] |
| 2-M-W | 1/2 | 16 | — |
| | 5/8 | 20 | 16 |
| | 3/4 | 24 | 24 |
| 2-M-F | 3/4 | 20 | 20 |
| 2-M-3 | 3/4 | 20 | 20 |

[1]All panels are continuous over two or more spans.

[2]Uniform deflection limitation: 1/360 of the span under 100 psf minimum load.

[3]Edges shall have tongue-and-groove joints or shall be supported with blocking. The tongue-and-groove panels are installed with the long dimension perpendicular to supports.

[4]A finish wearing surface is to be applied to the top of the panel.

[5]Floor sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.



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## TABLE NO. 25-U—ALLOWABLE SPANS FOR 2-INCH TONGUE-AND-GROOVE DECKING

| SPAN[1] (In Feet) | LIVE LOAD | DEFLECTION LIMIT | $f$ (psi) | $E$ (psi) |
|---|---|---|---|---|
| **ROOFS** | | | | |
| 4 | 20 | 1/240 | 160 | 170,000 |
| | | 1/360 | | 256,000 |
| | 30 | 1/240 | 210 | 256,000 |
| | | 1/360 | | 384,000 |
| | 40 | 1/240 | 270 | 340,000 |
| | | 1/360 | | 512,000 |
| 4.5 | 20 | 1/240 | 200 | 242,000 |
| | | 1/360 | | 365,000 |
| | 30 | 1/240 | 270 | 363,000 |
| | | 1/360 | | 405,000 |
| | 40 | 1/240 | 350 | 484,000 |
| | | 1/360 | | 725,000 |
| 5.0 | 20 | 1/240 | 250 | 332,000 |
| | | 1/360 | | 500,000 |
| | 30 | 1/240 | 330 | 495,000 |
| | | 1/360 | | 742,000 |
| | 40 | 1/240 | 420 | 660,000 |
| | | 1/360 | | 1,000,000 |
| 5.5 | 20 | 1/240 | 300 | 442,000 |
| | | 1/360 | | 660,000 |
| | 30 | 1/240 | 400 | 662,000 |
| | | 1/360 | | 998,000 |
| | 40 | 1/240 | 500 | 884,000 |
| | | 1/360 | | 1,330,000 |
| 6.0 | 20 | 1/240 | 360 | 575,000 |
| | | 1/360 | | 862,000 |
| | 30 | 1/240 | 480 | 862,000 |
| | | 1/360 | | 1,295,000 |
| | 40 | 1/240 | 600 | 1,150,000 |
| | | 1/360 | | 1,730,000 |
| 6.5 | 20 | 1/240 | 420 | 595,000 |
| | | 1/360 | | 892,000 |
| | 30 | 1/240 | 560 | 892,000 |
| | | 1/360 | | 1,340,000 |
| | 40 | 1/240 | 700 | 1,190,000 |
| | | 1/360 | | 1,730,000 |

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| SPAN[1] (In Feet) | LIVE LOAD | DEFLECTION LIMIT | $f$ (psi) | $E$ (psi) |
|---|---|---|---|---|
| 7.0 | 20 | 1/240 | 490 | 910,000 |
| | | 1/360 | | 1,360,000 |
| | 30 | 1/240 | 650 | 1,370,000 |
| | | 1/360 | | 2,000,000 |
| | 40 | 1/240 | 810 | 1,820,000 |
| | | 1/360 | | 2,725,000 |
| 7.5 | 20 | 1/240 | 560 | 1,125,000 |
| | | 1/360 | | 1,685,000 |
| | 30 | 1/240 | 750 | 1,685,000 |
| | | 1/360 | | 2,530,000 |
| | 40 | 1/240 | 930 | 2,250,000 |
| | | 1/360 | | 3,380,000 |
| 8.0 | 20 | 1/240 | 640 | 1,360,000 |
| | | 1/360 | | 2,040,000 |
| | 30 | 1/240 | 850 | 2,040,000 |
| | | 1/360 | | 3,060,000 |
| **FLOORS** | | | | |
| 4 | 40 | 1/360 | 840 | 1,000,000 |
| 4.5 | | | 950 | 1,300,000 |
| 5.0 | | | 1060 | 1,600,000 |

[1]Spans are based on simple beam action with 10 pounds per square foot dead load and provisions for a 300-pound concentrated load on a 12-inch width of floor decking. Random lay-up permitted in accordance with the provisions of Section 2517 (e) 3 or 2517 (h) 8. Lumber thickness assumed at 1½ inches, net.



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## TABLE NO. 25-U-J-1—ALLOWABLE SPANS FOR FLOOR JOISTS—40 LBS. PER SQ. FT. LIVE LOAD

**DESIGN CRITERIA: Deflection—For 40 lbs. per sq. ft. live load. Limited to span in inches divided by 360. Strength—Live load of 40 lbs. per sq. ft. plus dead load of 10 lbs. per sq. ft. determines the required fiber stress value.**

| JOIST SIZE | SPACING (IN) | Modulus of Elasticity, $E$, in 1,000,000 psi | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.2 |
| 2x6 | 12.0 | 8-6<br>720 | 8-10<br>780 | 9-2<br>830 | 9-6<br>890 | 9-9<br>940 | 10-0<br>990 | 10-3<br>1040 | 10-6<br>1090 | 10-9<br>1140 | 10-11<br>1190 | 11-2<br>1230 | 11-4<br>1280 | 11-7<br>1320 | 11-11<br>1410 |
| | 16.0 | 7-9<br>790 | 8-0<br>860 | 8-4<br>920 | 8-7<br>980 | 8-10<br>1040 | 9-1<br>1090 | 9-4<br>1150 | 9-6<br>1200 | 9-9<br>1250 | 9-11<br>1310 | 10-2<br>1360 | 10-4<br>1410 | 10-6<br>1460 | 10-10<br>1550 |
| | 24.0 | 6-9<br>900 | 7-0<br>980 | 7-3<br>1050 | 7-6<br>1120 | 7-9<br>1190 | 7-11<br>1250 | 8-2<br>1310 | 8-4<br>1380 | 8-6<br>1440 | 8-8<br>1500 | 8-10<br>1550 | 9-0<br>1610 | 9-2<br>1670 | 9-6<br>1780 |
| 2x8 | 12.0 | 11-3<br>720 | 11-8<br>780 | 12-1<br>830 | 12-6<br>890 | 12-10<br>940 | 13-2<br>990 | 13-6<br>1040 | 13-10<br>1090 | 14-2<br>1140 | 14-5<br>1190 | 14-8<br>1230 | 15-0<br>1280 | 15-3<br>1320 | 15-9<br>1410 |
| | 16.0 | 10-2<br>790 | 10-7<br>850 | 11-0<br>920 | 11-4<br>980 | 11-8<br>1040 | 12-0<br>1090 | 12-3<br>1150 | 12-7<br>1200 | 12-10<br>1250 | 13-1<br>1310 | 13-4<br>1360 | 13-7<br>1410 | 13-10<br>1460 | 14-3<br>1550 |
| | 24.0 | 8-11<br>900 | 9-3<br>980 | 9-7<br>1050 | 9-11<br>1120 | 10-2<br>1190 | 10-6<br>1250 | 10-9<br>1310 | 11-0<br>1380 | 11-3<br>1440 | 11-5<br>1500 | 11-8<br>1550 | 11-11<br>1610 | 12-1<br>1670 | 12-6<br>1780 |
| 2x10 | 12.0 | 14-4<br>720 | 14-11<br>780 | 15-5<br>830 | 15-11<br>890 | 16-5<br>940 | 16-10<br>990 | 17-3<br>1040 | 17-8<br>1090 | 18-0<br>1140 | 18-5<br>1190 | 18-9<br>1230 | 19-1<br>1280 | 19-5<br>1320 | 20-1<br>1410 |
| | 16.0 | 13-0<br>790 | 13-6<br>850 | 14-0<br>920 | 14-6<br>980 | 14-11<br>1040 | 15-3<br>1090 | 15-8<br>1150 | 16-0<br>1200 | 16-5<br>1250 | 16-9<br>1310 | 17-0<br>1360 | 17-4<br>1410 | 17-8<br>1460 | 18-3<br>1550 |
| | 24.0 | 11-4<br>900 | 11-10<br>980 | 12-3<br>1050 | 12-8<br>1120 | 13-0<br>1190 | 13-4<br>1250 | 13-8<br>1310 | 14-0<br>1380 | 14-4<br>1440 | 14-7<br>1500 | 14-11<br>1550 | 15-2<br>1610 | 15-5<br>1670 | 15-11<br>1780 |
| 2x12 | 12.0 | 17-5<br>720 | 18-1<br>780 | 18-9<br>830 | 19-4<br>890 | 19-11<br>940 | 20-6<br>990 | 21-0<br>1040 | 21-6<br>1090 | 21-11<br>1140 | 22-5<br>1190 | 22-10<br>1230 | 23-3<br>1280 | 23-7<br>1320 | 24-5<br>1410 |
| | 16.0 | 15-10<br>790 | 16-5<br>860 | 17-0<br>920 | 17-7<br>980 | 18-1<br>1040 | 18-7<br>1090 | 19-1<br>1150 | 19-6<br>1200 | 19-11<br>1250 | 20-4<br>1310 | 20-9<br>1360 | 21-1<br>1410 | 21-6<br>1460 | 22-2<br>1550 |
| | 24.0 | 13-10<br>900 | 14-4<br>980 | 14-11<br>1050 | 15-4<br>1120 | 15-10<br>1190 | 16-3<br>1250 | 16-8<br>1310 | 17-0<br>1380 | 17-5<br>1440 | 17-9<br>1500 | 18-1<br>1550 | 18-5<br>1610 | 18-9<br>1670 | 19-4<br>1780 |

**NOTES:**

(1)The required extreme fiber stress in bending ($F_b$) in pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.



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## TABLE NO. 25-U-J-6—ALLOWABLE SPANS FOR CEILING JOISTS—10 LBS. PER SQ. FT. LIVE LOAD (Drywall Ceiling)

**DESIGN CRITERIA: Deflection—For 10 lbs. per sq. ft. live load. Limited to span in inches divided by 240. Strength—Live load of 10 lbs. per sq. ft. plus dead load of 5 lbs. per sq. ft. determines tha required fiber stress value.**

| JOIST SIZE | SPACING (IN) | Modulus of Elasticity, *E*, in 1,000,000 psi | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.2 |
| 2x4 | 12.0 | 9-10<br>710 | 10-3<br>770 | 10-7<br>830 | 10-11<br>880 | 11-3<br>930 | 11-7<br>980 | 11-10<br>1030 | 12-2<br>1080 | 12-5<br>1130 | 12-8<br>1180 | 12-11<br>1220 | 13-2<br>1270 | 13-4<br>1310 | 13-9<br>1400 |
| | 16.0 | 8-11<br>780 | 9-4<br>850 | 9-8<br>910 | 9-11<br>970 | 10-3<br>1030 | 10-6<br>1080 | 10-9<br>1140 | 11-0<br>1190 | 11-3<br>1240 | 11-6<br>1290 | 11-9<br>1340 | 11-11<br>1390 | 12-2<br>1440 | 12-6<br>1540 |
| | 24.0 | 7-10<br>900 | 8-1<br>970 | 8-5<br>1040 | 8-8<br>1110 | 8-11<br>1170 | 9-2<br>1240 | 9-5<br>1300 | 9-8<br>1360 | 9-10<br>1420 | 10-0<br>1480 | 10-3<br>1540 | 10-5<br>1600 | 10-7<br>1650 | 10-11<br>1760 |
| 2x6 | 12.0 | 15-6<br>710 | 16-1<br>770 | 16-8<br>830 | 17-2<br>880 | 17-8<br>930 | 18-2<br>980 | 18-8<br>1030 | 19-1<br>1080 | 19-6<br>1130 | 19-11<br>1180 | 20-3<br>1220 | 20-8<br>1270 | 21-0<br>1310 | 21-8<br>1400 |
| | 16.0 | 14-1<br>780 | 14-7<br>850 | 15-2<br>910 | 15-7<br>970 | 16-1<br>1030 | 16-6<br>1080 | 16-11<br>1140 | 17-4<br>1190 | 17-8<br>1240 | 18-1<br>1290 | 18-5<br>1340 | 18-9<br>1390 | 19-1<br>1440 | 19-8<br>1540 |
| | 24.0 | 12-3<br>900 | 12-9<br>970 | 13-3<br>1040 | 13-8<br>1110 | 14-1<br>1170 | 14-5<br>1240 | 14-9<br>1300 | 15-2<br>1360 | 15-6<br>1420 | 15-9<br>1480 | 16-1<br>1540 | 16-4<br>1600 | 16-8<br>1650 | 17-2<br>1760 |
| 2x8 | 12.0 | 20-5<br>710 | 21-2<br>770 | 21-11<br>830 | 22-8<br>880 | 23-4<br>930 | 24-0<br>980 | 24-7<br>1030 | 25-2<br>1080 | 25-8<br>1130 | 26-2<br>1180 | 26-9<br>1220 | 27-2<br>1270 | 27-8<br>1310 | 28-7<br>1400 |
| | 16.0 | 18-6<br>780 | 19-3<br>850 | 19-11<br>910 | 20-7<br>970 | 21-2<br>1030 | 21-9<br>1080 | 22-4<br>1140 | 22-10<br>1190 | 23-4<br>1240 | 23-10<br>1290 | 24-3<br>1340 | 24-8<br>1390 | 25-2<br>1440 | 25-11<br>1540 |
| | 24.0 | 16-2<br>900 | 16-10<br>970 | 17-5<br>1040 | 18-0<br>1110 | 18-6<br>1170 | 19-0<br>1240 | 19-6<br>1300 | 19-11<br>1360 | 20-5<br>1420 | 20-10<br>1480 | 21-2<br>1540 | 21-7<br>1600 | 21-11<br>1650 | 22-8<br>1760 |
| 2x10 | 12.0 | 26-0<br>710 | 27-1<br>770 | 28-0<br>830 | 28-11<br>880 | 29-9<br>930 | 30-7<br>980 | 31-4<br>1030 | 32-1<br>1080 | 32-9<br>1130 | 33-5<br>1180 | 34-1<br>1220 | 34-8<br>1270 | 35-4<br>1310 | 36-5<br>1400 |
| | 16.0 | 23-8<br>780 | 24-7<br>850 | 25-5<br>910 | 26-3<br>970 | 27-1<br>1030 | 27-9<br>1080 | 28-6<br>1140 | 29-2<br>1190 | 29-9<br>1240 | 30-5<br>1290 | 31-0<br>1340 | 31-6<br>1390 | 32-1<br>1440 | 33-1<br>1540 |
| | 24.0 | 20-8<br>900 | 21-6<br>970 | 22-3<br>1040 | 22-11<br>1110 | 23-8<br>1170 | 24-3<br>1240 | 24-10<br>1300 | 25-5<br>1360 | 26-0<br>1420 | 26-6<br>1480 | 27-1<br>1540 | 27-6<br>1600 | 28-0<br>1650 | 28-11<br>1760 |

**NOTES:**

(1)The required extreme fiber stress in bending ($F_b$) in pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.



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## TABLE NO. 25-U-R-1—ALLOWABLE SPANS FOR LOW- OR HIGH-SLOPE RAFTERS 20 LBS. PER SQ. FT. LIVE LOAD (Supporting Drywall Ceiling)

**DESIGN CRITERIA: Strength—15 lbs. per sq. ft. dead load plus 20 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 20 lbs. per sq. ft. live load. Limited to span in inches divided by 240. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE (IN) | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x6 | 12.0 | 8-6<br>0.26 | 9-4<br>0.35 | 10-0<br>0.44 | 10-9<br>0.54 | 11-5<br>0.64 | 12-0<br>0.75 | 12-7<br>0.86 | 13-2<br>0.98 | 13-8<br>1.11 | 14-2<br>1.24 | 14-8<br>1.37 | 15-2<br>1.51 | 15-8<br>1.66 | 16-1<br>1.81 | 16-7<br>1.96 |
| | 16.0 | 7-4<br>0.23 | 8-1<br>0.30 | 8-8<br>0.38 | 9-4<br>0.46 | 9-10<br>0.55 | 10-5<br>0.65 | 10-11<br>0.75 | 11-5<br>0.85 | 11-10<br>0.97 | 12-4<br>1.07 | 12-9<br>1.19 | 13-2<br>1.31 | 13-7<br>1.44 | 13-11<br>1.56 | 14-4<br>1.70 |
| | 24.0 | 6-0<br>0.19 | 6-7<br>0.25 | 7-1<br>0.31 | 7-7<br>0.38 | 8-1<br>0.45 | 8-6<br>0.53 | 8-11<br>0.61 | 9-4<br>0.70 | 9-8<br>0.78 | 10-0<br>0.88 | 10-5<br>0.97 | 10-9<br>1.07 | 11-1<br>1.17 | 11-5<br>1.28 | 11-8<br>1.39 |
| 2x8 | 12.0 | 11-2<br>0.26 | 12-3<br>0.35 | 13-3<br>0.44 | 14-2<br>0.54 | 15-0<br>0.64 | 15-10<br>0.75 | 16-7<br>0.86 | 17-4<br>0.98 | 18-0<br>1.11 | 18-9<br>1.24 | 19-5<br>1.37 | 20-0<br>1.51 | 20-8<br>1.66 | 21-3<br>1.81 | 21-10<br>1.96 |
| | 16.0 | 9-8<br>0.23 | 10-7<br>0.30 | 11-6<br>0.38 | 12-3<br>0.46 | 13-0<br>0.55 | 13-8<br>0.65 | 14-4<br>0.75 | 15-0<br>0.85 | 15-7<br>0.96 | 16-3<br>1.07 | 16-9<br>1.19 | 17-4<br>1.31 | 17-10<br>1.44 | 18-5<br>1.56 | 18-11<br>1.70 |
| | 24.0 | 7-11<br>0.19 | 8-8<br>0.25 | 9-4<br>0.31 | 10-0<br>0.38 | 10-7<br>0.45 | 11-2<br>0.53 | 11-9<br>0.61 | 12-3<br>0.70 | 12-9<br>0.78 | 13-3<br>0.88 | 13-8<br>0.97 | 14-2<br>1.07 | 14-7<br>1.17 | 15-0<br>1.28 | 15-5<br>1.39 |
| 2x10 | 12.0 | 14-3<br>0.26 | 15-8<br>0.35 | 16-11<br>0.44 | 18-1<br>0.54 | 19-2<br>0.64 | 20-2<br>0.75 | 21-2<br>0.86 | 22-1<br>0.98 | 23-0<br>1.11 | 23-11<br>1.24 | 24-9<br>1.37 | 25-6<br>1.51 | 26-4<br>1.66 | 27-1<br>1.81 | 27-10<br>1.96 |
| | 16.0 | 12-4<br>0.23 | 13-6<br>0.30 | 14-8<br>0.38 | 15-8<br>0.46 | 16-7<br>0.55 | 17-6<br>0.65 | 18-4<br>0.75 | 19-2<br>0.85 | 19-11<br>0.96 | 20-8<br>1.07 | 21-5<br>1.19 | 22-1<br>1.31 | 22-10<br>1.44 | 23-5<br>1.56 | 24-1<br>1.70 |
| | 24.0 | 10-1<br>0.19 | 11-1<br>0.25 | 11-11<br>0.31 | 12-9<br>0.38 | 13-6<br>0.45 | 14-3<br>0.53 | 15-0<br>0.61 | 15-8<br>0.70 | 16-3<br>0.78 | 16-11<br>0.88 | 17-6<br>0.97 | 18-1<br>1.07 | 18-7<br>1.17 | 19-2<br>1.28 | 19-8<br>1.39 |
| 2x12 | 12.0 | 17-4<br>0.26 | 19-0<br>0.35 | 20-6<br>0.44 | 21-11<br>0.54 | 23-3<br>0.64 | 24-7<br>0.75 | 25-9<br>0.86 | 26-11<br>0.98 | 28-0<br>1.11 | 29-1<br>1.24 | 30-1<br>1.37 | 31-1<br>1.51 | 32-0<br>1.66 | 32-11<br>1.81 | 33-10<br>1.96 |
| | 16.0 | 15-0<br>0.23 | 16-6<br>0.30 | 17-9<br>0.38 | 19-0<br>0.46 | 20-2<br>0.55 | 21-3<br>0.65 | 22-4<br>0.75 | 23-3<br>0.85 | 24-3<br>0.97 | 25-2<br>1.07 | 26-0<br>1.19 | 26-11<br>1.31 | 27-9<br>1.44 | 28-6<br>1.56 | 29-4<br>1.70 |
| | 24.0 | 12-3<br>0.19 | 13-5<br>0.25 | 14-6<br>0.31 | 15-6<br>0.38 | 16-6<br>0.45 | 17-4<br>0.53 | 18-2<br>0.61 | 19-0<br>0.70 | 19-10<br>0.78 | 20-6<br>0.88 | 21-3<br>0.97 | 21-11<br>1.07 | 22-8<br>1.17 | 23-3<br>1.28 | 23-11<br>1.39 |

**NOTES:**

(1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.

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## TABLE NO. 25-U-R-2—ALLOWABLE SPANS FOR LOW- OR HIGH-SLOPE RAFTERS 30 LBS. PER SQ. FT. LIVE LOAD (Supporting Drywall Ceiling)

**DESIGN CRITERIA: Strength—15 lbs. per sq. ft. dead load plus 30 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 30 lbs. per sq. ft. live load. Limited to span in inches divided by 240. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE | SPACING (IN) | SPACING (M) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x6 | 12.0 | | 7-6<br>0.27 | 8-2<br>0.36 | 8-10<br>0.45 | 9-6<br>0.55 | 10-0<br>0.66 | 10-7<br>0.77 | 11-1<br>0.89 | 11-7<br>1.01 | 12-1<br>1.14 | 12-6<br>1.28 | 13-0<br>1.41 | 13-5<br>1.56 | 13-10<br>1.71 | 14-2<br>1.86 | 14-7<br>2.02 |
| | 16.0 | | 6-6<br>0.24 | 7-1<br>0.31 | 7-8<br>0.39 | 8-2<br>0.48 | 8-8<br>0.57 | 9-2<br>0.67 | 9-7<br>0.77 | 10-0<br>0.88 | 10-5<br>0.99 | 10-10<br>1.10 | 11-3<br>1.22 | 11-7<br>1.35 | 11-11<br>1.48 | 12-4<br>1.61 | 12-8<br>1.75 |
| | 24.0 | | 5-4<br>0.19 | 5-10<br>0.25 | 6-3<br>0.32 | 6-8<br>0.39 | 7-1<br>0.46 | 7-6<br>0.54 | 7-10<br>0.63 | 8-2<br>0.72 | 8-6<br>0.81 | 8-10<br>0.90 | 9-2<br>1.00 | 9-6<br>1.10 | 9-9<br>1.21 | 10-0<br>1.31 | 10-4<br>1.43 |
| 2x8 | 12.0 | | 9-10<br>0.27 | 10-10<br>0.36 | 11-8<br>0.45 | 12-6<br>0.55 | 13-3<br>0.66 | 13-11<br>0.77 | 14-8<br>0.89 | 15-3<br>1.01 | 15-11<br>1.14 | 16-6<br>1.28 | 17-1<br>1.41 | 17-8<br>1.56 | 18-2<br>1.71 | 18-9<br>1.86 | 19-3<br>2.02 |
| | 16.0 | | 8-7<br>0.24 | 9-4<br>0.31 | 10-1<br>0.39 | 10-10<br>0.48 | 11-6<br>0.57 | 12-1<br>0.67 | 12-8<br>0.77 | 13-3<br>0.88 | 13-9<br>0.99 | 14-4<br>1.10 | 14-10<br>1.22 | 15-3<br>1.35 | 15-9<br>1.48 | 16-3<br>1.61 | 16-8<br>1.75 |
| | 24.0 | | 7-0<br>0.19 | 7-8<br>0.25 | 8-3<br>0.32 | 8-10<br>0.39 | 9-4<br>0.46 | 9-10<br>0.54 | 10-4<br>0.63 | 10-10<br>0.72 | 11-3<br>0.81 | 11-8<br>0.90 | 12-1<br>1.00 | 12-6<br>1.10 | 12-10<br>1.21 | 13-3<br>1.31 | 13-7<br>1.43 |
| 2x10 | 12.0 | | 12-7<br>0.27 | 13-9<br>0.36 | 14-11<br>0.45 | 15-11<br>0.55 | 16-11<br>0.66 | 17-10<br>0.77 | 18-8<br>0.89 | 19-6<br>1.01 | 20-4<br>1.14 | 21-1<br>1.28 | 21-10<br>1.41 | 22-6<br>1.56 | 23-3<br>1.71 | 23-11<br>1.86 | 24-6<br>2.02 |
| | 16.0 | | 10-11<br>0.24 | 11-11<br>0.31 | 12-11<br>0.39 | 13-9<br>0.48 | 14-8<br>0.57 | 15-5<br>0.67 | 16-2<br>0.77 | 16-11<br>0.88 | 17-7<br>0.99 | 18-3<br>1.10 | 18-11<br>1.22 | 19-6<br>1.35 | 20-1<br>1.48 | 20-8<br>1.61 | 21-3<br>1.75 |
| | 24.0 | | 8-11<br>0.19 | 9-9<br>0.25 | 10-6<br>0.32 | 11-3<br>0.39 | 11-11<br>0.46 | 12-7<br>0.54 | 13-2<br>0.63 | 13-9<br>0.72 | 14-4<br>0.81 | 14-11<br>0.90 | 15-5<br>1.00 | 15-11<br>1.10 | 16-5<br>1.21 | 16-11<br>1.31 | 17-4<br>1.43 |
| 2x12 | 12.0 | | 15-4<br>0.27 | 16-9<br>0.36 | 18-1<br>0.45 | 19-4<br>0.55 | 20-6<br>0.66 | 21-8<br>0.77 | 22-8<br>0.89 | 23-9<br>1.01 | 24-8<br>1.14 | 25-7<br>1.28 | 26-6<br>1.41 | 27-5<br>1.56 | 28-3<br>1.71 | 29-1<br>1.86 | 29-10<br>2.02 |
| | 16.0 | | 13-3<br>0.24 | 14-6<br>0.31 | 15-8<br>0.39 | 16-9<br>0.48 | 17-9<br>0.57 | 18-9<br>0.67 | 19-8<br>0.77 | 20-6<br>0.88 | 21-5<br>0.99 | 22-2<br>1.10 | 23-0<br>1.22 | 23-9<br>1.35 | 24-5<br>1.48 | 25-2<br>1.61 | 25-10<br>1.75 |
| | 24.0 | | 10-10<br>0.19 | 11-10<br>0.25 | 12-10<br>0.32 | 13-8<br>0.39 | 14-6<br>0.46 | 15-4<br>0.54 | 16-1<br>0.63 | 16-9<br>0.72 | 17-5<br>0.81 | 18-1<br>0.90 | 18-9<br>1.00 | 19-4<br>1.10 | 20-0<br>1.21 | 20-6<br>1.31 | 21-1<br>1.43 |

**NOTES:** (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.





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## TABLE NO. 25-U-R-7—ALLOWABLE SPANS FOR LOW-SLOPE RAFTERS, SLOPE 3 IN 12 OR LESS 20 LBS. PER SQ. FT. LIVE LOAD (No Ceiling Load)

**DESIGN CRITERIA: Strength—10 lbs. per sq. ft. dead load plus 20 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 20 lbs. per sq. ft. live load. Limited to span in inches divided by 240. RAFTERS: Spans are measured along the horizontal projection and loads are considered ae applied on the horizontal projection.**

| RAFTER SIZE | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x6 | 12.0 | 9-2<br>0.33 | 10-0<br>0.44 | 10-10<br>0.55 | 11-7<br>0.67 | 12-4<br>0.80 | 13-0<br>0.94 | 13-7<br>1.09 | 14-2<br>1.24 | 14-9<br>1.40 | 15-4<br>1.56 | 15-11<br>1.73 | 16-5<br>1.91 | 16-11<br>2.09 | 17-5<br>2.28 | 17-10<br>2.47 |
| | 16.0 | 7-11<br>0.29 | 8-8<br>0.38 | 9-5<br>0.48 | 10-0<br>0.58 | 10-8<br>0.70 | 11-3<br>0.82 | 11-9<br>0.94 | 12-4<br>1.07 | 12-10<br>1.21 | 13-3<br>1.35 | 13-9<br>1.50 | 14-2<br>1.65 | 14-8<br>1.81 | 15-1<br>1.97 | 15-6<br>2.14 |
| | 24.0 | 6-6<br>0.24 | 7-1<br>0.31 | 7-8<br>0.39 | 8-2<br>0.48 | 8-8<br>0.57 | 9-2<br>0.67 | 9-7<br>0.77 | 10-0<br>0.88 | 10-5<br>0.99 | 10-10<br>1.10 | 11-3<br>1.22 | 11-7<br>1.35 | 11-11<br>1.48 | 12-4<br>1.61 | 12-8<br>1.75 |
| 2x8 | 12.0 | 12-1<br>0.33 | 13-3<br>0.44 | 14-4<br>0.55 | 15-3<br>0.67 | 16-3<br>0.80 | 17-1<br>0.94 | 17-11<br>1.09 | 18-9<br>1.24 | 19-6<br>1.40 | 20-3<br>1.56 | 20-11<br>1.73 | 21-7<br>1.91 | 22-3<br>2.09 | 22-11<br>2.28 | 23-7<br>2.47 |
| | 16.0 | 10-6<br>0.29 | 11-6<br>0.38 | 12-5<br>0.48 | 13-3<br>0.58 | 14-0<br>0.70 | 14-10<br>0.82 | 15-6<br>0.94 | 16-3<br>1.07 | 16-10<br>1.21 | 17-6<br>1.35 | 18-2<br>1.50 | 18-9<br>1.65 | 19-4<br>1.81 | 19-10<br>1.97 | 20-5<br>2.14 |
| | 24.0 | 8-7<br>0.24 | 9-4<br>0.31 | 10-1<br>0.39 | 10-10<br>0.48 | 11-6<br>0.57 | 12-1<br>0.67 | 12-8<br>0.77 | 13-3<br>0.88 | 13-9<br>0.99 | 14-4<br>1.10 | 14-10<br>1.22 | 15-3<br>1.35 | 15-9<br>1.48 | 16-3<br>1.61 | 16-8<br>1.75 |
| 2x10 | 12.0 | 15-5<br>0.33 | 16-11<br>0.44 | 18-3<br>0.55 | 19-6<br>0.67 | 20-8<br>0.80 | 21-10<br>0.94 | 22-10<br>1.09 | 23-11<br>1.24 | 24-10<br>1.40 | 25-10<br>1.56 | 26-8<br>1.73 | 27-7<br>1.91 | 28-5<br>2.09 | 29-3<br>2.28 | 30-1<br>2.47 |
| | 16.0 | 13-4<br>0.29 | 14-8<br>0.38 | 15-10<br>0.48 | 16-11<br>0.58 | 17-11<br>0.70 | 18-11<br>0.82 | 19-10<br>0.94 | 20-8<br>1.07 | 21-6<br>1.21 | 22-4<br>1.35 | 23-2<br>1.50 | 23-11<br>1.65 | 24-7<br>1.81 | 25-4<br>1.97 | 26-0<br>2.14 |
| | 24.0 | 10-11<br>0.24 | 11-11<br>0.31 | 12-11<br>0.39 | 13-9<br>0.48 | 14-8<br>0.57 | 15-5<br>0.67 | 16-2<br>0.77 | 16-11<br>0.88 | 17-7<br>0.99 | 18-3<br>1.10 | 18-11<br>1.22 | 19-6<br>1.35 | 20-1<br>1.48 | 20-8<br>1.61 | 21-3<br>1.75 |
| 2x12 | 12.0 | 18-9<br>0.33 | 20-6<br>0.44 | 22-2<br>0.55 | 23-9<br>0.67 | 25-2<br>0.80 | 26-6<br>0.94 | 27-10<br>1.09 | 29-1<br>1.24 | 30-3<br>1.40 | 31-4<br>1.56 | 32-6<br>1.73 | 33-6<br>1.91 | 34-7<br>2.09 | 35-7<br>2.28 | 36-7<br>2.47 |
| | 16.0 | 16-3<br>0.29 | 17-9<br>0.38 | 19-3<br>0.48 | 20-6<br>0.58 | 21-9<br>0.70 | 23-0<br>0.82 | 24-1<br>0.94 | 25-2<br>1.07 | 26-2<br>1.21 | 27-2<br>1.35 | 28-2<br>1.50 | 29-1<br>1.65 | 29-11<br>1.81 | 30-10<br>1.97 | 31-8<br>2.14 |
| | 24.0 | 13-3<br>0.24 | 14-6<br>0.31 | 15-8<br>0.39 | 16-9<br>0.48 | 17-9<br>0.57 | 18-9<br>0.67 | 19-8<br>0.77 | 20-6<br>0.88 | 21-5<br>0.99 | 22-2<br>1.10 | 23-0<br>1.22 | 23-9<br>1.35 | 24-5<br>1.48 | 25-2<br>1.61 | 25-10<br>1.75 |

**NOTES:** (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.

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## TABLE NO. 25-U-R-8—ALLOWABLE SPANS FOR LOW-SLOPE, RAFTERS SLOPE 3 IN 12 OR LESS 30 LBS. PER SQ. FT. LIVE LOAD (No Ceiling Load)

**DESIGN CRITERIA: Strength—10 lbs. per sq. ft. dead load plus 30 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 30 lbs. per sq. ft. live load. Limited to span in inches divided by 240. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x6 | 12.0 | 7-11<br>0.32 | 8-8<br>0.43 | 9-5<br>0.54 | 10-0<br>0.66 | 10-8<br>0.78 | 11-3<br>0.92 | 11-9<br>1.06 | 12-4<br>1.21 | 12-10<br>1.36 | 13-3<br>1.52 | 13-9<br>1.69 | 14-2<br>1.86 | 14-8<br>2.04 | 15-1<br>2.22 | 15-6<br>2.41 |
| | 16.0 | 6-11<br>0.28 | 7-6<br>0.37 | 8-2<br>0.47 | 8-8<br>0.57 | 9-3<br>0.68 | 9-9<br>0.80 | 10-2<br>0.92 | 10-8<br>1.05 | 11-1<br>1.18 | 11-6<br>1.32 | 11-11<br>1.46 | 12-4<br>1.61 | 12-8<br>1.76 | 13-1<br>1.92 | 13-5<br>2.08 |
| | 24.0 | 5-7<br>0.23 | 6-2<br>0.30 | 6-8<br>0.38 | 7-1<br>0.46 | 7-6<br>0.55 | 7-11<br>0.65 | 8-4<br>0.75 | 8-8<br>0.85 | 9-1<br>0.96 | 9-5<br>1.08 | 9-9<br>1.19 | 10-0<br>1.31 | 10-4<br>1.44 | 10-8<br>1.57 | 10-11<br>1.70 |
| 2x8 | 12.0 | 10-6<br>0.32 | 11-6<br>0.43 | 12-5<br>0.54 | 13-3<br>0.66 | 14-0<br>0.78 | 14-10<br>0.92 | 15-6<br>1.06 | 16-3<br>1.21 | 16-10<br>1.36 | 17-6<br>1.52 | 18-2<br>1.69 | 18-9<br>1.86 | 19-4<br>2.04 | 19-10<br>2.22 | 20-5<br>2.41 |
| | 16.0 | 9-1<br>0.28 | 9-11<br>0.37 | 10-9<br>0.47 | 11-6<br>0.57 | 12-2<br>0.68 | 12-10<br>0.80 | 13-5<br>0.92 | 14-0<br>1.05 | 14-7<br>1.18 | 15-2<br>1.32 | 15-8<br>1.46 | 16-3<br>1.61 | 16-9<br>1.76 | 17-2<br>1.92 | 17-8<br>2.08 |
| | 24.0 | 7-5<br>0.23 | 8-1<br>0.30 | 8-9<br>0.38 | 9-4<br>0.46 | 9-11<br>0.55 | 10-6<br>0.65 | 11-0<br>0.75 | 11-6<br>0.85 | 11-11<br>0.96 | 12-5<br>1.08 | 12-10<br>1.19 | 13-3<br>1.31 | 13-8<br>1.44 | 14-0<br>1.57 | 14-5<br>1.70 |
| 2x10 | 12.0 | 13-4<br>0.32 | 14-8<br>0.43 | 15-10<br>0.54 | 16-11<br>0.66 | 17-11<br>0.78 | 18-11<br>0.92 | 19-10<br>1.06 | 20-8<br>1.21 | 21-6<br>1.36 | 22-4<br>1.52 | 23-2<br>1.69 | 23-11<br>1.86 | 24-7<br>2.04 | 25-4<br>2.22 | 26-0<br>2.41 |
| | 16.0 | 11-7<br>0.28 | 12-8<br>0.37 | 13-8<br>0.47 | 14-8<br>0.57 | 15-6<br>0.68 | 16-4<br>0.80 | 17-2<br>0.92 | 17-11<br>1.05 | 18-8<br>1.18 | 19-4<br>1.32 | 20-0<br>1.46 | 20-8<br>1.61 | 21-4<br>1.76 | 21-11<br>1.92 | 22-6<br>2.08 |
| | 24.0 | 9-5<br>0.23 | 10-4<br>0.30 | 11-2<br>0.38 | 11-11<br>0.46 | 12-8<br>0.55 | 13-4<br>0.65 | 14-0<br>0.75 | 14-8<br>0.85 | 15-3<br>0.96 | 15-10<br>1.08 | 16-4<br>1.19 | 16-11<br>1.31 | 17-5<br>1.44 | 17-11<br>1.57 | 18-5<br>1.70 |
| 2x12 | 12.0 | 16-3<br>0.32 | 17-9<br>0.43 | 19-3<br>0.54 | 20-6<br>0.66 | 21-9<br>0.78 | 23-0<br>0.92 | 24-1<br>1.06 | 25-2<br>1.21 | 26-2<br>1.36 | 27-2<br>1.52 | 28-2<br>1.69 | 29-1<br>1.86 | 29-11<br>2.04 | 30-10<br>2.22 | 31-8<br>2.41 |
| | 16.0 | 14-1<br>0.28 | 15-5<br>0.37 | 16-8<br>0.47 | 17-9<br>0.57 | 18-10<br>0.68 | 19-11<br>0.80 | 20-10<br>0.92 | 21-9<br>1.05 | 22-8<br>1.18 | 23-6<br>1.32 | 24-4<br>1.46 | 25-2<br>1.61 | 25-11<br>1.76 | 26-8<br>1.92 | 27-5<br>2.08 |
| | 24.0 | 11-6<br>0.23 | 12-7<br>0.30 | 13-7<br>0.38 | 14-6<br>0.46 | 15-5<br>0.55 | 16-3<br>0.65 | 17-0<br>0.75 | 17-9<br>0.85 | 18-6<br>0.96 | 19-3<br>1.08 | 19-11<br>1.19 | 20-6<br>1.31 | 21-2<br>1.44 | 21-9<br>1.57 | 22-5<br>1.70 |

NOTES: (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.





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## TABLE NO. 25-U-R-10—ALLOWABLE SPANS FOR HIGH-SLOPE RAFTERS, SLOPE OVER 3 IN 12 20 LBS. PER SQ. FT. LIVE LOAD (Heavy Roof Covering)

**DESIGN CRITERIA: Strength—15 lbs. per sq. ft. dead load plus 20 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 20 lbs. per sq. ft. live load. Limited to span in inches divided by 180. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE (IN) | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x4 | 12.0 | 5-5<br>0.20 | 5-11<br>0.26 | 6-5<br>0.33 | 6-10<br>0.40 | 7-3<br>0.48 | 7-8<br>0.56 | 8-0<br>0.65 | 8-4<br>0.74 | 8-8<br>0.83 | 9-0<br>0.93 | 9-4<br>1.03 | 9-8<br>1.14 | 9-11<br>1.24 | 10-3<br>1.36 | 10-6<br>1.47 |
| | 16.0 | 4-8<br>0.17 | 5-1<br>0.23 | 5-6<br>0.28 | 5-11<br>0.35 | 6-3<br>0.41 | 6-7<br>0.49 | 6-11<br>0.56 | 7-3<br>0.64 | 7-6<br>0.72 | 7-10<br>0.80 | 8-1<br>0.89 | 8-4<br>0.98 | 8-7<br>1.08 | 8-10<br>1.17 | 9-1<br>1.27 |
| | 24.0 | 3-10<br>0.14 | 4-2<br>0.18 | 4-6<br>0.23 | 4-10<br>0.28 | 5-1<br>0.34 | 5-5<br>0.40 | 5-8<br>0.46 | 5-11<br>0.52 | 6-2<br>0.59 | 6-5<br>0.66 | 6-7<br>0.73 | 6-10<br>0.80 | 7-0<br>0.88 | 7-3<br>0.96 | 7-5<br>1.04 |
| 2x6 | 12.0 | 8-6<br>0.20 | 9-4<br>0.26 | 10-0<br>0.33 | 10-9<br>0.40 | 11-5<br>0.48 | 12-0<br>0.56 | 12-7<br>0.65 | 13-2<br>0.74 | 13-8<br>0.83 | 14-2<br>0.93 | 14-8<br>1.03 | 15-2<br>1.14 | 15-8<br>1.24 | 16-1<br>1.36 | 16-7<br>1.47 |
| | 16.0 | 7-4<br>0.17 | 8-1<br>0.23 | 8-8<br>0.28 | 9-4<br>0.35 | 9-10<br>0.41 | 10-5<br>0.49 | 10-11<br>0.56 | 11-5<br>0.64 | 11-10<br>0.72 | 12-4<br>0.80 | 12-9<br>0.89 | 13-2<br>0.98 | 13-7<br>1.08 | 13-11<br>1.17 | 14-4<br>1.27 |
| | 24.0 | 6-0<br>0.14 | 6-7<br>0.18 | 7-1<br>0.23 | 7-7<br>0.28 | 8-1<br>0.34 | 8-6<br>0.40 | 8-11<br>0.46 | 9-4<br>0.52 | 9-8<br>0.59 | 10-0<br>0.66 | 10-5<br>0.73 | 10-9<br>0.80 | 11-1<br>0.88 | 11-5<br>0.96 | 11-8<br>1.04 |
| 2x8 | 12.0 | 11-2<br>0.20 | 12-3<br>0.26 | 13-3<br>0.33 | 14-2<br>0.40 | 15-0<br>0.48 | 15-10<br>0.56 | 16-7<br>0.65 | 17-4<br>0.74 | 18-0<br>0.83 | 18-9<br>0.93 | 19-5<br>1.03 | 20-0<br>1.14 | 20-8<br>1.24 | 21-3<br>1.36 | 21-10<br>1.47 |
| | 16.0 | 9-8<br>0.17 | 10-7<br>0.23 | 11-6<br>0.28 | 12-3<br>0.35 | 13-0<br>0.41 | 13-8<br>0.49 | 14-4<br>0.56 | 15-0<br>0.64 | 15-7<br>0.72 | 16-3<br>0.80 | 16-9<br>0.89 | 17-4<br>0.98 | 17-10<br>1.08 | 18-5<br>1.17 | 18-11<br>1.27 |
| | 24.0 | 7-11<br>0.14 | 8-8<br>0.18 | 9-4<br>0.23 | 10-0<br>0.28 | 10-7<br>0.34 | 11-2<br>0.40 | 11-9<br>0.46 | 12-3<br>0.52 | 12-9<br>0.59 | 13-3<br>0.66 | 13-8<br>0.73 | 14-2<br>0.80 | 14-7<br>0.88 | 15-0<br>0.96 | 15-5<br>1.04 |
| 2x10 | 12.0 | 14-3<br>0.20 | 15-8<br>0.26 | 16-11<br>0.33 | 18-1<br>0.40 | 19-2<br>0.48 | 20-2<br>0.56 | 21-2<br>0.65 | 22-1<br>0.74 | 23-0<br>0.83 | 23-11<br>0.93 | 24-9<br>1.03 | 25-6<br>1.14 | 26-4<br>1.24 | 27-1<br>1.36 | 27-10<br>1.47 |
| | 16.0 | 12-4<br>0.17 | 13-6<br>0.23 | 14-8<br>0.28 | 15-8<br>0.35 | 16-7<br>0.41 | 17-6<br>0.49 | 18-4<br>0.56 | 19-2<br>0.64 | 19-11<br>0.72 | 20-8<br>0.80 | 21-5<br>0.89 | 22-1<br>0.98 | 22-10<br>1.08 | 23-5<br>1.17 | 24-1<br>1.27 |
| | 24.0 | 10-1<br>0.14 | 11-1<br>0.18 | 11-11<br>0.23 | 12-9<br>0.28 | 13-6<br>0.34 | 14-3<br>0.40 | 15-0<br>0.46 | 15-8<br>0.52 | 16-3<br>0.59 | 16-11<br>0.66 | 17-6<br>0.73 | 18-1<br>0.80 | 18-7<br>0.88 | 19-2<br>0 96 | 19-8<br>1.04 |

**NOTES:** (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.

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## TABLE NO. 25-U-R-11—ALLOWABLE SPANS FOR HIGH-SLOPE RAFTERS, SLOPE OVER 3 IN 12 30 LBS. PER SQ. FT. LIVE LOAD (Heavy Roof Covering)

**DESIGN CRITERIA: Strength—15 lbs. per sq. ft. dead load plus 30 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 30 lbs. per sq. ft. live load. Limited to span in inches divided by 180. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE (IN) | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x4 | 12.0 | 4-9<br>0.20 | 5-3<br>0.27 | 5-8<br>0.34 | 6-0<br>0.41 | 6-5<br>0.49 | 6-9<br>0.58 | 7-1<br>0.67 | 7-5<br>0.76 | 7-8<br>0.86 | 8-0<br>0.96 | 8-3<br>1.06 | 8-6<br>1.17 | 8-9<br>1.28 | 9-0<br>1.39 | 9-3<br>1.51 |
| | 16.0 | 4-1<br>0.18 | 4-6<br>0.23 | 4-11<br>0.29 | 5-3<br>0.36 | 5-6<br>0.43 | 5-10<br>0.50 | 6-1<br>0.58 | 6-5<br>0.66 | 6-8<br>0.74 | 6-11<br>0.83 | 7-2<br>0.92 | 7-5<br>1.01 | 7-7<br>1.11 | 7-10<br>1.21 | 8-0<br>1.31 |
| | 24.0 | 3-4<br>0.14 | 3-8<br>0.19 | 4-0<br>0.24 | 4-3<br>0.29 | 4-6<br>0.35 | 4-9<br>0.41 | 5-0<br>0.47 | 5-3<br>0.54 | 5-5<br>0.61 | 5-8<br>0.68 | 5-10<br>0.75 | 6-0<br>0.83 | 6-3<br>0.90 | 6-5<br>0.99 | 6-7<br>1.07 |
| 2x6 | 12.0 | 7-6<br>0.20 | 8-2<br>0.27 | 8-10<br>0.34 | 9-6<br>0.41 | 10-0<br>0.49 | 10-7<br>0.58 | 11-1<br>0.67 | 11-7<br>0.76 | 12-1<br>0.86 | 12-6<br>0.96 | 13-0<br>1.06 | 13-5<br>1.17 | 13-10<br>1.28 | 14-2<br>1.39 | 14-7<br>1.51 |
| | 16.0 | 6-6<br>0.18 | 7-1<br>0.23 | 7-8<br>0.29 | 8-2<br>0.36 | 8-8<br>0.43 | 9-2<br>0.50 | 9-7<br>0.58 | 10-0<br>0.66 | 10-5<br>0.74 | 10-10<br>0.83 | 11-3<br>0.92 | 11-7<br>1.01 | 11-11<br>1.11 | 12-4<br>1.21 | 12-8<br>1.31 |
| | 24.0 | 5-4<br>0.14 | 5-10<br>0.19 | 6-3<br>0.24 | 6-8<br>0.29 | 7-1<br>0.35 | 7-6<br>0.41 | 7-10<br>0.47 | 8-2<br>0.54 | 8-6<br>0.61 | 8-10<br>0.68 | 9-2<br>0.75 | 9-6<br>0.83 | 9-9<br>0.90 | 10-0<br>0.99 | 10-4<br>1.07 |
| 2x8 | 12.0 | 9-10<br>0.20 | 10-10<br>0.27 | 11-8<br>0.34 | 12-6<br>0.41 | 13-3<br>0.49 | 13-11<br>0.58 | 14-8<br>0.67 | 15-3<br>0.76 | 15-11<br>0.86 | 16-6<br>0.96 | 17-1<br>1.06 | 17-8<br>1.17 | 18-2<br>1.28 | 18-9<br>1.39 | 19-3<br>1.51 |
| | 16.0 | 8-7<br>0.18 | 9-4<br>0.23 | 10-1<br>0.29 | 10-10<br>0.36 | 11-6<br>0.43 | 12-1<br>0.50 | 12-8<br>0.58 | 13-3<br>0.66 | 13-9<br>0.74 | 14-4<br>0.83 | 14-10<br>0.92 | 15-3<br>1.01 | 15-9<br>1.11 | 16-3<br>1.21 | 16-8<br>1.31 |
| | 24.0 | 7-0<br>0.14 | 7-8<br>0.19 | 8-3<br>0.24 | 8-10<br>0.29 | 9-4<br>0.35 | 9-10<br>0.41 | 10-4<br>0.47 | 10-10<br>0.54 | 11-3<br>0.61 | 11-8<br>0.68 | 12-1<br>0.75 | 12-6<br>0.83 | 12-10<br>0.90 | 13-3<br>0.99 | 13-7<br>1.07 |
| 2x10 | 12.0 | 12-7<br>0.20 | 13-9<br>0.27 | 14-11<br>0.34 | 15-11<br>0.41 | 16-11<br>0.49 | 17-10<br>0.58 | 18-8<br>0.67 | 19-6<br>0.76 | 20-4<br>0.86 | 21-1<br>0.96 | 21-10<br>1.06 | 22-6<br>1.17 | 23-3<br>1.28 | 23-11<br>1.39 | 24-6<br>1.51 |
| | 16.0 | 10-11<br>0.18 | 11-11<br>0.23 | 12-11<br>0.29 | 13-9<br>0.36 | 14-8<br>0.43 | 15-5<br>0.50 | 16-2<br>0.58 | 16-11<br>0.66 | 17-7<br>0.74 | 18-3<br>0.83 | 18-11<br>0.92 | 19-6<br>1.01 | 20-1<br>1.11 | 20-8<br>1.21 | 21-3<br>1.31 |
| | 24.0 | 8-11<br>0.14 | 9-9<br>0.19 | 10-6<br>0.24 | 11-3<br>0.29 | 11-11<br>0.35 | 12-7<br>0.41 | 13-2<br>0.47 | 13-9<br>0.54 | 14-4<br>0.61 | 14-11<br>0.68 | 15-5<br>0.75 | 15-11<br>0.83 | 16-5<br>0.90 | 16-11<br>0.99 | 17-4<br>1.07 |

**NOTES:** (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.





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## TABLE NO. 25-U-R-13—ALLOWABLE SPANS FOR HIGH-SLOPE RAFTERS, SLOPE OVER 3 IN 12 20 LBS. PER SQ. FT. LIVE LOAD (Light Roof Covering)

**DESIGN CRITERIA: Strength—7 lbs. per sq. ft. dead load plus 20 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 20 lbs. per sq. ft. live load. Limited to span in inches divided by 180. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE | SPACING (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x4 | 12.0 | 6-2<br>0.29 | 6-9<br>0.38 | 7-3<br>0.49 | 7-9<br>0.59 | 8-3<br>0.71 | 8-8<br>0.83 | 9-1<br>0.96 | 9-6<br>1.09 | 9-11<br>1.23 | 10-3<br>1.37 | 10-8<br>1.52 | 11-0<br>1.68 | 11-4<br>1.84 | 11-8<br>2.00 | 12-0<br>2.17 |
| | 16.0 | 5-4<br>0.25 | 5-10<br>0.33 | 6-4<br>0.42 | 6-9<br>0.51 | 7-2<br>0.61 | 7-6<br>0.72 | 7-11<br>0.83 | 8-3<br>0.94 | 8-7<br>1.06 | 8-11<br>1.19 | 9-3<br>1.32 | 9-6<br>1.45 | 9-10<br>1.59 | 10-1<br>1.73 | 10-5<br>1.88 |
| | 24.0 | 4-4<br>0.21 | 4-9<br>0.27 | 5-2<br>0.34 | 5-6<br>0.42 | 5-10<br>0.50 | 6-2<br>0.59 | 6-5<br>0.68 | 6-9<br>0.77 | 7-0<br>0.87 | 7-3<br>0.97 | 7-6<br>1.08 | 7-9<br>1.19 | 8-0<br>1.30 | 8-3<br>1.41 | 8-6<br>1.53 |
| 2x6 | 12.0 | 9-8<br>0.29 | 10-7<br>0.38 | 11-5<br>0.49 | 12-3<br>0.59 | 13-0<br>0.71 | 13-8<br>0.83 | 14-4<br>0.96 | 15-0<br>1.09 | 15-7<br>1.23 | 16-2<br>1.37 | 16-9<br>1.52 | 17-3<br>1.68 | 17-10<br>1.84 | 18-4<br>2.00 | 18-10<br>2.17 |
| | 16.0 | 8-4<br>0.25 | 9-2<br>0.33 | 9-11<br>0.42 | 10-7<br>0.51 | 11-3<br>0.61 | 11-10<br>0.72 | 12-5<br>0.83 | 13-0<br>0.94 | 13-6<br>1.06 | 14-0<br>1.19 | 14-6<br>1.32 | 15-0<br>1.45 | 15-5<br>1.59 | 15-11<br>1.73 | 16-4<br>1.88 |
| | 24.0 | 6-10<br>0.21 | 7-6<br>0.27 | 8-1<br>0.34 | 8-8<br>0.42 | 9-2<br>0.50 | 9-8<br>0.59 | 10-2<br>0.68 | 10-7<br>0.77 | 11-0<br>0.87 | 11-5<br>0.97 | 11-10<br>1.08 | 12-3<br>1.19 | 12-7<br>1.30 | 13-0<br>1.41 | 13-4<br>1.53 |
| 2x8 | 12.0 | 12-9<br>0.29 | 13-11<br>0.38 | 15-1<br>0.49 | 16-1<br>0.59 | 17-1<br>0.71 | 18-0<br>0.83 | 18-11<br>0.96 | 19-9<br>1.09 | 20-6<br>1.23 | 21-4<br>1.37 | 22-1<br>1.52 | 22-9<br>1.68 | 23-6<br>1.84 | 24-2<br>2.00 | 24-10<br>2.17 |
| | 16.0 | 11-0<br>0.25 | 12-1<br>0.33 | 13-1<br>0.42 | 13-11<br>0.51 | 14-10<br>0.61 | 15-7<br>0.72 | 16-4<br>0.83 | 17-1<br>0.94 | 17-9<br>1.06 | 18-5<br>1.19 | 19-1<br>1.32 | 19-9<br>1.45 | 20-4<br>1.59 | 20-11<br>1.73 | 21-6<br>1.88 |
| | 24.0 | 9-0<br>0.21 | 9-10<br>0.27 | 10-8<br>0.34 | 11-5<br>0.42 | 12-1<br>0.50 | 12-9<br>0.59 | 13-4<br>0.68 | 13-11<br>0.77 | 14-6<br>0.87 | 15-1<br>0.97 | 15-7<br>1.08 | 16-1<br>1.19 | 16-7<br>1.30 | 17-1<br>1.41 | 17-7<br>1.53 |
| 2x10 | 12.0 | 16-3<br>0.29 | 17-10<br>0.38 | 19-3<br>0.49 | 20-7<br>0.59 | 21-10<br>0.71 | 23-0<br>0.83 | 24-1<br>0.96 | 25-2<br>1.09 | 26-2<br>1.23 | 27-2<br>1.37 | 28-2<br>1.52 | 29-1<br>1.68 | 30-0<br>1.84 | 30-10<br>2.00 | 31-8<br>2.17 |
| | 16.0 | 14-1<br>0.25 | 15-5<br>0.33 | 16-8<br>0.42 | 17-10<br>0.51 | 18-11<br>0.61 | 19-11<br>0.72 | 20-10<br>0.83 | 21-10<br>0.94 | 22-8<br>1.06 | 23-7<br>1.19 | 24-5<br>1.32 | 25-2<br>1.45 | 25-11<br>1.59 | 26-8<br>1.73 | 27-5<br>1.88 |
| | 24.0 | 11-6<br>0.21 | 12-7<br>0.27 | 13-7<br>0.34 | 14-6<br>0.42 | 15-5<br>0.50 | 16-3<br>0.59 | 17-1<br>0.68 | 17-10<br>0.77 | 18-6<br>0.87 | 19-3<br>0.97 | 19-11<br>1.08 | 20-7<br>1.19 | 21-2<br>1.30 | 21-10<br>1.41 | 22-5<br>1.53 |

NOTES: (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (e) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.

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## TABLE NO. 25-U-R-14—ALLOWABLE SPANS FOR HIGH-SLOPE RAFTERS, SLOPE OVER 3 IN 12 30 LBS. PER SQ. FT. LIVE LOAD (Light Roof Covering)

**DESIGN CRITERIA: Strength—7 lbs. per sq. ft. dead load plus 30 lbs. per sq. ft. live load determines required fiber stress. Deflection—For 30 lbs. per sq. ft. live load. Limited to span in inches divided by 180. RAFTERS: Spans are measured along the horizontal projection and loads are considered as applied on the horizontal projection.**

| RAFTER SIZE SPACING (IN) | (IN) | Allowable Extreme Fiber Stress in Bending $F_b$ (psi). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 |
| 2x4 | 12.0 | 5-3<br>0.27 | 5-9<br>0.36 | 6-3<br>0.45 | 6-8<br>0.55 | 7-1<br>0.66 | 7-5<br>0.77 | 7-9<br>0.89 | 8-2<br>1.02 | 8-6<br>1.15 | 8-9<br>1.28 | 9-1<br>1.42 | 9-5<br>1.57 | 9-8<br>1.72 | 10-0<br>1.87 | 10-3<br>2.03 |
| | 16.0 | 4-7<br>0.24 | 5-0<br>0.31 | 5-5<br>0.39 | 5-9<br>0.48 | 6-1<br>0.57 | 6-5<br>0.67 | 6-9<br>0.77 | 7-1<br>0.88 | 7-4<br>0.99 | 7-7<br>1.11 | 7-11<br>1.23 | 8-2<br>1.36 | 8-5<br>1.49 | 8-8<br>1.62 | 8-10<br>1.76 |
| | 24.0 | 3-9<br>0.19 | 4-1<br>0.25 | 4-5<br>0.32 | 4-8<br>0.39 | 5-0<br>0.47 | 5-3<br>0.55 | 5-6<br>0.63 | 5-9<br>0.72 | 6-0<br>0.81 | 6-3<br>0.91 | 6-5<br>1.01 | 6-8<br>1.11 | 6-10<br>1.21 | 7-1<br>1.32 | 7-3<br>1.43 |
| 2x6 | 12.0 | 8-3<br>0.27 | 9-1<br>0.36 | 9-9<br>0.45 | 10-5<br>0.55 | 11-1<br>0.66 | 11-8<br>0.77 | 12-3<br>0.89 | 12-9<br>1.02 | 13-4<br>1.15 | 13-10<br>1.28 | 14-4<br>1.42 | 14-9<br>1.57 | 15-3<br>1.72 | 15-8<br>1.87 | 16-1<br>2.03 |
| | 16.0 | 7-2<br>0.24 | 7-10<br>0.31 | 8-5<br>0.39 | 9-1<br>0.48 | 9-7<br>0.57 | 10-1<br>0.67 | 10-7<br>0.77 | 11-1<br>0.88 | 11-6<br>0.99 | 12-0<br>1.11 | 12-5<br>1.23 | 12-9<br>1.36 | 13-2<br>1.49 | 13-7<br>1.62 | 13-11<br>1.76 |
| | 24.0 | 5-10<br>0.19 | 6-5<br>0.25 | 6-11<br>0.32 | 7-5<br>0.39 | 7-10<br>0.47 | 8-3<br>0.55 | 8-8<br>0.63 | 9-1<br>0.72 | 9-5<br>0.81 | 9-9<br>0.91 | 10-1<br>1.01 | 10-5<br>1.11 | 10-9<br>1.21 | 11-1<br>1.32 | 11-5<br>1.43 |
| 2x8 | 12.0 | 10-11<br>0.27 | 11-11<br>0.36 | 12-10<br>0.45 | 13-9<br>0.55 | 14-7<br>0.66 | 15-5<br>0.77 | 16-2<br>0.89 | 16-10<br>1.02 | 17-7<br>1.15 | 18-2<br>1.28 | 18-10<br>1.42 | 19-6<br>1.57 | 20-1<br>1.72 | 20-8<br>1.87 | 21-3<br>2.03 |
| | 16.0 | 9-5<br>0.24 | 10-4<br>0.31 | 11-2<br>0.39 | 11-11<br>0.48 | 12-8<br>0.57 | 13-4<br>0.67 | 14-0<br>0.77 | 14-7<br>0.88 | 15-2<br>0.99 | 15-9<br>1.11 | 16-4<br>1.23 | 16-10<br>1.36 | 17-4<br>1.49 | 17-11<br>1.62 | 18-4<br>1.76 |
| | 24.0 | 7-8<br>0.19 | 8-5<br>0.25 | 9-1<br>0.32 | 9-9<br>0.39 | 10-4<br>0.47 | 10-11<br>0.55 | 11-5<br>0.63 | 11-11<br>0.72 | 12-5<br>0.81 | 12-10<br>0.91 | 13-4<br>1.01 | 13-9<br>1.11 | 14-2<br>1.21 | 14-7<br>1.32 | 15-0<br>1.43 |
| 2x10 | 12.0 | 13-11<br>0.27 | 15-2<br>0.36 | 16-5<br>0.45 | 17-7<br>0.55 | 18-7<br>0.66 | 19-8<br>0.77 | 20-7<br>0.89 | 21-6<br>1.02 | 22-5<br>1.15 | 23-3<br>1.28 | 24-1<br>1.42 | 24-10<br>1.57 | 25-7<br>1.72 | 26-4<br>1.87 | 27-1<br>2.03 |
| | 16.0 | 12-0<br>0.26 | 13-2<br>0.34 | 14-3<br>0.43 | 15-2<br>0.53 | 16-2<br>0.63 | 17-0<br>0.74 | 17-10<br>0.85 | 18-7<br>0.97 | 19-5<br>1.09 | 20-1<br>1.22 | 20-10<br>1.35 | 21-6<br>1.49 | 22-2<br>1.63 | 22-10<br>1.78 | 23-5<br>1.93 |
| | 24.0 | 9-10<br>0.19 | 10-9<br>0.25 | 11-7<br>0.32 | 12-5<br>0.39 | 13-2<br>0.47 | 13-11<br>0.55 | 14-7<br>0.63 | 15-2<br>0.72 | 15-10<br>0.81 | 16-5<br>0.91 | 17-0<br>1.01 | 17-7<br>1.11 | 18-1<br>1.21 | 18-7<br>1.32 | 19-2<br>1.43 |

**NOTES:** (1)The required modulus of elasticity ($E$) in 1,000,000 pounds per square inch is shown below each span.

(2)Use single or repetitive member bending stress values ($F_b$) and modulus of elasticity values ($E$) from Tables Nos. 25-A-1 and 25-A-2. For duration of load stress increases, see Section 2504 (c) 4.

(3)For more comprehensive tables covering a broader range of bending stress values ($F_b$) and modulus of elasticity values ($E$), other spacing of members and other conditions of loading, see U.B.C. Standard No. 25-21.

(4)These spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.





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## TABLE NO. 25-V—WALL BRACING

| SEISMIC ZONE | CONDITION | TYPE OF BRACE[1] | | | | | | | | AMOUNT OF BRACING[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | O | E | F | G | H | |
| 0, 1 and 2 | One Story Top of Two or Three Story | X | X | X | X | X | X | X | X | Each end and each 25′ of wall. |
| | First Story of Two Story or Second Story of Three Story | X | X | X | X | X | X | X | X | |
| | First Story of Three Story | | X | X | X | X[3] | X | X | X | |
| 3 and 4 | One Story Top of Two or Three Story | X | X | X | X | X | X | X | X | Each end and each 25′ of wall. |
| | First Story of Two Story or Second Story of Three Story | | X | X | X | X[3] | X | X | X | Each end. 25% of wall length to be sheathed. |
| | First Story of Three Story | | X | X | X | X[3] | X | X | X | Each end. 40% of wall length to be sheathed. |

[1]See Section 2517 (g) 3 for full description.

[2]Bracing at ends shall be near thereto as possible. Braces shall be installed so that there is no unbraced section along the wall exceeding 25 feet.

[3]Gypsum wallboard applied to supports at 16 inches on center.



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# Chapter 26
# CONCRETE

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The contents of this chapter are patterned after and in general conformity with, the provisions of ACI Standard 318 for reinforced concrete design. For additional background information and research data used in developing the similar design requirements, reference to the ACI Code Commentary (ACI 318R) published by the American Concrete Institute is suggested.

In order to make reference to the ACI commentary easier for users of the code, the ACI chapter and section designations are shown in brackets. To clearly distinguish where the Uniform Building Code differs from ACI Standard 318-83 (Revised 1986), those portions of the code are shown in italics.

## Scope

**Sec. 2601.** *The design of structures in concrete of cast-in-place or precast construction, plain, reinforced or prestressed, shall conform to the rules and principles specified in this chapter.*

## Definitions [Chapter 2]

**Sec. 2602.** [2.1] The following terms are defined for general use in this code. Specialized definitions appear in individual *sections*.

**ADMIXTURE** is material other than water, aggregate, or hydraulic cement used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

**AGGREGATE** is granular material, such as sand, gravel, crushed stone and iron blast-furnace slag, and when used with a cementing medium forms a hydraulic cement concrete or mortar.

**AGGREGATE, LIGHTWEIGHT,** is aggregate with a dry, loose weight of 70 pounds per cubic foot or less.

***AIR-DRY WEIGHT*** *is the unit weight of a lightweight concrete specimen cured for seven days with neither loss nor gain of moisture at 60° to 80°F. and dried for 21 days in 50 ± 7 percent relative humidity at 73.4 ± 2°F.*

**ANCHORAGE** in posttensioning is a device used to anchor tendons to concrete member; in pretensioning, a device used to anchor tendons during hardening of concrete.

**BONDED TENDON** is a prestressing tendon that is bonded to concrete either directly or through grouting.

**COLUMN** is a member with a ratio of height-to-least-lateral dimension of 3 or greater used primarily to support axial compressive load.

**COMPOSITE CONCRETE FLEXURAL MEMBERS** are concrete flexural members of precast and cast-in-place concrete elements or both constructed in separate placements but so interconnected that all elements respond to loads as a unit. See Section 2617.



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**CONCRETE** is a mixture of portland cement or any other hydraulic cement, fine aggregate, coarse aggregate and water, with or without admixtures.

**CONCRETE, SPECIFIED COMPRESSIVE STRENGTH OF** ($f'_c$), is the compressive strength of concrete used in design and evaluated in accordance with provisions of Section 2604, expressed in pounds per square inch (psi). Whenever the quantity $f'_c$ is under a radical sign, square root of numerical value only is intended, and result has units of pounds per square inch (psi).

**CONCRETE, STRUCTURAL LIGHTWEIGHT,** is concrete containing lightweight aggregate which conforms to Section 2603 (d) and having an air-dry unit weight as determined by definition above, not exceeding 115 pcf. In this code, a lightweight concrete without natural sand is termed "all-lightweight concrete" and lightweight concrete in which all fine aggregate consists of normal weight sand is termed "sand-lightweight concrete."

**CURVATURE FRICTION** is friction resulting from bends or curves in the specified prestressing tendon profile.

**DEFORMED REINFORCEMENT** is deformed reinforcing bars, bar and rod mats, deformed wire, welded smooth wire fabric and welded deformed wire fabric conforming to Section 2603 (f) 2.

**DEVELOPMENT LENGTH** is the length of embedded reinforcement required to develop the design strength of reinforcement at a critical section. See Section 2609 (d), last paragraph.

**EFFECTIVE DEPTH OF SECTION** (*d*) is the distance measured from extreme compression fiber to centroid of tension reinforcement.

**EFFECTIVE PRESTRESS** is the stress remaining in prestressing tendons after all losses have occurred, excluding effects of dead load and superimposed load.

**EMBEDMENT LENGTH** is the length of embedded reinforcement provided beyond a critical section.

**JACKING FORCE** is the temporary force exerted by device that introduces tension into prestressing tendons in prestressed concrete.

**LOAD, DEAD,** is the dead weight supported by a member, as defined by *Section 2302* (without load factors).

**LOAD, FACTORED,** is the load, multiplied by appropriate load factors, used to proportion members by the strength design method of this code. See Sections 2608 (b) and 2609 (c).

**LOAD, LIVE,** *is the live load specified by Section 2302* (without load factors).

**LOAD, SERVICE,** *is the live and dead loads* (without load factors).

**MODULUS OF ELASTICITY** is the ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material. See Section 2608 (f).

**PEDESTAL** is an upright compression member with a ratio of unsupported height to average least lateral dimension of 3 or less.



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**PLAIN CONCRETE** is concrete that does not conform to definition of reinforced concrete.

**PLAIN REINFORCEMENT** is reinforcement that does not conform to definition of deformed reinforcement. See Section 2603 (f) 3.

**POSTTENSIONING** is a method of prestressing in which tendons are tensioned after concrete has hardened.

**PRECAST CONCRETE** is plain or reinforced concrete element cast in other than its final position in the structure.

**PRESTRESSED CONCRETE** is reinforced concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads.

**PRETENSIONING** is a method of prestressing in which tendons are tensioned before concrete is placed.

**REINFORCED CONCRETE** is concrete *containing adequate reinforcement,* prestressed or nonprestressed, and designed on the assumption that the two materials act together in resisting forces.

**REINFORCEMENT** is material that conforms to Section 2603 (f), excluding prestressing tendons unless specifically included.

**SPAN LENGTH.** See Section 2608 (h).

**SPIRAL REINFORCEMENT** is continuously wound reinforcement in the form of a cylindrical helix.

**SPLITTING TENSILE STRENGTH** ($f_{ct}$) is the tensile strength of concrete determined in accordance with *U.B.C. Standard No. 26-3.* See Section 2604 (b), last paragraph.

**STIRRUP** is reinforcement used to resist shear and torsion stresses in a structural member; typically bars, wires, or welded wire fabric (smooth or deformed) bent into L, U or rectangular shapes and located perpendicular to or at an angle to longitudinal reinforcement. (The term "stirrups" is usually applied to lateral reinforcement in flexural members and the term "ties" to those in compression members.) See **TIE.**

**STRENGTH, DESIGN,** is the nominal strength multiplied by a strength reduction factor $\phi$. See Section 2609 (d).

**STRENGTH, NOMINAL,** is the strength of a member or cross section calculated in accordance with provisions and assumptions of the strength design method of this code before application of any strength reduction factors. See Section 2609 (d), first paragraph.

**STRENGTH, REQUIRED,** is the strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as are stipulated in this code. See Section 2609 (b).

**STRESS** is the intensity of force per unit area.

**TENDON** is a steel element such as wire, cable, bar, rod or strand, or a bundle of such elements, used to impart prestress to concrete.



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**TIE** is a loop of reinforcing bar or wire enclosing longitudinal reinforcement. See **STIRRUP.**

**TRANSFER** is the act of transferring stress in prestressing tendons from jacks or pretensioning bed to concrete member.

**WALL** is a member, usually vertical, used to enclose or separate spaces.

**WOBBLE FRICTION** in prestressed concrete, is friction caused by unintended deviation of prestressing sheath or duct from its specified profile.

**YIELD STRENGTH** is the specified minimum yield strength or yield point of reinforcement in pounds per square inch. Yield strength or yield point shall be determined in tension according to applicable *U.B.C. Standards* as modified by Section 2603 (f).

## Specifications for Tests and Materials [Chapter 3]

**Sec. 2603.** (a) **Notations.** [3.0]

$d_b$ = nominal diameter of bar, inches.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

(b) **Tests of Materials.** [3.1] The building official *may require the* testing of any materials used in concrete construction to determine if materials are of quality specified.

Tests of materials and of concrete shall be made *by an approved agency and at no expense to the jurisdiction. Such tests shall be made in accordance with the standards listed in Section 2603 (i).*

A complete record of tests of materials and of concrete shall be available for inspection during progress of work and for two years after completion of the project, and shall be preserved by inspecting engineer or architect for that purpose.

*(c) Cements.* [3.2] *Cement shall conform to U.B.C. Standard No. 26-1 and shall correspond to that on which the selection of concrete proportions was based [see Section 2604 (c)].*

(d) **Aggregates.** [3.3] Conerete *aggregates shall conform to U.B.C. Standard No. 26-2 or U.B.C. Standard No. 26-3, except that* aggregates failing to meet these specifications but which have been shown by special test or aetual service to produce concrete of adequate strength and durability may be used where authorized by the building official.

The nominal maximum size of coarse aggregate shall be not larger than:

1. One fifth the narrowest dimension between sides of forms, nor
2. One third the depth of slabs, nor
3. Three fourths the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or prestressing tendons or ducts.

These limitations may be waived if, in the judgment of the *building official,* workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.



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(e) **Water.** [3:4] Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances that may be deleterious to concrete or reinforcement.

In addition, mixing water for prestressed concrete or for concrete that will contain aluminum embedments, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ions. See Section 2604 (f).

Nonpotable water shall not be used in concrete unless the following are satisfied:

1. Selection of concrete proportions shall be based on concrete mixes using water from the same source.

2. Mortar test cubes made with nonpotable mixing water shall have 7-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortars, identical except for the mixing water, prepared and tested in accordance with *approved standards*.

(f) **Metal Reinforcement.** [3.5] 1. **General.** Reinforcement shall be deformed reinforcement, except that plain reinforcement may be used for spirals or tendons, and reinforcement consisting of structural steel, steel pipe or steel tubing may be used as specified in this chapter.

*Reinforcement* to be welded shall be indicated on the drawings and welding procedure to be used shall be specified. *Steel specifications*, except for A706, shall be supplemented to require a report of material properties necessary to conform to welding procedures specified in *U.B.C. Standard No. 26-8*.

2. **Deformed reinforcement.** Deformed reinforcing bars shall conform to *U.B.C. Standard No. 26-4*.

Deformed reinforcing bars with a specified yield strength $f_y$ exceeding 60,000 psi may be used, provided $f_y$ shall be the stress corresponding to a strain of 0.35 percent and the bars otherwise conform to *U.B.C. Standard No. 26-4*. See Section 2609 (e).

Bar *and rod* mats for concrete reinforcement shall conform to *U.B.C. Standard No. 26-5*. *Reinforcement* used in bar *and rod* mats shall conform to *U.B.C. Standard No. 26-4*.

Deformed wire for concrete reinforcement shall conform to *U.B.C. Standard No. 26-6*, except that wire shall be not smaller than size D4, and for wire with a specified yield strength $f_y$ exceeding 60,000 psi, $f_y$ shall be the stress corresponding to a strain of 0.35 percent.

Welded *smooth* wire fabric for concrete reinforcement shall conform to *U.B.C. Standard No. 26-6*, except that for wire with a specified yield strength $f_y$ exceeding 60,000 psi, $f_y$ shall be the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 12 inches in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 2612 (o).

Welded deformed wire fabric for concrete reinforcement shall conform to



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*U.B.C. Standard No. 26-6*, except that for wire with a specified yield strength $f_y$ exceeding 60,000 psi, $f_y$ shall be the stress corresponding to a strain of 0.35 percent. Welded intersections shall not be spaced farther apart than 16 inches in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 2612 (o).

*Deformed reinforcement* may be galvanized or epoxy coated. Zinc or epoxy-coated *reinforcement* shall conform to *U.B.C. Standard No. 26-4*.

3. **Plain reinforcement.** Plain bars for spiral reinforcement shall conform to the specification *for A615, A616 and A617 contained in U.B.C. Standard No. 26-4*.

*Smooth* wire for spiral reinforcement shall conform to *U.B.C. Standard No. 24-15* except that for wire with a specified yield strength $f_y$ exceeding 60,000 psi, $f_y$ shall be the stress corresponding to a strain of 0.35 percent.

4. **Prestressing tendons.** *Wire, strands and bars for tendons in prestressed concrete shall conform to U.B.C. Standard No. 26-7.*

Wire, strands and bars not specifically listed in *U.B.C. Standard No. 26-7* may be used, provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed.

5. **Structural steel, steel pipe or tubing.** Structural steel used with reinforcing bars in composite compression members meeting requirements of Section 2610 (o) 7 or 2610 (o) 8 shall conform to *U.B.C. Standard No. 27-1, Grades A36, A242, A441, A572 and A588*.

Steel pipe or tubing for composite compression members composed of a steel-encased concrete core meeting requirements of Section 2610 (o) 6 shall conform to *U.B.C. Standard No. 27-1, Grades A53, A500 and A501*.

(g) **Admixtures.** [3.6] Admixtures to be used in concrete shall be subject to prior approval by the *building official*.

An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Section 2604 (c).

Calcium chloride or admixtures containing chloride from other than impurities from admixture ingredients shall not be used in prestressed concrete, in concrete containing embedded aluminum, or in concrete cast against stay-in-place galvanized metal forms. See Section 2604 (f).

Air-entraining admixtures shall conform to *U.B.C. Standard No. 26-9*.

Water-reducing admixtures, retarding admixtures, accelerating admixtures, water-reducing and retarding admixtures, and water-reducing and accelerating admixtures shall conform to *U.B.C. Standard No. 26-9*.

Fly ash or other pozzolans used as admixtures shall conform to *U.B.C. Standard No. 26-9*.

(h) **Storage of Materials.** [3.7] Cement and aggregate shall be stored in such manner as to prevent deterioration or intrusion of foreign matter. Any material that has deteriorated or has been contaminated shall not be used for concrete.



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*(i) **Material and Test Standards.** [3.8] The quality, testing and design of concrete used structurally in buildings or structures shall conform to the requirements specified in this chapter and the applicable standards listed in Chapter 60.*

*The welding of reinforcing steel, metal inserts and connections in reinforced concrete construction shall conform to U.B.C. Standard No. 26-8.*

## Construction Requirements—Concrete Quality [Chapter 4]

**Sec. 2604.** (a) **Notations.** [4.0]

$f'_c$ = specified compressive strength of concrete, psi.

$f_{ct}$ = average splitting tensile strength of lightweight aggregate concrete, psi.

$f'_{cr}$ = required average compressive strength of concrete used as the basis for selection of concrete portions, psi.

$s$ = standard deviation, psi.

(b) **General.** [4.1] Concrete shall be proportioned to provide an average compressive strength as prescribed in Section 2604 (d) 2. Concrete shall be produced to minimize frequency of strengths below $f'_c$ as prescribed in Section 2604 (h) 2 C.

Requirements for $f'_c$ shall be based on tests of cylinders made and tested as prescribed in Section 2604 (h) 2.

Unless otherwise specified, $f'_c$ shall be based on 28-day tests. If other than 28 days, test age for $f'_c$ shall be as indicated in design drawings or specifications.

*Design drawings shall show specified compressive strength of concrete $f'_c$ for which each part of structure is designed.*

Where design criteria in Sections 2609 (f) 2 C, 2611 (c) and 2612 (c) provide for use of a splitting tensile strength value of concrete, laboratory tests shall be made in accordance with *U.B.C. Standard No. 26-3* to establish value of $f_{ct}$ corresponding to specified values of $f'_c$. Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

(c) **Selection of Concrete Proportions.** [4.2] Proportions of materials for concrete shall be established to provide:

1. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed without segregation or excessive bleeding.
2. Resistance to special exposures as required by Section 2604 (f).
3. Conformance with strength test requirements of Section 2604 (h).

Where different materials are to be used for different portions of proposed work, each combination shall be evaluated.

Concrete proportions, including water-cement ratio, shall be established on the basis of field experience and/or trial mixtures with materials to be employed, except as permitted in Section 2604 (e) or required by Section 2604 (f).

(d) **Proportioning on the Basis of Field Experience and Trial Mixtures.** [4.3] 1. **Standard deviation.** A. **With test records.** Where a concrete production



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facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated:

(i) Must represent materials, quality control procedures and conditions similar to those expected and changes in materials and proportions within the test records shall not have been more restricted than those for proposed work.

(ii) Must represent concrete produced to meet a specified strength or strengths $f'_c$ within 1000 psi of that specified for proposed work.

(iii) Must consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in Section 2604 (h) D, except as provided in Section 2604 (d) 1 B.

B. **Without test records.** Where a concrete production facility does not have test records meeting requirements of Section 2604 (d) 1 A, but does have a record based on 15 to 29 consecutive tests, a standard deviation may be established as the product of the calculated standard deviation and the modification factor of Table No. 26-A-1. To be acceptable, the test record must meet the requirements of Items (i) and (ii) of Section 2604 (d) 1 A and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

2. **Required average strength.** Required average compressive strength $f'_{cr}$ used as the basis for selection of concrete proportions shall be the larger of Formula (4-1) or (4-2) using a standard deviation calculated in accordance with Section 2604 (d) 1 A or Section 2604 (d) 1 B.

$$f'_{cr} = f'_c + 1.34s \quad \text{.....(4-1)}$$

or

$$f'_{cr} = f'_c + 2.33s - 500 \quad \text{.....(4-2)}$$

When a concrete produetion facility does not have field strength test records for calculation of standard deviation meeting requirements of Section 2604 (d) A or B, required average strength $f'_{cr}$ shall be determined from Table No. 26-A-2 and documentation of average strength shall be in accordance with requirements of Section 2604 (d) 3.

3. **Documentation of average strength.** Documentation that proposed conerete proportions will produce an average compressive strength equal to or greater than required average compressive strength may consist of a field strength test record, several strength test records, or trial mixtures as follows:

A. When test records are used to demonstrate that proposed conerete proportions will produce the required average strength $f'_{cr}$, such reeords shall represent materials and conditions similar to those expeeted. Changes in materials, conditions and proportions within the test records shall not have been more restricted than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than ten consecutive tests may be used, provided test records encompass a period of time not less than 45 days. Required



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concrete proportions may be established by interpolation between the strengths and proportions of two or more test records each of which meets other requirements of this section.

B. When an acceptable record of field test results is not available, concrete proportions may be established based on trial mixtures meeting the following restrictions:

(i) Combination of materials shall be those for proposed work.

(ii) Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water-cement ratios or cement contents that will produce a range of strengths encompassing the required average strength $f'_{cr}$.

(iii) Trial mixture shall be designed to produce a slump within ± 0.75 inch of maximum permitted, and for air-entrained concrete, within ± 0.5 percent of maximum allowable air content.

(iv) For each water-cement ratio or cement content, at least three test cylinders for each test age shall be made and cured in accordance with *U.B.C. Standard No. 26-10*. Cylinders shall be tested at 28 days or at test age designated for determination of $f'_c$.

(v) From results of cylinder tests, a curve shall be plotted showing relationship between water-cement ratio or cement content and compressive strength at designated test age.

(vi) Maximum water-cement ratio or minimum cement content for concrete to be used in proposed work shall be that shown by the curve to produce the average strength required by Section 2604 (d) 2, unless a lower water-cement ratio or higher strength is required by Section 2604 (f).

(e) **Proportioning by Water-Cement Ratio.** [4.4] If data required by Section 2604 (d) are not available, permission may be granted to base concrete proportions on water-cement ratio limits in Table No. 26-A-3.

Table No. 26-A-3 shall be used only for concrete to be made with cements meeting strength requirements for Types I, I-A, II, II-A, III, III-A or V; or Types IS, IS-A, IS(MS), IS-A(MS), I(SM), I(SM)-A, IP, IP-A, I(PM), I(PM)-A, IP(MS), IP-A(MS), or P of *U.B.C. Standard No. 26-1*, and shall not be applied to concrete containing lightweight aggregates or admixtures other than those for entraining air.

Concrete proportioned by water-cement ratio limits prescribed in Table No. 26-A-3 shall also conform to special exposure requirements of Section 2604 (f) and to compressive strength test criteria of Section 2604 (h).

(f) **Special Exposure Requirements.** [4.5] Normal-weight and lightweight concrete exposed to freezing and thawing or de-icer chemicals shall be air entrained with air content indicated in Table No. 26-A-4. Tolerance on air content



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as delivered shall be ± 1.5 percent. For specified compressive strength $f'_c$ greater than 5000 psi, air content indicated in Table No. 26-A-4 may be reduced 1 percent.

Concrete that is intended to be watertight or concrete that will be subject to freezing and thawing in a moist condition shall conform to requirements of Table No. 26-A-5.

Concrete to be exposed to sulfate-containing solutions shall conform to requirements of Table No. 26-A-6 or be made with a cement that provides sulfate resistance and used in concrete with maximum water-cement ratio or minimum compressive strength from Table No. 26-A-6.

Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate-containing solutions as defined in Table No. 26-A-6.

For corrosion protection, maximum water-soluble chloride ion concentrations in hardened concrete at an age of 28 days contributed from the ingredients including water, aggregates, cementitious materials and admixtures shall not exceed limits of Table No. 26-A-7.

When reinforced concrete will be exposed to de-icing salts, brackish water, seawater or spray from these sources, requirements of Table No. 26-A-5 for water-cement ratio or concrete strength and minimum concrete cover requirements of Section 2607 (h) shall be satisfied.

(g) **Average Strength Reduction.** [4.6] As data become available during construction, amount by which value of $f'_{cr}$ must exceed specified value of $f'_c$ may be reduced, provided:

1. Thirty or more test results are available and average of test results exceeds that required by Section 2604 (d) 2 A, using a standard deviation calculated in accordance with Section 2604 (d) 1 A, or
2. Fifteen to 29 test results are available and average of test results exceeds that required by Section 2604 (d) 2 A, using a standard deviation calculated in accordance with Section 2604 (d) 1 B, and
3. Special exposure requirements of Section 2604 (f) are met.

(h) **Evaluation and Acceptance of Concrete.** [4.7] 1. **Frequency of testing.** *The frequency of testing shall be in accordance with the following:*

A. Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 150 cubic yards of concrete, nor less than once for each 5000 square feet of surface area for slabs or walls.

B. On a given project, if total volume of concrete is such that frequency of testing required by Item A above would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

C. When total quantity of a given class of concrete is less than 50 cubic yards, strength tests may be waived by the building official if, in his judgment, evidence of satisfactory strength is provided.

D. A strength test shall be the average of the strengths of two cylinders made



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from the same sample of concrete and tested at 28 days or at test age designated for determination of $f'_c$.

2. **Laboratory-cured specimens.** *Laboratory-cured specimens shall comply with the following:*

A. Samples for strength tests shall be taken in accordance with *U.B.C. Standard No. 26-10.*

B. Cylinders for strength tests shall be molded, laboratory cured and tested in accordance with *U.B.C. Standard No. 26-10.*

C. Strength level of an individual class of concrete shall be considered satisfactory if both the following requirements are met:

(i) Average of all sets of three consecutive strength tests equal or exceed $f'_c$.

(ii) No individual strength test (average of two cylinders) falls below $f'_c$ by more than 500 psi.

D. If either of the requirements of Section 2604 (h) 2 C are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Section 2604 (h) 4 shall be observed if requirement of Section 2604 (h) 2 C (ii) is not met.

3. **Field-cured specimens.** *Field-cured specimens shall comply with the following:*

A. The building official may require strength tests of cylinders cured under field conditions to check adequacy of curing and protection of concrete in the structure.

B. Field-cured cylinders shall be cured under field conditions in accordance with *U.B.C. Standard No. 26-10.*

C. Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

D. Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of $f'_c$ is less than 85 percent of that of companion laboratory-cured cylinders. The 85 percent may be waived if field-cured strength exceeds $f'_c$ by more than 500 psi.

4. **Investigation of low-strength test results.** *Investigation of low-strength test results shall be in accordance with the following:*

A. If any strength test of laboratory-cured cylinders falls below specified value of $f'_c$ by more than 500 psi or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that load-carrying capacity of the structure is not jeopardized.

B. If the likelihood of low-strength concrete is confirmed and computations indicate that load-carrying capacity may have been significantly reduced, tests of cores drilled from the area in question may be required in accordance with *U.B.C. Standard No. 26-10.* In such case, three cores shall be taken for each strength test more than 500 psi below specified value of $f'_c$.



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C. If concrete in the structure will be dry under service conditions, cores shall be air dried (temperatures 60° to 80°F., relative humidity less than 60 percent) for seven days before test and shall be tested dry. If concrete in the structure will be more than superficially wet under service conditions, cores shall be immersed in water for at least 40 hours and be tested wet.

D. Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of $f'_c$ and if no single core is less than 75 percent of $f'_c$. To check testing accuracy, locations represented by erratic core strengths may be retested.

E. If criteria of Section 2604 (h) 4 D are not met, and if structural adequacy remains in doubt, the responsible authority may order load tests as outlined in Section 2620 for the questionable portion of the structure, or take other appropriate action.

## Mixing and Placing Concrete [Chapter 5]

**Sec. 2605.** (a) **Preparation of Equipment and Place of Deposit.** [5.1] Preparation before concrete placement shall include the following:

1. All equipment for mixing and transporting concrete shall be clean.

2. All debris and ice shall be removed from spaces to be occupied by concrete.

3. Forms shall be properly coated.

4. Masonry filler units that will be in contact with concrete shall be well drenched.

5. Reinforcement shall be thoroughly clean of ice or other deleterious coatings.

6. Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or unless otherwise permitted by the building official.

7. All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.

(b) **Mixing.** [5.2] All concrete shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged. Ready-mixed concrete shall be mixed and delivered in accordance with requirements of *U.B.C. Standard No. 26-13 or 26-14*.

Job-mixed concrete shall be mixed in accordance with the following:

1. Mixing shall be done in a batch mixer of an approved type.

2. Mixer shall be rotated at a speed recommended by the manufacturer.

3. Mixing shall be continued for at least 1 1/2 minutes after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of *U.B.C. Standard No. 26-13*.

4. Materials handling, batching and mixing shall conform to applicable provisions of *U.B.C. Standard No. 26-13*.

5. A detailed record shall be kept to identify:

   (i) Number of batches produced;

   (ii) Proportions of materials used;



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(iii) Approximate location of final deposit in structure;

(iv) Time and date of mixing and placing.

(c) **Conveying.** [5.3] Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials.

Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.

(d) **Depositing.** [5.4] Concrete shall be deposited as nearly as practicable in its final position to avoid segregation due to rehandling or flowing.

Conereting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.

Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the *building official*.

After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed, except as permitted or prohibited by Section 2606 (d).

Top surfaces of vertically formed lifts shall be generally level.

When construction joints are required, joints shall be made in accordance with Section 2606 (d).

All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

(e) **Curing.** [5.5] 1. **General.** Concrete (other than high-early-strength) shall be maintained above 50°F. and in a moist condition for at least the first 7 days after placement, except when cured in accordance with Section 2605 (e) 3.

2. **High-early-strength.** High-early-strength concrete shall be maintained above 50°F. and in a moist condition for at least the first 3 days, except when cured in accordance with Section 2605 (e) 3.

3. **Accelerated curing.** Curing by high-pressure steam, steam at atmospheric pressure, heat and moisture or other accepted processes, may be employed to accelerate strength gain and reduce time of curing. Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.

Curing process shall be such as to produce concrete with a durability at least equivalent to the curing method of Section 2605 (e) 1 or 2605 (e) 2.

Supplementary strength tests in accordance with Section 2604 (h) 3 may be required to assure that curing is satisfactory.

(f) **Cold Weather Requirements.** [5.6] Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather. All concrete materials and all reinforcement, forms, fillers and



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ground with which concrete is to come in contact shall be free from frost. Frozen materials or materials containing ice shall not be used.

(g) **Hot Weather Requirements.** [5.7] During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection and curing to prevent excessive concrete temperatures or water evaporation that may impair required strength or serviceability of the member or structure.

## Formwork, Embedded Pipes and Construction Joints [Chapter 6]

**Sec. 2606.** (a) **Design of Formwork.** [6.1] Forms shall result in a final structure that conforms to shapes, lines and dimensions of the members as required by the design drawings and specifications.

Forms shall be substantial and sufficiently tight to prevent leakage of mortar. They shall be properly braced or tied together to maintain position and shape. Forms and their supports shall be designed so as not to damage previously placed structure.

Design of formwork shall include consideration of the following factors:

1. Rate and method of placing concrete.
2. Construction loads, including vertical, horizontal and impact loads.
3. Special form requirements for construction of shells, folded plates, domes, architectural concrete or similar types of elements.

Forms for prestressed concrete members shall be designed and constructed to permit movement of the member without damage during application of prestressing force.

(b) **Removal of Forms and Shores.** [6.2] Construction loads shall not be supported on, nor any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with remaining forming and shoring system has sufficient strength to support safely its weight and loads placed thereon.

Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of forming and shoring system and concrete strength data. Concrete strength data may be based on tests of field-cured cylinders or, when approved by the building official, on other procedures to evaluate concrete strength. Structural analysis and concrete strength test data shall be furnished to the building official when so required.

Construction loads exceeding the combination of superimposed dead load plus specified live load shall not be supported on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads.

Forms shall be removed in such manner as not to impair safety and serviceability of the structure. All concrete to be exposed by form removal shall have sufficient strength not to be damaged thereby.

Form supports for prestressed concrete members may be removed when sufficient prestressing has been applied to enable prestressed members to carry their dead load and anticipated construction loads.



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(c) **Conduits and Pipes Embedded in Concrete.** [6.3] 1. Conduits, pipes and sleeves of any material not harmful to concrete and within limitations of *this subsection* may be embedded in concrete with approval of the *building official*, provided they are not considered to replace structurally the displaced concrete.

2. Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.

3. Conduits, pipes and sleeves passing through a slab, wall or beam shall not impair significantly the strength of the construction.

4. Conduits and pipes, with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated or which is required for fire protection.

5. Except when plans for conduits and pipes are approved by the *building official*, conduits and pipes embedded within a slab, wall or beam (other than those merely passing through) shall satisfy the following:

A. They shall be not larger in outside dimension than one third the overall thickness of slab, wall or beam in which they are embedded.

B. They shall be spaced not closer than three diameters or widths on center.

C. They shall not impair significantly the strength of the construction.

6. Conduits, pipes and sleeves may be considered as replacing structurally in compression the displaced concrete, provided:

A. They are not exposed to rusting or other deterioration,

B. They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe, and

C. They have a nominal inside diameter not over 2 inches and are spaced not less than three diameters on centers.

7. In addition to other requirements of this subsection, pipes that will contain liquid, gas or vapor may be embedded in structural concrete under the following conditions:

A. Pipes and fittings shall be designed to resist effects of the material, pressure and temperature to which they will be subjected.

B. Temperature of liquid, gas or vapor shall not exceed 150°F.

C. Maximum pressure to which any piping or fittings shall be subjected shall not exceed 200 psi above atmospheric pressure.

D. All piping and fittings, except as provided in Subsection E, shall be tested as a unit for leaks before concrete placement. Testing pressure above atmospheric pressure shall be 50 pereent in excess of pressure to which piping and fittings may be subjected, but minimum testing pressure shall not be less than 150 psi above atmospheric pressure. Pressure test shall be held for four hours with no drop in pressure except that which may be caused by air temperature.

E. Drain pipes and other piping designed for pressures of not more than 1 psi above atmospheric pressure need not be tested as required in the preceding Subsection D.



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F. Pipes carrying liquid, gas or vapor that is explosive or injurious to health shall again be tested as specified in Subsection D after concrete has hardened.

G. Liquid, gas or vapor, except water not exceeding 90°F. nor 50 psi pressure, shall not be placed in the pipes until the concrete has attained its design strength.

H. Piping in solid slabs, unless used for radiant heating or snow melting, shall be placed between top and bottom reinforcement.

I. Concrete cover for pipes and fittings shall be not less than 1 1/2 inches for concrete exposed to earth or weather, nor 3/4 inch for concrete not exposed to weather or in contact with ground.

J. Reinforcement with an area not less than 0.002 times the area of concrete section shall be provided normal to the piping.

K. Piping and fittings shall be assembled by welding, brazing, solder-sweating or other equally satisfactory method. Screw connections shall not be permitted. Piping shall be so fabricated and installed that cutting, bending or displacement of reinforcement from its proper location will not be required.

(d) **Construction Joints.** [6.4] 1. **General.** Surface of concrete construction joints shall be cleaned and laitance removed. Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed. Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints. See Section 2611 (h) 9.

2. **In floors.** Construction joints in floors shall be located within the middle third of spans of slabs, beams and girders. Joints in girders shall be offset a minimum distance of two times the width of intersecting beams.

3. **In beams, girders or slabs.** Beams, girders or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.

## Details of Reinforcement [Chapter 7]

**Sec. 2607.** (a) **Notations.** [7.0]

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches

$d_b$ = nominal diameter of bar, wire or prestressing strand, inches

$f_y$ = specified yield strength of nonprestressed reinforcement, psi

$l_d$ = development length, inches. See Section 2612.

(b) **Standard Hooks.** [7.1] "Standard hook" as used in this code is one of the following:

1. One-hundred-eighty-degree bend plus $4d_b$ extension, but not less than 2 1/2 inches at free end of bar.
2. Ninety-degree bend plus $12d_b$ extension at free end of bar.



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3. For stirrup and tie hooks:
   (i) No. 5 bar and smaller, 90-degree bend plus $6d_b$ extension at free end of bar, or
   (ii) No. 6, No. 7 and No. 8 bar, 90-degree bend, plus $12d_b$ extension at free end of bar, or
   (iii) No. 8 bar and smaller, 135-degree bend plus $6d_b$ extension at free end of bar.
   (iv) *For stirrup and tie hooks in Seismic Zones Nos. 3 and 4, refer to the hoop and crosstie provisions of Section 2625 (b).*

(c) **Minimum Bend Diameters.** [7.2] Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes No. 3 through No. 5, shall not be less than the values in Table No. 26-C.

Inside diameter of bends for stirrups and ties shall be not less than $4d_b$ for No. 5 bar and smaller. For bars larger than No. 5, diameter of bend shall be in accordance with Table No. 26-C.

Inside diameter of bends in welded wire fabric (smooth or deformed) for stirrups and ties shall be not less than $4d_b$ for deformed wire larger than D6 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall be not less than $4d_b$ from nearest welded intersection.

(d) **Bending.** [7.3] All reinforcement shall be bent cold, unless otherwise permitted by the *building official*. Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the *building official*.

(e) **Surface Conditions of Reinforcement.** [7.4] When concrete is placed, metal reinforcement shall be free from mud, oil or other nonmetallic coatings that adversely affect bonding capacity.

Metal reinforcement, except prestressing tendons, with rust, mill scale or a combination of both, shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen are not less than applicable specification requirements.

Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide is permissible.

(f) **Placing Reinforcement.** [7.5] Reinforcement, prestressing tendons and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances of this section.

Unless otherwise *approved by the building official*, reinforcement, prestressing tendons and prestressing ducts shall be placed within the following tolerances:

1. Tolerance for depth $d$, and minimum concrete cover in flexural members, walls and compression members shall be as follows:

| | TOLERANCE ON $d$ | TOLERANCE ON MINIMUM CONCRETE COVER |
|---|---|---|
| $d \leq 8$ in. | $\pm 3/8$ in. | $-3/8$ in. |
| $d > 8$ in. | $\pm 1/2$ in. | $-1/2$ in. |



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except that tolerance for the clear distance to formed soffits shall be minus 1/4 inch and tolerance for cover shall not exceed minus one third the minimum concrete cover required by the approved plans or specifications.

2. Tolerance for longitudinal location of bends and ends of reinforcement shall be ±2 inches except at discontinuous ends of members where tolerance shall be ± 1/2 inch.

3. Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 10 feet in span may be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is either continuous over, or securely anchored at, support.

Welding of crossing bars shall be not permitted for assembly of reinforcement.

**EXCEPTIONS:** *1. Reinforcing steel not required by design.*

*2. When specifically approved by the building official, welding of crossing bars for assembly purposes in Seismic Zones Nos. 0, 1 and 2 may be permitted, provided that data are submitted to the building official to show that there is no detrimental effect upon the action of the structural member as a result of welding of the crossing bars.*

(g) **Spacing Limits for Reinforcement.** [7.6] 1. **General.** Clear distance between parallel bars in a layer shall be not less than $d_b$ nor 1 inch. See also the second paragraph of Section 2603 (d).

Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers not less than 1 inch.

In spirally reinforced or tied reinforced compression members, clear distance between longitudinal bars shall be not less than $1.5d_b$ nor 1 1/2 inches. See also the second paragraph of Section 2603 (d).

Clear distance limitation between bars shall apply also to the clear distance between a contact lap splice and adjacent splices or bars.

In walls and slabs other than concrete joist construction, primary flexural reinforcement shall not be spaced farther apart than three times the wall or slab thickness, nor 18 inches.

2. **Bundled bars.** Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to 4 bars in one bundle. Bundled bars shall be enclosed within stirrups or ties. Bars larger than No. 11 shall not be bundled in beams.

Individual bars within a bundle terminated within the span of flexural members shall terminate at different points with at least $40d_b$ stagger.

Where spacing limitations and minimum concrete cover are based on bar diameter $d_b$, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

3. **Prestressing tendons and ducts.** Clear distance between pretensioning tendons at each end of a member shall be not less than $4d_b$ for wire, nor $3d_b$ for strands. See also the second paragraph of Section 2603 (d). Closer vertical spacing and bundling of strands may be permitted in the middle portion of a span.

Posttensioning ducts may be bundled if it is shown that concrete can be



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satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

(h) **Concrete Protection for Reinforcement.** [7.7] 1. **Cast-in-place concrete (nonprestressed).** The following minimum concrete cover shall be provided for reinforcement:

| | MINIMUM COVER, INCHES |
|---|---|
| A. Concrete cast against and permanently exposed to earth | 3 |
| B. Concrete exposed to earth or weather: | |
| No. 6 through No. 18 bar | 2 |
| No. 5 bar, W31 or D31 wire, and smaller | 1 1/2 |
| C. Concrete not exposed to weather or in contact with ground: | |
| Slabs, walls, joists: | |
| No. 14 and No. 18 bar | 1 1/2 |
| No. 11 bar and smaller | 3/4 |
| Beams, columns: | |
| Primary reinforcement, ties, stirrups, spirals | 1 1/2 |
| Shells, folded plate members: | |
| No. 6 bar and larger | 3/4 |
| No. 5 bar, W31 or D31 wire, and smaller | 1/2 |

2. **Precast concrete (manufactured under plant control conditions).** The following minimum concrete cover shall be provided for reinforcement:

| | MINIMUM COVER, INCHES |
|---|---|
| A. Concrete exposed to earth or weather: | |
| Wall panels: | |
| No. 14 and No. 18 bar | 1 1/2 |
| No. 11 bar and smaller | 3/4 |
| Other members: | |
| No. 14 and No. 18 bar | 2 |
| No. 6 through No. 11 bar | 1 1/2 |
| No. 5 bar, W31 or D31 wire, and smaller | 1 1/4 |
| B. Concrete not exposed to weather or in contact with ground: | |
| Slabs, walls, joists: | |
| No. 14 and No. 18 bar | 1 1/4 |
| No. 11 bar and smaller | 5/8 |
| Beams, columns: | |
| Primary reinforcement | $d_b$ but not less than 5/8 and need not exceed 1 1/2 |
| Ties, stirrups, spirals | 3/8 |
| Shells, folded plate members: | |
| No. 6 bar and larger | 5/8 |
| No. 5 bar, W31 or D31 wire, and smaller | 3/8 |



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3. **Prestressed concrete.** A. The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts and end fittings, except as provided in Section 2607 (h).3 B and C:

| | MINIMUM COVER, INCHES |
|---|---|
| (i) Concrete cast against and permanently exposed to earth | 3 |
| (ii) Concrete exposed to earth or weather: | |
| Wall panels, slabs, joists | 1 |
| Other members | 1 1/2 |
| (iii) Concrete not exposed to weather or in contact with ground: | |
| Slabs, walls, joists | 3/4 |
| Beams, columns: | |
| Primary reinforcement | 1 1/2 |
| Ties, stirrups, spirals | 1 |
| Shells, folded plate members: | |
| No. 5 bars, W31 or D31 wire, and smaller | 3/8 |
| Other reinforcement | $d_b$ but not less than 3/4 |

B. For prestressed concrete members exposed to earth, weather or corrosive environments, and in which permissible tensile stress of Section 2618 (e) 2 B is exceeded, minimum cover shall be increased 50 percent.

C. For prestressed concrete members manufactured under plant control conditions, minimum concrete cover for nonprestressed reinforcement shall be as required in Section 2607 (h) 2.

4. For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 2 inches; except for concrete cast against and permanently exposed to earth, minimum cover shall be 3 inches.

5. In corrosive environments or other severe exposure conditions, amount of concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other protection shall be provided.

6. Exposed reinforcement, inserts and plates intended for bonding with future extensions shall be protected from corrosion.

7. When a thickness of cover for fire protection greater than the minimum concrete cover specified in Section 2607 (h) is required, such greater thickness shall be used.

(i) **Special Reinforcing Details for Columns.** [7.8] 1. **Offset bars.** Offset bent longitudinal bars shall conform to the following:

A. Slope of inclined portion of an offset bar with axis of column shall not exceed 1 in 6.

B. Portions of bar above and below an offset shall be parallel to axis of column.

C. Horizontal support at offset bends shall be provided by lateral ties, spirals or parts of the floor construction. Horizontal support provided shall be designed to



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resist one and one-half times the horizontal component of the computed force in the inclined portion of an offset bar. Lateral ties or spirals, if used, shall be placed not more than 6 inches from points of bend.

D. Offset bars shall be bent before placement in the forms. See Section 2607 (d).

E. Where a column face is offset 3 inches or greater, longitudinal bars shall not be offset bent. Separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided. Lap splices shall conform to Section 2612 (r).

2. **Steel cores.** Load transfer in structural steel cores of composite compression members shall be provided by the following:

A. Ends of structural steel cores shall be accurately finished to bear at end bearing splices, with positive provision for alignment of one core above the other in concentric contact.

B. At end bearing splices, bearing shall be considered effective to transfer not more than 50 percent of the total compressive stress in the steel core.

C. Transfer of stress between column base and footing shall be designed in accordance with Section 2615 (i).

D. Base of structural steel section shall be designed to transfer the total load from the entire composite member to the footing; or, the base may be designed to transfer the load from the steel core only, provided ample concrete section is available for transfer of the portion of the total load carried by the reinforced concrete section to the footing by compression in the concrete and by reinforcement.

(j) **Connections.** [7.9] At connections of principal framing elements (such as beams and columns), enclosure shall be provided for splices of continuing reinforcement and for end anchorage of reinforcement terminating in such connections.

Enclosure at connections may consist of external concrete or internal closed ties, spirals or stirrups.

(k) **Lateral Reinforcement for Compression Members.** [7.10] 1. **General.** Lateral reinforcement for compression members shall conform to the provisions of Subsections 2607 (k) 2 and 2607 (k) 3 and, where shear or torsion reinforcement is required, shall also conform to provisions of Section 2611.

Lateral reinforcement requirements for composite compression members shall conform to Section 2610 (o). Lateral reinforcement requirements for prestressing tendons shall conform to Section 2618 (l).

Lateral reinforcement requirements of Sections 2607 (k), 2610 (o) and 2618 (l) may be waived where tests and structural analysis show adequate strength and feasibility of construction.

2. **Spirals.** Spiral reinforcement for compression members shall conform to Section 2610 (j) 3 and to the following:

A. Spirals shall consist of evenly spaced continuous bar or wire of such size and so assembled to permit handling and placing without distortion from designed dimensions.



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B. For cast-in-place construction, size of spirals shall be not less than 3/8-inch-diameter.

C. Clear spacing between spirals shall not exceed 3 inches nor be less than 1 inch. See also Section 2603 (d).

D. Anchorage of spiral reinforcement shall be provided by one and one-half extra turns of spiral bar or wire at each end of a spiral unit.

E. Splices in spiral reinforcement shall be lap splices of $48d_b$, but not less than 12 inches or welded.

F. Spirals shall extend from top of footing or slab in any story to level of lowest horizontal reinforcement in members supported above.

G. Where beams or brackets do not frame into all sides of a column, ties shall extend above termination of spiral to bottom of slab or drop panel.

H. In columns with capitals, spirals shall extend to a level at which the diameter or width of capital is two times that of the column.

I. Spirals shall be held firmly in place and true to line by vertical spacers.

J. For spiral bar or wire smaller than 5/8-inch-diameter, a minimum of two spacers shall be used for spirals less than 20 inches in diameter, three spacers for spirals 20 to 30 inches in diameter and four spacers for spirals greater than 30 inches in diameter.

K. For spiral bar or wire 5/8-inch-diameter or larger, a minimum of three spacers shall be used for spirals 24 inches or less in diameter, and four spacers for spirals greater than 24 inches in diameter.

3. **Ties.** Tie reinforcement for compression members shall conform to the following:

A. All nonprestressed bars shall be enclosed by lateral ties, at least No. 3 in size for longitudinal bars No. 10 or smaller, and at least No. 4 in size for No. 11, No. 14, No. 18 and bundled longitudinal bars. Deformed wire or welded wire fabric of equivalent area may be used.

*B. In Seismic Zones Nos. 0 and 1, vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or least dimension of the compression member. In Seismic Zones Nos. 2, 3 and 4, lateral ties shall be placed at top and bottom of the column for a distance of one sixth of the clear column height, or the maximum column dimension, whichever is greater, but not less than 18 inches. The tie spacing shall be not greater than 8 bar diameters, 24 tie diameters or one half the least column dimension. Ties for the remaining column height may be spaced as required in Seismic Zones Nos. 0 and 1.*

> **EXCEPTION:** *In regions of columns confined by special transverse reinforcement conforming to the provisions of Section 2625 (e) 4, supplementary crossties engaging the hoops only may be considered as meeting this requirement.*

C. Ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle of not more than 135 degrees and a bar shall be not farther than 6 inches clear on each side along the tie from such a laterally supported bar. Where longitudinal bars are



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located around the perimeter of a circle, a complete circular tie may be used.

*D. In Seismic Zones Nos. 0, 1 and 2, column lateral ties shall be as specified in Section 2607 (b) 3 (iii). In Seismic Zones Nos. 3 and 4, lateral ties shall have a 135-degree minimum turn plus an extension of at least six bar diameters, but not less than 4 inches at the free end.*

*Additional ties which engage at least four vertical column bars shall be provided around anchor bolts which are set in the top of a column for buildings located in Seismic Zones Nos. 2, 3 and 4. Such ties shall be within 5 inches of the top of the column and shall consist of two No. 4 or three No. 3 bars.*

E. Ties shall be located vertically not more than half a tie spacing above the top of footing or slab in any story and shall be spaced as provided herein to not more than half a tie spacing below the lowest horizontal reinforcement *in members supported above.*

F. Where beams or brackets frame from four directions into a column, ties may be terminated not more than 3 inches below lowest reinforcement in shallowest of such beams or brackets.

(l) **Lateral Reinforcement for Flexural Members.** [7.11] Compression reinforcement in beams shall be enclosed by ties or stirrups satisfying the size and spacing limitations in Section 2607 (k) 3 or by welded wire fabric of equivalent area. Such ties or stirrups shall be provided throughout the distance where compression reinforcement is required.

Lateral reinforcement for flexural framing members subject to stress reversals or to torsion at supports shall consist of closed ties, closed stirrups, or spirals extending around the flexural reinforcement.

Closed ties or stirrups may be formed in one piece by overlapping standard stirrup or tie end hooks around a longitudinal bar, or formed in one or two pieces lap spliced with a Class C splice (lap of $1.7l_d$), or anchored in accordance with Section 2612 (o).

(m) **Shrinkage and Temperature Reinforcement.** [7.12] 1. **In structural slabs.** Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only. Shrinkage and temperature reinforcement shall be provided in accordance with either Subsection 2 or 3 below.

2. **Deformed reinforcement.** Deformed reinforcement conforming to Section 2603 (f) 2 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

A. Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area, but not less than 0.0014:

| | |
|---|---|
| (i) Slabs where Grade 40 or 50 deformed bars are used | 0.0020 |
| (ii) Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) are used | 0.0018 |



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(iii) Slabs where reinforcement with yield stress exceeding 60,000 psi measured at a yield strain of 0.35 percent is used $\frac{0.0018 \times 60{,}000}{f_y}$

B. Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor 18 inches.

C. At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength $f_y$ in tension in accordance with Section 2612 (b) or 2612 (p).

3. **Prestressing tendons.** Prestressing tendons conforming to Section 2603 (f) 4 used for shrinkage and temperature reinforcement shall be proportioned to provide a minimum average compressive stress of 100 psi on gross concrete area using effective prestress, after losses, in accordance with Section 2618 (g). Spacing of prestressed tendons used for shrinkage and temperature reinforcement shall not exceed 6 feet. When the spacing of prestressed tendons used for shrinkage and temperature reinforcement exceeds 54 inches, additional bonded shrinkage and temperature reinforcement conforming with Section 2607 (m) 2 shall be provided between the tendons at slab edges extending from the slab edge for a distance equal to the tendon spacing.

## Analysis and Design [Chapter 8]

**Sec. 2608.** (a) **Notations.** [8.0]

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A'_s$ = area of compression reinforcement, square inches.

$b$ = width of compression face of member, inches.

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$E_c$ = modulus of elasticity of concrete, psi. See Section 2608 (f).

$E_s$ = modulus of elasticity of reinforcement, psi. See Section 2608 (f).

$f'_c$ = specified compressive strength of concrete, psi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$l_n$ = clear span for positive moment or shear and average of adjacent clear spans for negative moment.

$V_c$ = nominal shear strength provided by concrete.

$w_u$ = factored load per unit length of beam or per unit area of slab.

$w_c$ = unit weight of concrete, pounds per cubic foot.

$\beta_1$ = factor defined in Section 2610 (c) 7.

$\rho$ = ratio of nonprestressed tension reinforcement.
$= A_s/bd$.

$\rho'$ = ratio of nonprestressed compression reinforcement.
$= A'_s/bd$.



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$\rho_b$ = reinforcement ratio producing balanced strain conditions. See Section 2610 (d) 2.

$\phi$ = strength reduction factor. See Section 2609 (d).

(b) **Design Methods.** [8.1] In design of reinforced concrete structures, members shall be proportioned for adequate strength in accordance with provisions of this code, using load factors and strength reduction factors $\phi$ specified in Section 2609.

Alternatively, nonprestressed reinforced concrete members may be designed using service loads and permissible service load stresses in accordance with provisions of Section 2626, Alternate Design Method.

(c) **Loading.** [8.2] Design provisions of this code are based on the assumption that structures shall be designed to resist all applicable loads.

Service loads shall be in accordance with *Chapter 23 with appropriate* live load reductions as *permitted therein.*

In design for wind and earthquake loads, integral structural parts shall be designed to resist the total lateral loads.

Consideration shall be given to effects of forces due to prestressing, crane loads, vibration, impact, shrinkage, temperature changes, creep and unequal settlement of supports.

(d) **Methods of Analysis.** [8.3] All members of frames or continuous construction shall be designed for the maximum effects of factored loads as determined by the theory of elastic analysis, except as modified by this section. Simplifying assumptions of Section 2608 (g) through Section 2608 (j) may be used.

Except for prestressed concrete, approximate methods of frame analysis may be used for buildings of usual types of construction, spans and story heights.

In lieu of a more accurate method of frame analysis, the following approximate moments and shears may be used in design of continuous beams and one-way slabs (slabs reinforced to resist flexural stresses in only one direction), provided:

1. There are two or more spans,
2. Spans are approximately equal, with the larger of two adjacent spans not greater than the shorter by more than 20 percent,
3. Loads are uniformly distributed, and
4. Unit live load does not exceed three times unit dead load.

Positive moment:

End spans

Discontinuous end unrestrained ..... $w_u l_n^2/11$

Discontinuous end integral with support ..... $w_u l_n^2/14$

Interior spans ..... $w_u l_n^2/16$

Negative moment at exterior face of first interior support

Two spans ..... $w_u l_n^2/9$

More than two spans ..... $w_u l_n^2/10$



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Negative moment at other faces of interior supports ..... $w_u l_n^2/11$

Negative moment at face of all supports for:

Slabs with spans not exceeding 10 feet, and beams where ratio of sum of column stiffnesses to beam stiffness exceeds eight at each end of the span ..... $w_u l_n^2/12$

Negative moment at interior face of exterior support for members built integrally with supports:

Where support is a spandrel beam ..... $w_u l_n^2/24$

Where support is a column ..... $w_u l_n^2/16$

Shear in end members at face of first interior support ..... $1.15\, w_u l_n/2$

Shear at face of all other supports ..... $w_u l_n/2$

(e) **Redistribution of Negative Moments in Continuous Nonprestressed Flexural Members.** [8.4] Except where approximate values for moments are used, negative moments calculated by elastic theory at supports of continuous flexural members for any assumed loading arrangement may each be increased or decreased by not more than

$$20\left(1 - \frac{\rho - \rho'}{\rho_b}\right) \text{ percent}$$

The modified negative moments shall be used for calculating moments at sections within the spans.

Redistribution of negative moments shall be made only when the section, at which moment is reduced, is so designed that $\rho$ or $\rho - \rho'$ is not greater than $0.50\, \rho_b$, where

$$\rho_b = \frac{0.85\, \beta_1 f'_c}{f_y} \cdot \frac{87{,}000}{87{,}000 + f_y} \qquad (8\text{-}1)$$

For criteria on moment redistribution for prestressed concrete members, see Section 2618.

(f) **Modulus of Elasticity.** [8.5] Modulus of elasticity $E_c$ for concrete may be taken as $w^{1.5}_c 33\sqrt{f'_c}$ (in psi) for values of $w_c$ between 90 and 155 pounds per cubic foot. For normal-weight concrete, $E_c$ may be taken as $57{,}000\sqrt{f'_c}$.

Modulus of elasticity $E_s$ for nonprestressed reinforcement may be taken as 29,000,000 psi. Modulus of elasticity $E_s$ for prestressing tendons shall be determined by tests or supplied by the manufacturer.

(g) **Stiffness.** [8.6] Any reasonable assumptions may be adopted for computing relative flexural and torsional stiffnesses of columns, walls, floors and roof systems. Assumptions shall be consistent throughout analysis.

Effect of haunches shall be considered both in determining moments and in design of members.



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(h) **Span Length.** [8.7] Span length of members not built integrally with supports shall be considered the clear span plus depth of member but need not exceed distance between centers of supports.

In analysis of frames or continuous construction for determination of moments, span length shall be taken as the distance center-to-center of supports. For beams built integrally with supports, moments at faces of support may be used for design.

Solid or ribbed slabs built integrally with supports, with clear spans not more than 10 feet, may be analyzed as continuous slabs on knife edge supports with spans equal to the clear spans of the slab and width of beams otherwise neglected.

(i) **Columns.** [8.8] Columns shall be designed to resist the axial forces from factored loads on all floors or roof and the maximum moment from factored loads on a single adjacent span of the floor or roof under consideration. Loading condition giving the maximum ratio of moment to axial load shall also be considered.

In frames or continuous construction, consideration shall be given to the effect of unbalanced floor or roof loads on both exterior and interior columns and of eccentric loading due to other causes.

In computing moments in columns due to gravity loading, far ends of columns built integrally with the structure may be considered fixed.

Resistance to moments at any floor or roof level shall be provided by distributing the moment between columns immediately above and below the given floor in proportion to the relative column stiffnesses and conditions of restraint.

(j) **Arrangement of Live Load.** [8.9] Live load may be considered to be applied only to the floor or roof under consideration, and far ends of columns built integrally with the structure may be considered fixed.

Arrangement of live load may be limited to combinations of:

1. Factored dead load on all spans with full-factored live load on two adjacent spans, and

2. Factored dead load on all spans with full-factored live load on alternate spans.

(k) **T-beam Construction.** [8.10] 1. In T-beam construction, the flange and web shall be built integrally or otherwise effectively bonded together.

2. Width of slab effective as a T-beam flange shall not exceed one fourth the span length of the beam, and the effective overhanging slab width on each side of the web shall not exceed:

A. Eight times the slab thickness, nor

B. One half the clear distance to the next web.

3. For beams with a slab on one side only, the effective overhanging flange width shall not exceed:

A. One twelfth the span length of the beam,

B. Six times the slab thickness, nor

C. One half the clear distance to the next web.



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4. Isolated beams, in which the T-shape is used to provide a flange for additional compression area, shall have a flange thickness not less than one half the width of web and an effective flange width not more than four times the width of web.

5. Where primary flexural reinforcement in a slab that is considered as a T-beam flange (excluding joist construction) is parallel to the beam, reinforcement perpendicular to the beam shall be provided in the top of the slab in accordance with the following:

A. Transverse reinforcement shall be designed to carry the factored load on the overhanging slab width assumed to act as a cantilever. For isolated beams, the full width of overhanging flange shall be considered. For other T-beams, only the effective overhanging slab width need be considered.

B. Transverse reinforcement shall be spaced not farther apart than five times the slab thickness nor 18 inches.

(l) **Joist Construction.** [8.11] 1. Joist construction consists of a monolithic combination of regularly spaced ribs and a top slab arranged to span in one direction or two orthogonal directions.

Ribs shall be not less than 4 inches in width and shall have a depth of not more than three and one-half times the minimum width of rib. Clear spacing between ribs shall not exceed 30 inches.

Joist construction not meeting the limitations of the preceding two paragraphs shall be designed as slabs and beams.

2. When permanent burned clay or concrete tile fillers of material having a unit compressive strength at least equal to that of the specified strength of concrete in the joists are used:

A. Vertical shells of fillers in contact with the ribs may be included in strength computations for shear and negative moment. Other portions of fillers shall not be included in strength computations.

B. Slab thickness over permanent fillers shall be not less than one twelfth the clear distance between ribs nor less than one and one-half inches.

C. In one-way joists, reinforcement normal to the ribs shall be provided in the slab as required by Section 2607 (m).

3. When removable forms or fillers not complying with Section 2608 (l) 2 are used.

A. Slab thickness shall not be less than one twelfth the clear distance between ribs, nor less than 2 inches.

B. Reinforcement normal to the ribs shall be provided in the slab as required for flexure, considering load concentrations, if any, but not less than required by Section 2607 (m).

4. Where conduits or pipes as permitted by Section 2603 (c) are embedded within the slab, slab thickness shall be at least 1 inch greater than the total overall depth of the conduits or pipes at any point. Conduits or pipes shall not impair significantly the strength of the construction.



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5. Shear strength provided by concrete $V_c$ for the ribs may be taken as 10 percent greater than provided in Section 2611. Shear strength may be increased by use of shear reinforcement or by widening the ends of the ribs.

(m) **Separate Floor Finish.** [8.12] A floor finish shall not be included as part of a structural member unless placed monolithically with the floor slab or designed in accordance with requirements of Section 2617. All concrete floor finishes may be considered as part of required cover or total thickness for nonstructural considerations.

## Strength and Serviceability Requirements [Chapter 9]

**Sec. 2609.** (a) **Notations.** [9.0]

$A_g$ = gross area of section, square inches.

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A'_s$ = area of compression reinforcement, square inches.

$d'$ = distance from extreme compression fiber to centroid of compression reinforcement, inches.

$d_s$ = distance from extreme tension fiber to centroid of tension reinforcement, inches.

$D$ = dead loads, or related internal moments and forces.

$E$ = load effects of earthquake, or related internal moments and forces.

$E_c$ = modulus of elasticity of concrete, psi. See Section 2608 (f).

$f'_c$ = specified compressive strength of concrete, psi.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

$f_{ct}$ = average splitting tensile strength of lightweight aggregate concrete, psi.

$f_r$ = modulus of rupture of concrete, psi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$F$ = loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights, or related internal moments and forces.

$h$ = overall thickness of member, inches.

$H$ = loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces.

$I_{cr}$ = moment of inertia of cracked section transformed to concrete.

$I_e$ = effective moment of inertia for computation of deflection.

$I_g$ = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement.

$l$ = span length of beam or one-way slab, as defined in Section 2608 (h); clear projection of cantilever, inches.

$l_n$ = length of clear span in long direction of two-way construction, measured face-to-face of supports in slabs without beams and face-to-face of beams or other supports in other cases.



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$L$ = live loads, or related internal moments and forces.

$M_a$ = maximum moment in member at stage deflection is computed.

$M_{cr}$ = cracking moment. *See Formula (9-8).*

$P_b$ = nominal axial load strength at balanced strain conditions. See Section 2610 (d) 2.

$P_n$ = nominal axial load strength at given eccentricity.

$P_u$ = factored axial load at given eccentricity $\leq \phi P_n$.

$T$ = *time dependent factor for sustained load. See Section 2609 (f) 2 E.*

$U$ = required strength to resist factored loads or related internal moments and forces.

$w_c$ = weight of concrete, pounds per cubic foot.

$W$ = wind load, or related internal moments and forces.

$y_t$ = distance from centroidal axis of gross section, neglecting reinforcement, to extreme fiber in tension.

$\alpha$ = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by center line of adjacent panel (if any) on each side of beam. See Section 2613.

$\alpha_m$ = average value of $\alpha$ for all beams on edges of a panel.

$\beta$ = ratio of clear spans in long-to-short direction of two-way slabs.

$\beta_s$ = ratio of length of continuous edges to total perimeter of a slab panel.

$\phi$ = strength reduction factor. See Section 2609 (d).

$\lambda$ = multiplier for additional long-time deflection as defined in Section 2609 (f) 2 E.

$\rho'$ = reinforcement ratio for nonprestressed compression reinforcement, $A'_g/bd$.

(b) **General.** [9.1] Structures and structural members shall be designed to have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in such combinations as are stipulated in this code.

Members also shall meet all other requirements of this code to ensure adequate performance at service load levels.

(c) **Required Strength.** [9.2] 1. Required strength $U$ to resist dead load $D$ and live load $L$ shall be at least equal to

$$U = 1.4D + 1.7L \quad \text{(9-1)}$$

2. If resistance to structural effects of a specified wind load $W$ are included in design, the following combinations of $D$, $L$ and $W$ shall be investigated to determine the greatest required strength $U$

$$U = 0.75\,(1.4D + 1.7L + 1.7W) \quad \text{(9-2)}$$



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where load combinations shall include both full value and zero value of $L$ to determine the more severe condition, and

$$U_1 = 0.9D + 1.3W \quad (9\text{-}3)$$

but for any combination of $D$, $L$ and $W$, required strength $U$ shall be not less than Formula (9-1).

3. If resistance to specified earthquake loads or forces $E$ are included in design, load combinations of Section 2609 (c) 2 shall apply, except that $1.1E$ shall be substituted for $W$. *Load factors contained in Sections 2625 and 2627 shall be used where applicable.*

4. If resistance to earth pressure $H$ is included in design, required strength $U$ shall be at least equal to

$$U = 1.4D + 1.7L + 1.7H \quad (9\text{-}4)$$

except that where $D$ or $L$ reduces the effect of $H$, $0.9D$ shall be substituted for $1.4D$ and zero value of $L$ shall be used to determine the greatest required strength $U$. For any combination of $D$, $L$ and $H$, required strength $U$ shall be not less than Formula (9-1).

5. If resistance to loadings due to weight and pressure of fluids with well-defined densities and controllable maximum heights $F$ is included in design, such loading shall have a load factor of 1.4 and be added to all loading combinations that include live load.

6. If resistance to impact effects is taken into account in design, such effects shall be included with live load $L$.

7. Where structural effects $T$ of differential settlement, creep, shrinkage or temperature change may be significant in design, required strength $U$ shall be at least equal to

$$U = 0.75\,(1.4D + 1.4T + 1.7L) \quad (9\text{-}5)$$

but required strength $U$ shall be not less than

$$U = 1.4\,(D + T) \quad (9\text{-}6)$$

Estimations of differential settlement, creep, shrinkage or temperature change shall be based on a realistic assessment of such effects occurring in service.

(d) **Design Strength.** [9.3] Design strength provided by a member or cross section in terms of load, moment, shear or stress shall be taken as the nominal strength calculated in accordance with requirements and assumptions of this code, multiplied by a strength reduction factor $\phi$.

Strength reduction factor $\phi$ shall be as follows:

1. Flexure, without axial load ..... 0.90



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2. Axial load and axial load with flexure. (For axial load with flexure, both axial load and moment nominal strength shall be multiplied by appropriate single value of $\phi$.)

| | |
|---|---|
| Axial tension and axial tension with flexure | 0.90 |
| Axial compression and axial compression with flexure: | |
| Members with spiral reinforcement conforming to Section 2610 (j) 3 | 0.75 |
| Other reinforced members | 0.70 |

except that for low values of axial load, $\phi$ may be increased in accordance with the following:

For members in which $f_y$ does not exceed 60,000 psi, with symmetric reinforcement, and with $(h - d' - d_s)/h$ not less than 0.70, $\phi$ may be increased linearly to 0.90 as $\phi P_n$ decreases from $0.10 f'_c A_g$ to zero.

For other reinforced members, $\phi$ may be increased linearly to 0.90 as $\phi P_n$ decreases from $0.10 f'_c A_g$ or $\phi P_b$, whichever is smaller, to zero.

| | |
|---|---|
| 3. Shear and torsion *[See also Section 2625 (c) 3 A for shear walls in Seismic Zones Nos. 3 and 4]* | 0.85 |
| 4. Bearing on concrete [See also Section 2618 (n)] | 0.70 |
| 5. Flexure in plain concrete | 0.65 |

Development lengths specified in Section 2612 do not require a $\phi$ factor.

(e) **Design Strength for Reinforcement.** [9.4] Designs shall not be based on a yield strength of reinforcement $f_y$ in excess of 80,000 psi, except for prestressing tendons.

(f) **Control of Deflections.** [9.5] 1. **General.** Reinforced concrete members subject to flexure shall be designed to have adequate stiffness to limit deflections or any deformations that may adversely affect strength or serviceability of a structure at service loads. *(See Section 2307 for deflection limits.)*

2. **One-way construction (nonprestressed).** A. Minimum thickness stipulated in Table No. 26-D shall apply for one-way construction not supporting or attached to partitions or other construction likely to be damaged by large deflections, unless computation of deflection indicates a lesser thickness may be used without adverse effects.

B. Where deflections are to be computed, deflections that occur immediately on application of load shall be computed by usual methods or formulas for elastic deflections, considering effects of cracking and reinforcement on member stiffness.

C. Unless stiffness values are obtained by a more comprehensive analysis, immediate deflection shall be computed with the modulus of elasticity $E_c$ for concrete as specified in Section 2608 (f) (normal weight or lightweight concrete) and with the effective moment of inertia as follows, but not greater than $I_g$.



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$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \quad \text{.....(9-7)}$$

**WHERE:**

$$M_{cr} = \frac{f_r I_g}{y_t} \quad \text{.....(9-8)}$$

and for normal-weight concrete

$$f_r = 7.5\sqrt{f'c} \quad \text{.....(9-9)}$$

When lightweight aggregate concrete is used, one of the following modifications shall apply:

(i) When $f_{ct}$ is specified and concrete is proportioned in accordance with Section 2604 (c), $f_r$ shall be modified by substituting $f_{ct}/6.7$ for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ shall not exceed $\sqrt{f'_c}$.

(ii) When $f_{ct}$ is not specified, $f_r$ shall be multiplied by 0.75 for "all-lightweight" concrete, and 0.85 for "sand-lightweight" concrete. Linear interpolation may be used when partial sand replacement is used.

D. For continuous members, effective moment of inertia may be taken as the average of values obtained from Formula (9-7) for the critical positive and negative moment sections. For prismatic members, effective moment of inertia may be taken as the value obtained from Formula (9-7) at midspan for simple and continuous spans, and at support for cantilevers.

E. Unless values are obtained by a more comprehensive analysis, additional longtime deflection resulting from creep and shrinkage of flexural members (normal-weight or lightweight concrete) shall be determined by multiplying the immediate deflection caused by the sustained load considered, by the factor

$$\lambda = \frac{T}{1 + 50\rho'} \quad \text{.....(9-10)}$$

where $\rho'$ shall be the value at midspan for simple and continuous spans, and at support for cantilevers. Time-dependent factor $T$ for sustained loads may be taken equal to

| | |
|---|---|
| 5 years or more | 2.0 |
| 12 months | 1.4 |
| 6 months | 1.2 |
| 3 months | 1.0 |

F. Deflection computed in accordance with this section shall not exceed limits stipulated in *Section 2307*.

3. **Two-way construction (nonprestressed).** Minimum thickness of slabs of other two-way construction designed in accordance with provisions of Section 2613 and having a ratio of long to short span not exceeding 2 shall be governed by Formulas (9-11), (9-12) and (9-13) and the other provisions of this section.



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$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000 + 5000\beta\left[\alpha_m - 0.5\,(1 - \beta_s)\left(1 + \frac{1}{\beta}\right)\right]} \quad \text{.....(9-11)}$$

but not less than

$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000 + 5000\beta(1 + \beta_s)} \quad \text{.....(9-12)}$$

and need not be more than

$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000} \quad \text{.....(9-13)}$$

However, the thickness shall be not less than the following values:

For slabs without beams or drop panels ..... 5 inches

For slabs without beams, but with drop panels conforming to the *following paragraph* ..... 4 inches

For slabs with beams on all four edges, with a value of $\alpha_m$ at least equal to 2.0 ..... 3½ inches

For slabs without beams, but with drop panels extending in each direction from center line of support, a distance not less than one sixth the span length in that direction measured center-to-center of supports, and a projection below the slab at least one fourth the slab thickness beyond the drop, thickness required by *Formula* (9-11), (9-12) or (9-13) may be reduced by 10 percent.

At discontinuous edges, an edge beam shall be provided with a stiffness ratio $\alpha$ not less than 0.80; or the minimum thickness required by *Formula* (9-11), (9-12), (9-13) or *the previous paragraph*, shall be increased by at least 10 percent in the panel with a discontinuous edge.

Slab thickness less than the minimum thickness required by this section may be used if shown by computation that deflection will not *adversely affect strength or serviceability of a structure at service loads*. Deflections shall be computed taking into account size and shape of panel, conditions of support, and nature of restraints at panel edges. For deflection computations, modulus of elasticity $E_c$ for concrete shall be as specified in Section 2608 (f). Effective moment of inertia shall be that given by Formula (9-7); other values may be used if computed deflection is in reasonable agreement with results of comprehensive tests. Additional longtime deflection shall be computed in accordance with Section 2609 (f) 2 F.

4. **Prestressed concrete construction.** For flexural members designed in accordance with provisions of Section 2618, immediate deflection shall be computed by usual methods or formulas for elastic deflections, and the moment of inertia of the gross concrete section may be used for uncracked sections.

Additional long-time deflection of prestressed concrete members shall be



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computed taking into account stresses in concrete and steel under sustained load and including effects of creep and shrinkage of concrete and relaxation of steel.

*Deflection shall not exceed limits stipulated in Section 2307.*

5. **Composite construction.** A. **Shored construction.** If composite flexural members are supported during construction so that, after removal of temporary supports, dead load is resisted by the full composite section, the composite member may be considered equivalent to a monolithically cast member for computation of deflection. For nonprestressed members, the portion of the member in compression shall determine whether values in Table No. 26-D for normal-weight or lightweight concrete shall apply. If deflection is computed, account should be taken of curvatures resulting from differential shrinkage of precast and cast-in-place components, and of axial creep effects in a prestressed concrete member.

*Deflection shall not exceed limits stipulated in Section 2307.*

B. **Unshored construction.** If the thickness of a nonprestressed precast flexural member meets the requirements of Table No. 26-D, deflection need not be computed. If the thickness of a nonprestressed composite member meets the requirements of Table No. 26-D, deflection occurring after the member becomes composite need not be computed, but the long-time deflection of the precast member should be investigated for magnitude and duration of load prior to beginning of effective composite action.

*Deflection shall not exceed limits stipulated in Section 2307.*

## Flexure and Axial Loads [Chapter 10]

**Sec. 2610.** (a) **Notations.** [10.0]

$a$ = depth of equivalent rectangular stress block as defined in Section 2610 (c) 7.

$A$ = effective tension area of concrete surrounding the flexural tension reinforcement and having the same centroid as that reinforcement, divided by the number of bars or wires, square inches. When the flexural reinforcement consists of different bar or wire sizes, the number of bars or wires shall be computed as the total area of reinforcement divided by the area of the largest bar or wire used.

$A_c$ = area of core of spirally reinforced compression member measured to outside diameter of spiral, square inches.

$A_g$ = gross area of section, square inches.

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A_{st}$ = total area of longitudinal reinforcement (bars or steel shapes), square inches.

$A_t$ = area of structural steel shape, pipe or tubing in a composite section, square inches.

$A_1$ = loaded area.

$A_2$ = the area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge contained wholly within the support and having for its



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upper base the loaded area, and having side slopes of 1 vertical to 2 horizontal.

$b$ = width of compression face of member, inches.

$c$ = distance from extreme compression fiber to neutral axis, inches.

$C_m$ = a factor relating actual moment diagram to an equivalent uniform moment diagram.

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$d_c$ = thickness of concrete cover measured from extreme tension fiber to center of bar or wire located closest thereto, inches.

$E_c$ = modulus of elasticity of concrete, psi. See Section 2608 (f).

$E_s$ = modulus of elasticity of reinforcement, psi. See Section 2608 (f).

$EI$ = flexural stiffness of compression member. See Formula (10-9).

$f'_c$ = specified compressive strength of concrete, psi.

$f_s$ = calculated stress in reinforcement at service loads, ksi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$h$ = overall thickness of member, inches.

$I_g$ = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement.

$I_{se}$ = moment of inertia of reinforcement about centroidal axis of member cross section.

$I_t$ = moment of inertia of structural steel shape, pipe or tubing about centroidal axis of composite member cross section.

$k$ = effective length factor for compression members.

$l_u$ = unsupported length of compression member.

$M_c$ = factored moment to be used for design of compression member.

$M_1$ = *value of smaller factored end mament on compression member calculated by conventional elastic frame analysis, positive if member is bent in single curvature, negative if bent in double curvature.*

$M_{1b}$ = value of smaller factored end moment on a *braced* compression member, calculated by conventional elastic frame analysis; positive if member is bent in single curvature, negative if bent in double curvature.

$M_2$ = *value of larger factored end moment on compression member calculated by conventional elastic frame analysis, always positive.*

$M_{2b}$ = value of larger factored end moment on compression members due to loads which result in no appreciable sidesway, calculated by conventional elastic frame analysis.

$M_{2s}$ = value of larger factored end moment on compression member due to loads which result in appreciable sidesway, calculated by conventional elastic frame analysis.

$P_b$ = nominal axial load strength at balanced strain conditions. See Section 2610 (d) 2.



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$P_c$ = critical load. See Formula (10-9).

$P_n$ = nominal axial load strength at given eccentricity.

$P_o$ = nominal axial load strength at zero eccentricity.

$P_u$ = factored axial load at given eccentricity $\leq \phi P_n$.

$r$ = radius of gyration of cross section of a compression member.

$z$ = quantity limiting distribution of flexural reinforcement. See Section 2610 (g).

$\beta_1$ = factor defined in Section 2610 (c).

$\beta_d$ = ratio of maximum factored dead load moment to maximum factored total load moment, always positive.

$\delta_b$ = moment magnification factor for frames braced against sidesway to reflect effects of member curvature between ends of compression members.

$\delta_s$ = moment magnification factor for frames not braced against sidesway to reflect lateral drift resulting from lateral and gravity loads.

$\rho$ = ratio of nonprestressed tension reinforcement.

$= A_s/bd$.

$\rho_b$ = reinforcement ratio producing balanced strain conditions. See Section 2610 (d) 2.

$\rho_s$ = ratio of volume of spiral reinforcement to total volume of core (out-to-out of spirals) of a spirally reinforced compression member.

$\phi$ = strength reduction factor. See Section 2609 (d).

(b) **Scope.** [10.1] Provisions of Section 2610 shall apply for design of members subject to flexure or axial loads or to combined flexure and axial loads.

(c) **Design Assumptions.** [10.2] 1. Strength design of members for flexure and axial loads shall be based on assumptions given in Section 2610 (c) 2 through 7, and on satisfaction of applicable conditions of equilibrium and compatibility of strains.

2. Strain in reinforcement and concrete shall be assumed directly proportional to the distance from the neutral axis, except, for deep flexural members with overall depth to clear span ratios greater than two fifths for continuous spans and four fifths for simple spans, a nonlinear distribution of strain shall be considered. See Section 2610 (g).

3. Maximum usable strain at extreme concrete compression fiber shall be assumed equal to 0.003.

4. Stress in reinforcement below specified yield strength $f_y$ for grade of reinforcement used shall be taken as $E_s$ times steel strain. For strains greater than that corresponding to $f_y$, stress in reinforcement shall be considered independent of strain and equal to $f_y$.

5. Tensile strength of concrete shall be neglected in flexural calculations of reinforced concrete, except when meeting requirements of Section 2618 (c).



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6. Relationship between concrete compressive stress distribution and concrete strain may be assumed to be rectangular, trapezoidal, parabolic or any other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

7. Requirements of Section 2610 (c) 6 may be considered satisfied by an equivalent rectangular concrete stress distribution defined by the following:

A. Concrete stress of $0.85f'_c$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = \beta_1 c$ from the fiber of maximum compressive strain.

B. Distance $c$ from fiber of maximum strain to the neutral axis shall be measured in a direction perpendicular to the axis.

C. Factor $\beta_1$ shall be taken as 0.85 for concrete strengths $f'_c$ up to and including 4000 psi. For strengths above 4000 psi, $\beta_1$ shall be reduced continuously at a rate of 0.05 for each 1000 psi of strength in excess of 4000 psi, but $\beta_1$ shall not be taken less than 0.65.

(d) **General Principles and Requirements.** 1. Design of cross section subject to flexure or axial loads or to combined flexure and axial loads shall be based on stress and strain compatibility using assumptions in Section 2610 (c).

2. Balanced strain conditions exist at a cross section when tension reinforcement reaches the strain corresponding to its specified yield strength $f_y$ just as concrete in compression reaches its assumed ultimate strain of 0.003.

3. For flexural members, and for members subject to combined flexure and compressive axial load when the design axial load strength $\phi P_n$ is less than the smaller of $0.10f'_c A_g$ or $\phi P_b$, the ratio of reinforcement $\rho$ provided shall not exceed 0.75 of the ratio $\rho_b$ that would produce balanced strain conditions for the section under flexure without axial load. For members with compression reinforcement, the portion of $\rho_b$ equalized by compression reinforeemcnt need not be reduced by the 0.75 factor.

4. Compression reinforcement in conjunction with additional tension reinforcement may be used to increase the strength of flexural members.

5. Design axial load strength $\phi P_n$ of compression members shall not be taken greater than the following:

A. For nonprestressed members with spiral reinforeement eonforming to Section 2607 (k) 2 or composite members eonforming to Section 2610 (o):

$$\phi P_{n(max.)} = 0.85\phi[0.85f'_c (A_g - A_{st}) + f_y A_{st}] \quad \text{.....(10-1)}$$

B. For nonprestressed members with tie reinforcement conforming to Section 2607 (k) 3:

$$\phi P_{n(max.)} = 0.80\phi[0.85f'_c (A_g - A_{st}) + f_y A_{st}] \quad \text{.....(10-2)}$$

C. For prestressed members, design axial load strength $\phi P_n$ shall not be taken



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greater than 0.85 (for members with spiral reinforcement) or 0.80 (for members with tie reinforcement) of the design axial load strength at zero eccentricity $\phi P_o$.

6. Members subject to compressive axial load shall be designed for the maximum moment that can accompany the axial load. The factored axial load $P_u$ at given eccentricity shall not exceed that given in Section 2610 (d) 5. The maximum factored moment $M_u$ shall be magnified for slenderness effects in accordance with Section 2610 (k).

(e) **Distance Between Lateral Supports of Flexural Members.** [10.4] Spacing of lateral supports for a beam shall not exceed 50 times the least width $b$ of compression flange or face.

Effects of lateral eccentricity of load shall be taken into account in determining spacing of lateral supports.

(f) **Minimum Reinforcement of Flexural Members.** [10.5] 1. At any section of a flexural member, except as provided in Sections 2610 (f) 2 and 2610 (f) 3 where positive reinforcement is required by analysis, the ratio $\rho$ provided shall be not less than that given by:

$$\rho_{min.} = \frac{200}{f_y} \qquad (10\text{-}3)$$

In T-beams and joists where the web is in tension, the ratio $\rho$ shall be computed for this purpose using width of web.

2. Alternatively, area of reinforcement provided at every section, positive or negative, shall be at least one-third greater than that required by analysis.

3. For structural slabs of uniform thickness, minimum area and maximum spacing of reinforcement in the direction of the span shall be as required for shrinkage and temperature according to Section 2607 (m).

(g) **Distribution of Flexural Reinforcement in Beams and One-way Slabs.** [10.6] 1. This section prescribes rules for distribution of flexural reinforcement to control flexural cracking in beams and in one-way slabs (slabs reinforced to resist flexural stresses in only one direction).

2. Distribution of flexural reinforcement in two-way slabs shall be as required by Section 2613 (e).

3. Flexural tension reinforcement shall be well distributed within maximum flexural tension zones of a member cross section as required by Section 2610 (g) 4.

4. When design yield strength $f_y$ for tension reinforcement exceeds 40,000 psi, cross sections of maximum positive and negative moment shall be so proportioned that the quantity $z$ given by

$$z = f_s \sqrt[3]{d_c A} \qquad (10\text{-}4)$$

does not exceed 175 kips per inch for interior exposure and 145 kips per inch for exterior exposure. Calculated stress in reinforcement at service load $f_s$ (kips per square inch) shall be computed as the moment divided by the product of steel area



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and internal moment arm. In lieu of such computations, $f_s$ may be taken as 60 percent of specified yield strength $f_y$.

5. Provisions of Section 2610 (g) 4 may not be sufficient for structures subject to very aggressive exposure or designed to be watertight. For such structures, special investigations and precautions are required.

6. Where flanges of T-beam construction are in tension, part of the flexural tension reinforcement shall be distributed over an effective flange width as defined in Section 2608 (k), or a width equal to one tenth the span, whichever is smaller. If the effective flange width exceeds one tenth the span, some longitudinal reinforcement shall be provided in the outer portions of the flange.

7. If the depth of the web exceeds 3 feet longitudinal reinforcement having a total area equal to at least 10 percent of the area of the flexural tension, reinforcement shall be placed near the side faces of the web and distributed in the zone of flexural tension with a spacing not more than the web width nor 12 inches. Such reinforcement may be included in strength computations only if a strain compatibility analysis is made to determine stresses in the individual bars or wires.

(h) **Deep Flexural Members.** [10.7] 1. Flexural members with overall depth to clear span ratios greater than two fifths for continuous spans, or four fifths for simple spans, shall be designed as deep flexural members, taking into account nonlinear distribution of strain and lateral buckling.

2. Design of deep flexural members for shear effects shall be in accordance with Section 2611 (i).

3. Minimum flexural tension reinforcement shall conform to Section 2610 (f).

4. Minimum horizontal and vertical reinforcement in the side faces of deep flexural members shall be the greater of the requirements of Section 2611 (i) 7 and 8 or Section 2614 (d).

(i) **Design Dimensions for Compression Members.** [10.8] 1. **Isolated compression member with multiple spirals.** Outer limits of the effective cross section of a compression member with two or more interlocking spirals shall be taken at a distance outside the extreme limits of the spirals equal to the minimum concrete cover required by Section 2607 (h).

2. **Compression member built monolithically with wall.** Outer limits of the effective cross section of a spirally reinforced or tied reinforced compression member built monolithically with a concrete wall or pier shall be taken not greater than 1 1/2 inches outside the spiral or tie reinforcement.

3. **Equivalent circular compression member.** In lieu of using full gross area for design, a compression member with a square, octagonal or other shaped cross section may be considered as a circular section with a diameter equal to the least lateral dimension of the actual shape. Cross area considered, required percentage of reinforcement, and design strength shall be based on that circular section.

4. **Limits of section.** For a compression member with a larger cross section than required by considerations of loading, a reduced effective area $A_g$ not less than one half the total area may be used to determine minimum reinforcement and design strength.



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(j) **Limits for Reinforcement of Compression Members.** [10.9] 1. Area of longitudinal reinforcement for noncomposite compression members shall be not less than 0.01 nor more than 0.08 times gross area $A_g$ of section.

2. Minimum number of longitudinal bars in compression members shall be four for bars within rectangular or circular ties, three for bars within triangular ties, and six for bars enclosed by spirals conforming to Section 2610 (j) 3.

3. Ratio of spiral reinforcement $\rho_s$ shall be not less than the value given by

$$\rho_s = 0.45\left(\frac{A_g}{A_c} - 1\right)\frac{f'_c}{f_y} \quad \text{(10-5)}$$

where $f_y$ is the specified yield strength of spiral reinforcement but not more than 60,000 psi.

(k) **Slenderness Effects in Compression Members.** [10.10] 1. Design of compression members shall be based on forces and moments determined from analysis of the structure. Such analysis shall take into account influence of axial loads and variable moment of inertia on member stiffness and fixed-end moments, effect of deflections on moments and forces and the effects of duration of loads.

2. In lieu of the procedure prescribed in Section 2610 (k) 1, slenderness effects in compression members may be evaluated in accordance with the approximate procedure presented in Section 2610 (l).

3. The detailed requirements of Section 2610 (l) need not be applied if slenderness effects in compression members are evaluated in accordance with Section 2610 (k) 1.

(l) **Approximate Evaluation of Slenderness Effects.** [10.11] 1. **Unsupported length of compression members.** A. Unsupported length $l_u$ of a compression member shall be taken as the clear distance between floor slabs, beams or other members capable of providing lateral support for that compression member.

B. Where column capitals or haunches are present, unsupported length shall be measured to the lower extremity of capital or haunch in the plan considered.

2. **Effective length of compression members.** A. For compression members braced against sidesway, effective length factor $k$ shall be taken as 1.0, unless analysis shows that a lower value may be used.

B. For compression members not braced against sidesway, effective length factor $k$ shall be determined with due consideration of cracking and reinforcement on relative stiffness, and shall be greater than 1.0.

3. **Radius of gyration.** Radius of gyration $r$ may be taken equal to 0.30 times the overall dimension in the direction stability is being considered for rectangular compression members and 0.25 times the diameter for circular compression members. For other shapes, $r$ may be computed for the gross concrete section.

4. **Consideration of slenderness effects.** A. For compression members braced against sidesway, effects of slenderness may be neglected when $kl_u/r$ is less than $34 - 12M_{1b}/M_{2b}$.



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B. For compression members not braced against sidesway, effects of slenderness may be neglected when $kl_u/r$ is less than 22.

C. For all compression members with $kl_u/r$ greater than 100, an analysis as defined in Section 2610 (k) 1 shall be made.

5. **Moment magnification.** A. *Braced* compression members shall be designed using the factored axial load $P_u$ from a conventional frame analysis and a magnified factored moment $M_c$ defined by:

**WHERE:**

$$M_c = \delta_b M_{2b} + \delta_s M_{2s} \quad \text{(10-6)}$$

$$\delta_b = \frac{C_m}{1 - \dfrac{P_u}{\phi P_c}} \geq 1.0 \quad \text{(10-7)}$$

$$\delta_s = \frac{1}{1 - \dfrac{\Sigma P_u}{\phi \Sigma P_c}} \geq 1.0 \quad \text{(10-8)}$$

**AND**

$$P_c = \frac{\pi^2 EI}{(kl_u)^2} \quad \text{(10-9)}$$

$\Sigma P_u$ and $\Sigma P_c$ are the summations for all columns in a story. For frames not braced against sidesway, both $\delta_b$ and $\delta_s$ shall be computed. For frames braced against sidesways, $\delta_s$ shall be taken as 1.0. In calculation of $P_c$, $k$ shall be computed according to Section 2610 (l) 2 A for $\delta_b$ and according to Section 2610 (l) 2 B for $\delta_s$.

B. In lieu of a more accurate calculation, $EI$ in Formula (10-9) may be taken either as

$$EI = \frac{(E_c I_g/5) + E_s I_{se}}{1 + \beta_d} \quad \text{(10-10)}$$

or conservatively

$$EI = \frac{E_c I_g/2.5}{1 + \beta_d} \quad \text{(10-11)}$$



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C. In Formula (10-7), for members braced against sidesway and without transverse loads between supports, $C_m$ may be taken as

$$C_m = 0.6 + 0.4 \frac{M_{1b}}{M_{2b}} \quad \text{(10-12)}$$

but not less than 0.4. For all other cases, $C_m$ shall be taken as 1.0.

D. If computations show that there is no moment at both ends of a braced compression member or that computed end eccentricities are less than $(0.6 + 0.03h)$ inches, $M_{2b}$ in Formula (10-6) shall be based on a minimum eccentricity of $(0.6 + 0.03h)$ inches about each principal axis separately. Ratio $M_{1b}/M_{2b}$ in Formula (10-12) shall be determined by either of the following:

(i) When computed end eccentricities are less than $(0.6 + 0.03h)$ inches, computed end moments may be used to evaluate $M_{1b}/M_{2b}$ in Formula (10-12).

(ii) If computations show that there is essentially no moment at both ends of a braced compression member, the ratio $M_{1b}/M_{2b}$ shall be taken equal to one.

E. If computations show that there is no moment at both ends of a compression member not braced against sidesway or that computed end eccentricities are less than $(0.6 + 0.03h)$ inch, $M_{2b}$ in Formula (10-6) shall be based on a minimum eccentricity of $(0.6 + 0.03h)$ inch, about each principal axis separately.

6. **Moment magnification for flexural members.** In frames not braced against sidesway, flexural members shall be designed for the total magnified end moments of the compression members at the joint.

7. **Moment magnifier $\delta$ for biaxial bending.** For compression members subject to bending about both principal axes, moment about each axis shall be magnified by $\delta$, computed from corresponding conditions of restraint about that axis.

(m) **Axially Loaded Members Supporting Slab System.** [10.12] Axially loaded members supporting slab system included within the scope of Section 2613 (b) shall be designed as provided in Section 2610 and in accordance with the additional requirements of Section 2613.

(n) **Transmission of Column Loads Through Floor System.** [10.13] When the specified compressive strength of concrete in a column is greater than 1.4 times that specified for a floor system, transmission of load through the floor system shall be provided by one of the following:

1. Concrete of strength specified for the column shall be placed in the floor at the column location. Top surface of the column concrete shall extend 2 feet into the slab from face of larger column. Column concrete shall be well integrated with floor concrete, and shall be placed in accordance with Section 2606.(d) 3.

2. Strength of a column through a floor system shall be based on the lower value of concrete strength with vertical dowels and spirals as required.

3. For columns laterally supported on four sides by beams of approximately equal depth or by slabs, strength of the column may be based on an assumed



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concrete strength in the column joint equal to 75 percent of column concrete strength plus 35 percent of floor concrete strength.

(o) **Composite Compression Members.** [10.14] 1. Composite compression members shall include all such members reinforced longitudinally with structural steel shapes, pipe or tubing with or without longitudinal bars.

2. Strength of a composite member shall be computed for the same limiting conditions applicable to ordinary reinforced concrete members.

3. Any axial load strength assigned to concrete of a composite member shall be transferred to the concrete by members or brackets in direct bearing on the composite member concrete.

4. All axial load strength not assigned to concrete of a composite member shall be developed by direct connection to the structural steel shape, pipe or tube.

5. For evaluation of slenderness effects, radius of gyration of a composite section shall be not greater than the value given by:

$$r = \sqrt{\frac{(E_c I_g/5) + E_s I_t}{(E_c A_g/5) + E_s A_t}} \qquad (10\text{-}13)$$

*For computing $P_c$ in Formula (10-8), EI of the composite section shall be not greater than*

$$EI = \frac{E_c I_g/5}{1 + \beta_d} + E_s I_t \qquad (10\text{-}14)$$

6. **Structural steel encased concrete core.** A. For a composite member with concrete core encased by structural steel, thickness of the steel encasement shall be not less than

$$b\sqrt{\frac{f_y}{3E_s}}, \text{ for each face of width } b$$

nor

$$h\sqrt{\frac{f_y}{8E_s}}, \text{ for eircular sections of diameter } h$$

B. Longitudinal bars located within the encased concrete core may be considered in computing $A_t$ and $I_t$.

7. **Spiral reinforcement around structural steel core.** A composite member with spirally reinforced concrete around a struetural steel core shall conform to the following:

A. Specified compressive strength of concrete $f'_c$ shall be not less than 2500 psi.



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B. Design yield strength of structural steel core shall be the specified minimum yield strength for grade of structural steel used but not to exceed 50,000 psi.

C. Spiral reinforcement shall conform to Section 2610 (j) 3.

D. Longitudinal bars located within the spiral shall be not less than 0.01 nor more than 0.08 times net area of concrete section.

E. Longitudinal bars located within the spiral may be considered in computing $A_t$ and $I_t$.

8. **Tie reinforcement around structural steel core.** A composite member with laterally tied concrete around a structural steel core shall conform to the following:

A. Specified compressive strength of concrete $f'_c$ shall be not less than 2500 psi.

B. Design yield strength of structural steel core shall be the specified minimum yield strength for grade of structural steel used but not to exceed 50,000 psi.

C. Lateral ties shall extend completely around the structural steel core.

D. Lateral ties shall have a diameter not less than 1/50 times the greatest side dimension of composite member, except that ties shall not be smaller than No. 3 and need not be larger than No. 5. Welded wire fabric of equivalent area may be used.

E. Vertical spacing of lateral ties shall not exceed 16 longitudinal bar diameters, 48 tie bar diameters, or one half times the least side dimension of the composite member.

F. Longitudinal bars located within the ties shall be not less than 0.01 nor more than 0.08 times net area of concrete section.

G. A longitudinal bar shall be located at every corner of a rectangular cross section, with other longitudinal bars spaced not farther apart than one-half the least side dimension of the composite member.

H. Longitudinal bars located within the ties may be considered in computing $A_t$ for strength but not in computing $I_t$ for evaluation of slenderness effects.

(p) **Bearing Strength.** [10.15] Design bearing strength on concrete shall not exceed $\phi$ $(0.85f'_c A_1)$, except when the supporting surface is wider on all sides than the loaded area, design bearing strength on the loaded area may be multiplied by $\sqrt{A_2/A_1}$, but not more than 2.

*This* section does not apply to posttensioning anchorages.

## Shear and Torsion [Chapter 11]

**Sec. 2611.** (a) **Notations.** [11.0]

$a$ = shear span, distance between concentrated load and face of supports.

$A_c$ = area of concrete section resisting shear transfer, square inches.

$A_f$ = area of reinforcement in bracket or corbel resisting factored moment $[V_u a + N_{uc}(h-d)]$, square inches.

$A_g$ = gross area of section, square inches.



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$A_h$ = area of shear reinforcement parallel to flexural tension reinforcement, square inches.

$A_l$ = total area of longitudinal reinforcement to resist torsion, square inches.

$A_n$ = area of reinforcement in bracket or corbel resisting tensile force $N_{uc}$, square inches.

$A_{ps}$ = area of prestressed reinforcement in tension zone, square inches.

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A_t$ = area of one leg of a closed stirrup resisting torsion within a distance $s$, square inches.

$A_v$ = area of shear reinforcement within a distance $s$, or area of shear reinforcement perpendicular to flexural tension reinforcement within a distance $s$ for deep flexural members, square inches.

$A_{vf}$ = area of shear-friction reinforcement, square inches.

$A_{vh}$ = area of shear reinforcement parallel to flexural tension reinforcement within a distance $s_2$, square inches.

$b$ = width of compression face of member, inches.

$b_o$ = perimeter of critical section for slabs and footings, inches.

$b_w$ = web width, or diameter of circular section, inches.

$b_1$ = total width of the critical section defined in Section 2611 (l) 1 B measured in the direction of the span for which moments are determined, inches.

$b_2$ = total width of the critical section defined in Section 2611 (l) 1 B measured in the direction perpendicular to $b_1$, inches.

$c_1$ = size of rectangular or equivalent rectangular column, capital or bracket measured in the direction of the span for which moments are being determined, inches.

$C_t$ = factor relating shear and torsional stress properties.

$$= \frac{b_w d}{\Sigma x^2 y}$$

$d$ = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, but need not be less than $0.80h$ for prestressed members, inches. (For circular sections, $d$ need not be less than the distance from extreme compression fiber to centroid of tension reinforcement in opposite half of member.)

$f'_c$ = specified compressive strength of concrete, psi.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

$f_{ct}$ = average splitting tensile strength of lightweight aggregate concrete, psi.

$f_d$ = stress due to unfactored dead load, at extreme fiber of section where tensile stress is caused by externally applied loads, psi.

$f_{pc}$ = compressive stress in concrete (after allowance for all prestress losses) at centroid of cross section resisting externally applied loads or at junction of web and flange when the centroid lies within the flange, psi.



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(In a composite member, $f_{pc}$ is resultant compressive stress at centroid of composite section; or at junction of web and flange when the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone.)

$f_{pe}$ = compressive stress in concrete due to effective prestress forces only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads, psi.

$f_{pu}$ = specified tensile strength of prestressing tendons, psi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$h$ = overall thickness of member, inches.

$h_v$ = total depth of shearhead cross section, inches.

$h_w$ = total height of wall from base to top, inches.

$I$ = moment of inertia of section resisting externally applied factored loads.

$I_n$ = clear span measured face-to-face of supports.

$I_v$ = length of shearhead arm from centroid of concentrated load or reaction, inches.

$I_w$ = horizontal length of wall, inches.

$M_{cr}$ = moment causing flexural cracking at section due to externally applied loads. See Section 2611 (e) 2 A.

$M_m$ = modified moment.

$M_{max}$ = maximum factored moment at section due to externally applied loads.

$M_p$ = required plastic moment strength of shearhead cross section.

$M_u$ = factored moment at section.

$M_v$ = moment resistance contributed by shearhead reinforcement.

$N_u$ = factored axial load normal to cross section occurring simultaneously with $V_u$; to be taken as positive for compression, negative for tension, and to include effects of tension due to creep and shrinkage.

$N_{uc}$ = factored tensile force applied at top of bracket or corbel acting simultaneously with $V_{us}$ to be taken as positive for tension.

$s$ = spacing of shear or torsion reinforcement in direction parallel to longitudinal reinforcement, inches.

$s_1$ = spacing of vertical reinforcement in wall, inches.

$s_2$ = spacing of shear or torsion reinforcement in direction perpendicular to longitudinal reinforcement—or spacing of horizontal reinforcement in wall, inches.

$T_c$ = nominal torsional moment strength provided by concrete.

$T_n$ = nominal torsional moment strength.

$T_s$ = nominal torsional moment strength provided by torsion reinforcement. See Section 2611 (g) 9 A.

$T_u$ = factored torsional moment at section.

$V_c$ = nominal shear strength provided by concrete.



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$V_{ci}$ = nominal shear strength provided by concrete when diagonal cracking results from combined shear and moment.

$V_{cw}$ = nominal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web.

$V_d$ = shear force at section due to unfactored dead load.

$V_i$ = factored shear force at section due to externally applied loads occurring simultaneously with $M_{max}$.

$V_n$ = nominal shear strength.

$V_p$ = vertical component of effective prestress force at section.

$V_s$ = nominal shear strength provided by shear reinforcement.

$V_u$ = factored shear force at section.

$v_c$ = permissible shear stress carried by concrete, psi. See Section 2611 (m) 2 D.

$x$ = shorter overall dimension of rectangular part of cross section.

$y$ = longer overall dimension of rectangular part of cross section.

$\Sigma x^2 y$ = torsional section properties. See Sections 2611 (g) 1 A and 2611 (g) 1 B.

$x_1$ = shorter center-to-center dimension of closed rectangular stirrup.

$y_1$ = longer center-to-center dimension of closed rectangular stirrup.

$y_t$ = distance from centroidal axis of gross section, neglecting reinforcement, to extreme fiber in tension.

$\alpha$ = angle between included stirrups and longitudinal axis of member.

$\alpha_f$ = angle between shear-friction reinforcement and shear plane.

$\alpha_1$ = coefficient $y_1/x_1$. See Section 2611 (g) 9 A.

$\alpha_v$ = ratio of stiffness of shearhead arm to surrounding composite slab section. See Section 2611 (l) 4 E.

$\beta_c$ = ratio of long side to short side of concentrated load or reaction area.

$\mu$ = coefficient of friction. See Section 2611 (h) 6.

$\lambda$ = correction factor related to unit weight of concrete.

$\gamma_f$ = fraction of unbalanced moment transferred by flexure at slab-column connection. See Section 2613 (d) 4.

$\gamma_v$ = fraction of unbalanced moment transferred by eccentricity of shear at slab-column connections. See Section 2611 (m) 2 C.

$= 1 - \gamma_f$.

$\rho$ = ratio of nonprestressed tension reinforcement.

$= A_s/bd$.

$\rho_h$ = ratio of horizontal shear reinforcement area to gross concrete area of vertical section.

$\rho_n$ = ratio of vertical shear reinforcement area to gross concrete area of horizontal section.

$\rho_w = A_s/b_w d$.



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$\phi$ = strength reduction factor. See Section 2609 (d).

$\eta$ = number of identical arms of shearhead.

(b) **Shear Strength.** [11.1] 1. Design of cross sections subject to shear shall be based on

$$V_u \leq \phi V_n \quad \text{.....(11-1)}$$

where $V_u$ is factored shear force at section considered and $V_n$ is nominal shear strength computed by

$$V_n = V_c + V_s \quad \text{.....(11-2)}$$

where $V_c$ is nominal shear strength provided by concrete in accordance with Section 2611 (d) or Section 2611 (e), and $V_s$ is nominal shear strength provided by shear reinforcement in accordance with Section 2611 (f) 6. When determining $V_n$ the effect of openings shall be taken into consideration.

2. In determining shear strength $V_c$, whenever applicable, effects of axial tension due to creep and shrinkage in restrained members shall be considered and effects of inclined flexural compression in variable-depth members may be included.

3. Maximum factored shear force $V_u$ at supports may be computed in accordance with Section 2611 (b) 4 or 2611 (b) 5 when both of the following conditions are satisfied:

A. Support reaction, in direction of applied shear, introduces compression into the end regions of member, and

B. No concentrated load occurs between face of support and location of critical section defined in Sections 2611 (b) 4 and 2611 (b) 5.

4. For nonprestressed members, sections located less than a distance $d$ from face of support may be designed for the same shear $V_u$ as that computed at a distance $d$.

5. For prestressed members, sections located less than a distance $h/2$ from face of support may be designed for the same shear $V_u$ as that computed at a distance $h/2$.

6. For deep flexural members, brackets and corbels, walls and slabs and footings, the special provisions of Section 2611 (i) through (l) shall apply.

(c) **Lightweight Concrete.** [11.2] 1. Provisions for shear strength $V_c$ and torsional moment strength $T_c$ apply to normal-weight concrete. When lightweight aggregate concrete is used, one of the following modifications shall apply:

A. When $f_{ct}$ is specified and concrete is proportioned in accordance with Section 2604 (c), provisions for $V_c$ and $T_c$ shall be modified by substituting $f_{ct}/6.7$ for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ shall not exceed $\sqrt{f'_c}$.

B. When $f_{ct}$ is not specified, all values of $\sqrt{f'_c}$ affecting $V_c$, $T_c$ and $M_{cr}$ shall be



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multiplied by 0.75 for "all-lightweight" concrete and 0.85 for "sand-lightweight" concrete. Linear interpolation may be used when partial sand replacement is used.

(d) **Shear Strength Provided by Concrete for Nonprestressed Members.** [11.3] 1. Shear strength $V_c$ shall be computed by provisions of Section 2611 (d)1 A through D unless a more detailed calculation is made in accordance with Section 2611 (d) 2.

A. For members subject to shear and flexure only,

$$V_c = 2\sqrt{f'_c}\, b_w d \qquad (11\text{-}3)$$

B. For members subject to axial compression,

$$V_c = 2\left(1 + \frac{N_u}{2000 A_g}\right)\sqrt{f'_c}\, b_w d \qquad (11\text{-}4)$$

Quantity $N_u/A_g$ shall be expressed in psi.

C. For members subject to significant axial tension, shear reinforcement shall be designed to carry total shear.

D. At sections where factored torsional moment $T_u$ exceeds $\phi\,(0.5\sqrt{f'_c}\,\Sigma x^2 y)$,

$$V_c = \frac{2\sqrt{f'_c}\, b_w d}{\sqrt{\left[1 + \left(2.5 C_t \frac{T_u}{V_u}\right)^2\right]}} \qquad (11\text{-}5)$$

2. Shear strength $V_c$ may be computed by the more detailed calculation of Section 2611 (d) 2 A through C.

A. For members subject to shear and flexure only,

$$V_c = \left(1.9\sqrt{f'_c} + 2500\rho_w \frac{V_u d}{M_u}\right) b_w d \qquad (11\text{-}6)$$

but not greater than $3.5\sqrt{f'_c}\, b_w d$. Quantity $V_u d/M_u$ shall not be taken greater than 1.0 in computing $V_c$ by Formula (11-6), where $M_u$ is factored moment occurring simultaneously with $V_u$ at section considered.

B. For members subject to axial compression, Formula (11-6) may be used to compute $V_c$ with $M_m$ substituted for $M_u$ and $V_u d/M_u$ not then limited to 1.0, where

$$M_m = M_u - N_u \frac{(4h - d)}{8} \qquad (11\text{-}7)$$



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However, $V_c$ shall not be taken greater than

$$V_c = 3.5\sqrt{f'_c}b_w d\sqrt{1 + \frac{N_u}{500A_g}} \quad \text{(11-8)}$$

Quantity $N_u/A_g$ shall be expressed in psi. When $M_m$ as computed by Formula (11-7) is negative, $V_c$ shall be computed by Formula (11-8).

C. For members subject to significant axial tension,

$$V_c = 2\left(1 + \frac{N_u}{500A_g}\right)\sqrt{f'_c}b_w \quad \text{(11-9)}$$

where $N_u$ is negative for tension. Quantity $N_u/A_g$ shall be expressed in psi.

(e) **Shear Strength Provided by Concrete for Prestressed Members.** [11.4] 1. For members with effective prestress force not less than 40 percent of the tensile strength of flexural reinforcement, unless a more detailed calculation is made in accordance with Section 2611 (e) 2.

$$V_c = \left(0.6\sqrt{f'_c} + 700\frac{V_u d}{M_u}\right)b_w d \quad \text{(11-10)}$$

but $V_c$ need not be taken less than $2\sqrt{f'_c}b_w d$ nor shall $V_c$ be taken greater than $5\sqrt{f'_c}b_w d$ nor the value given in Section 2611 (e) 2 D. The quantity $V_u d/M_u$ shall not be taken greater than 1.0, where $M_u$ is factored moment occurring simultaneously with $V_u$ at section considered. When applying Formula (11-10), $d$ in the term $V_u d/M_u$ shall be the distance from extreme compression fiber to centroid of prestressed reinforcement.

2. Shear strength $V_c$ may be computed in accordance with Section 2611 (e) 2 A and B, where $V_c$ shall be the lesser of $V_{ci}$ or $V_{cw}$.

A. Shear strength $V_{ci}$ shall be computed by

$$V_{ci} = 0.6\sqrt{f'_c}b_w d + V_d + \frac{V_i M_{cr}}{M_{max}} \quad \text{(11-11)}$$

but $V_{ci}$ need not be taken less than $1.7\sqrt{f'_c}b_w d$, where

$$M_{cr} = (I/y_t)(6\sqrt{f'_c} + f_{pe} - f_d) \quad \text{(11-12)}$$

and values of $M_{max}$ and $V_i$ shall be computed from the load combination causing maximum moment to occur at the section.



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B. Shear strength $V_{cw}$ shall be computed by

$$V_{cw} = (3.5\sqrt{f'_c} + 0.3f_{pc})\,b_w d + V_p \quad \text{.....(11-13)}$$

Alternatively, $V_{cw}$ may be computed as the shear force corresponding to dead load plus live load that results in a principal tensile stress of $4\sqrt{f'_c}$ at centroidal axis of member, or at intersection of flange and web when centroidal axis is in the flange. In composite members, principal tensile stress shall be computed using the cross section that resists live load.

C. In Formulas (11-11) and (11-13), $d$ shall be the distance from extreme compression fiber to centroid of prestressed reinforcement or $0.8h$, whichever is greater.

D. In a pretensioned member in which the section at a distance $h/2$ from face of support is closer to end of member than the transfer length of the prestressing tendons, the reduced prestress shall be considered when computing $V_{cw}$. This value of $V_{cw}$ shall also be taken as the maximum limit for Formula (11-10). Prestress force may be assumed to vary linearly from zero at end of tendon to a maximum at a distance from end of tendon equal to the transfer length, assumed to be 50 diameters for strand and 100 diameters for single wire.

E. In a pretensioned member where bonding of some tendons does not extend to end of member, a reduced prestress shall be considered when computing $V_c$ in accordance with Section 2611 (e) 1 or 2611 (e) 2. Value of $V_{cw}$ calculated using the reduced prestress shall also be taken as the maximum limit for Formula (11-10). Prestress force due to tendons for which bonding does not extend to end of member may be assumed to vary linearly from zero at the point at which bonding commences to a maximum at a distance from this point equal to the transfer length, assumed to be 50 diameters for strand and 100 diameters for single wire.

(f) **Shear Strength Provided by Shear Reinforcement.** [11.5] 1. **Types of shear reinforcement.** A. Shear reinforcement may consist of:

(i) Stirrups perpendicular to axis of member.

(ii) Welded wire fabric with wires located perpendicular to axis of member.

B. For nonprestressed members, shear reinforcement may also consist of:

(i) Stirrups making an angle of 45 degrees or more with longitudinal tension reinforcement.

(ii) Longitudinal reinforcement with bent portion making an angle of 30 degrees or more with the longitudinal tension reinforcement.

(iii) Combination of stirrups and bent longitudinal reinforcement.

(iv) Spirals.

2. Design yield strength of shear reinforcement shall not exceed 60,000 psi.

3. Stirrups and other bars or wires used as shear reinforcement shall extend to a distance $d$ from extreme compression fiber and shall be anchored at both ends according to Section 2612 (n) to develop the design yield strength of reinforcement.



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4. **Spacing limits for shear reinforcement.** A. Spacing of shear reinforcement placed perpendicular to axis of member shall not exeeed $d/2$ in nonprestressed members and $(3/4)h$ in prestressed members nor 24 inches.

B. Inclined stirrups and bent longitudinal reinforcement shall be so spaced that every 45-degree line, extending toward the reaction from middepth of member $d/2$ to longitudinal tension reinforcement, shall be crossed by at least one line of shear reinforcement.

C. When $V_s$ exceeds $4\sqrt{f'_c}b_w d$, maximum spaeings given in Seetion 2611 (f) 4 A and B shall be redueed by one half.

5. **Minimum shear reinforcement.** A. A minimum area of shear reinforcement shall be provided in all reinforced concrete flexural members (prestressed and nonprestressed) where factored shear force $V_u$ exceeds one half the shear strength provided by concrete $\phi V_c$, except:

(i) Slabs and footings.

(ii) Concrete joist construction defined by Section 2608 (1).

(iii) Beams with total depth not greater than 10 inches, two and one half times thickness of flange or one-half the width of web, whichever is greater.

B. Minimum shear reinforeement requirements of Section 2611 (f) 5 A may be waived if shown by test that required nominal flexural and shear strengths can be developed when shear reinforcement is omitted. Such tests shall simulate effects of differential settlement, creep, shrinkage and temperature change, based on a realistic assessment of such effects occurring in service.

C. Where shear reinforcement is required by Section 2611 (f) 5 A or by analysis, and where factored torsional moment $T_u$ does not exceed $\phi(0.5\sqrt{f'_c}\Sigma x^2 y)$, minimum area of shear reinforcement for prestressed [except as provided in Seetion 2611 (f) 5 D] and nonprestressed members shall be computed by

$$A_v = 50\frac{b_w s}{f_y} \qquad (11\text{-}14)$$

where $b_w$ and $s$ are in inches.

D. For prestressed members with effective prestress force not less than 40 percent of the tensile strength of flexural reinforcement, the area of shear reinforcement shall be not less than the smaller $A_v$, computed by Formula (11-14) or (11-15).

$$A_v = \frac{A_{ps}}{80}\cdot\frac{f_{pu}}{f_y}\cdot\frac{s}{d}\sqrt{\frac{d}{b_w}} \qquad (11\text{-}15)$$

E. Where factored torsional moment $T_u$ exceeds $\phi(0.5\sqrt{f'_c}\Sigma x^2 y)$, and where web reinforcement is required by Section 2611 (f) 5 A or by analysis, minimum area of closed stirrups shall be computed by

$$A_v + 2A_t = 50\frac{b_w s}{f_y} \qquad (11\text{-}16)$$



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6. **Design of shear reinforcement.** A. Where factored shear force $V_u$ exceeds shear strength $\phi V_c$, shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength $V_s$ shall be computed in accordance with Section 2611 (f) 6 B through H.

B. When shear reinforcement perpendicular to axis of member is used,

$$V_s = \frac{A_v f_y d}{s} \quad \text{(11-17)}$$

where $A_v$ is the area of shear reinforcement within a distance $s$.

C. When inclined stirrups are used as shear reinforcement,

$$V_s = \frac{A_v f_y (\sin \alpha + \cos \alpha) d}{s} \quad \text{(11-18)}$$

D. When shear reinforcement consists of a single bar or a single group of parallel bars, all bent up at the same distance from the support,

$$V_s = A_v f_y \sin \alpha \quad \text{(11-19)}$$

but not greater than $3\sqrt{f'_c} b_w d$.

E. When shear reinforcement consists of a series of parallel bent-up bars or groups of parallel bent-up bars at different distances from the support, shear strength $V_s$ shall be computed by Formula (11-18).

F. Only the center three fourths of the inclined portion of any longitudinal bent bar shall be considered effective for shear reinforcement.

G. Where more than one type of shear reinforcement is used to reinforce the same portion of a member, shear strength $V_s$ shall be computed as the sum of the $V_s$ values computed for the various types.

H. Shear strength $V_s$ shall not be taken greater than $8\sqrt{f'_c} b_w d$.

(g) **Combined Shear and Torsion Strength for Nonprestressed Members with Rectangular or Flanged Sections.** [11.6] 1. Torsion effects shall be included with shear and flexure where factored torsional moment $T_u$ exceeds $\phi(0.5\sqrt{f'_c}\Sigma x^2 y)$. Otherwise, torsion effects may be neglected.

A. For members with rectangular or flanged sections, the sum $\Sigma x^2 y$ shall be taken for the component rectangles of the section, but the overhanging flange width used in design shall not exceed three times the flange thickness.

B. A rectangular box section may be taken as a solid section, provided wall thickness $h$ is at least $x/4$. A box section with wall thickness less than $x/4$ but greater than $x/10$ may also be taken as a solid section, except that $\Sigma x^2 y$ shall be multiplied by $4h/x$. When $h$ is less than $x/10$, stiffness of wall shall be considered. Fillets shall be provided at interior corners of all box sections.



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2. If the factored torsional moment $T_u$ in a member is required to maintain equilibrium, the member shall be designed to carry that torsional moment in accordance with Section 2611 (g) 4 through 10.

3. In a statically indeterminate structure where reduction of torsional moment in a member can occur due to redistribution of internal forces, maximum factored torsional moment $T_u$ may be reduced to $\phi(4\sqrt{f'_c}\Sigma x^2y/3)$.

A. In such a case the correspondingly adjusted moments and shears in adjoining members shall be used in design.

B. In lieu of more exact analysis, torsional loading from a slab shall be taken as uniformly distributed along the member.

4. Sections located less than a distance $d$ from face of support may be designed for the same torsional moment $T_u$ as that computed at a distance $d$.

5. **Torsional moment strength.** Design of cross sections subject to torsion shall be based on

$$T_u \leq \phi T_n \quad \text{.....(11-20)}$$

Where $T_u$ is factored torsional moment at section considered and $T_n$ is nominal torsional moment strength computed by

$$T_n = T_c + T_s \quad \text{.....(11-21)}$$

where $T_c$ is nominal torsional moment strength provided by concrete in accordance with Section 2611 (g) 6 and $T_s$ is nominal torsional moment strength provided by torsion reinforcement in accordance with Section 2611 (g) 9.

6. **Torsional moment strength provided by concrete.** A. Torsional moment strength $T_c$ shall be computed by

$$T_c = \frac{0.8\sqrt{f'_c}\Sigma x^2y}{\sqrt{1 + \left(\frac{0.4V_u}{C_tT_u}\right)^2}} \quad \text{.....(11-22)}$$

B. For members subject to significant axial tension, torsion reinforcement shall be designed to carry the total torsional moment, unless a more detailed calculation is made in which $T_c$ is given by Formula (11-22) and $V_c$ given by Formula (11-5) shall be multiplied by $(1 + N_u/500A_g)$, where $N_u$ is negative for tension.

7. **Torsion reinforcement requirements.** A. Torsion reinforcement, where required, shall be provided in addition to reinforcement required to resist shear, flexure and axial forces.

B. Reinforcement required for torsion may be combined with that required for other forces, provided the area furnished is the sum of individually required areas and the most restrictive requirements for spacing and placement are met.

C. Torsion reinforcement shall consist of closed stirrups, closed ties or spirals, combined with longitudinal bars.



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D: Design yield strength of torsion reinforcement shall not exceed 60,000 psi.

E. Stirrups and other bars and wires used as torsion reinforcement shall extend to a distance $d$ from extreme compression fiber and shall be anchored according to Section 2612 (n) to develop the design yield strength of reinforcement.

F. Torsion reinforcement shall be provided at least a distance $(d + b)$ beyond the point theoretically required.

8. **Spacing limits for torsion reinforcement.** A. Spacing of closed stirrups shall not exceed the smaller of $(x_1 + y_1)/4$ or 12 inches.

B. Spacing of longitudinal bars, not less than No. 3, distributed around the perimeter of the closed stirrups, shall not exceed 12 inches. At least one longitudinal bar shall be placed in each corner of the closed stirrups.

9. **Design of torsion reinforcement.** A. Where factored torsional moment $T_u$ exceeds torsional moment strength $\phi T_c$, torsion reinforcement shall be provided to satisfy Formulas (11-20) and (11-21), where torsional moment strength $T_s$ shall be computed by

$$T_s = \frac{A_t \alpha_t x_1 y_1 f_y}{s} \qquad (11\text{-}23)$$

where $A_t$ is the area of one leg of a closed stirrup resisting torsion within a distance $s$, and $\alpha_t = [0.66 + 0.33\ (y_1/x_1)]$ but not more than 1.50. Longitudinal bars distributed around the perimeter of the closed stirrups $A_t$ shall be provided in accordance with Section 2611 (g) 9 C.

B. A minimum area of closed stirrups shall be provided in accordance with Section 2611 (f) 5 E.

C. Required area of longitudinal bars $A_l$ distributed around the perimeter of the closed stirrups $A_t$ shall be computed by

$$A_l = 2A_t \left( \frac{x_1 + y_1}{s} \right) \qquad (11\text{-}24)$$

or by

$$A_l = \left[ \frac{400xs}{f_y} \left( \frac{T_u}{T_u + \dfrac{V_u}{3C_t}} \right) - 2A_t \right] \left( \frac{x_1 + y_1}{s} \right) \qquad (11\text{-}25)$$

whichever is greater. Value of $A_l$ computed by Formula (11-25) need not exceed that obtained by substituting

$$\frac{50b_w s}{f_y} \text{ for } 2A_t$$



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D. Torsional moment strength $T_s$ shall not exceed $4T_c$.

(h) **Shear Friction.** [11.7] 1. Provisions of Section 2611 (h) shall be applied where it is appropriate to consider shear transfer across a given plane, such as an existing or potential crack, an interface between dissimilar materials, or an interface between two concretes cast at different times.

2. Design of cross sections subject to shear transfer as described in Section 2611 (h) 1 shall be based on Formula (11-1) where $V_n$ is calculated in accordance with provisions of Section 2611 (h) 3 or 2611 (h) 4.

3. A crack shall be assumed to occur along the shear plane considered. Required area of shear-friction reinforcement $A_{vf}$ across the shear plane may be designed using either Section 2611 (h) 4 or any other shear transfer design methods that result in prediction of strength in substantial agreement with results of comprehensive tests. Provisions of Sections 2611 (h) 5 through 2611 (h) 10 shall apply for all calculations of shear transfer strength.

4. Shear-friction design methods shall comply with the following:

A. When shear-friction reinforcement is perpendicular to shear plane, shear strength $V_n$ shall be computed by

$$V_n = A_{vf} f_y \mu \quad \text{.....(11-26)}$$

where $\mu$ is coefficient of friction in accordance with Section 2611 (h) 4 C.

B. When shear-friction reinforcement is inclined to shear plane such that the shear force produces tension in shear-friction reinforcement, shear strength $V_n$ shall be computed by

$$V_n = A_{vf} f_y (\mu \sin \alpha_1 + \cos \alpha_1) \quad \text{.....(11-27)}$$

where $\alpha_1$ is angle between shear-friction reinforcement and shear plane.

C. Coefficient of friction $\mu$ in Formula (11-26) and Formula (11-27) shall be

| | |
|---|---|
| Concrete placed monolithically | $1.4\lambda$ |
| Concrete placed against hardened concrete with surface intentionally roughened as specified in Section 2611 (h) 9 | $1.0\lambda$ |
| Concrete placed against hardened concrete not intentionally roughened | $0.6\lambda$ |
| Concrete anchored to as-rolled structural steel by headed studs or by reinforcing bars [see Section 2611 (h) 10] | $0.7\lambda$ |

where $\lambda = 1.0$ for normal-weight concrete, 0.85 for "sand-lightweight" concrete and 0.75 for "all-lightweight" concrete. Linear interpolation may be applied when partial sand replacement is used.



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5. Shear strength $V_n$ shall not be taken greater than $0.2f'_cA_c$ nor 800 $A_c$ in pounds, where $A_c$ is area of concrete section resisting shear transfer.

6. Design yield strength of shear-friction reinforcement shall not exceed 60,000 psi.

7. Net tension across shear plane shall be resisted by additional reinforcement. Permanent net compression across shear plane may be taken as additive to the force in the shear-friction reinforcement $A_{vf}f_y$ when calculating required $A_{vf}$.

8. Shear-friction reinforcement shall be appropriately placed along the shear plane and shall be anchored to develop the specified yield strength on both sides by embedment, hooks or welding to special devices.

9. For the purpose of Section 2611 (h), when concrete is placed against previously hardened concrete, the interface for shear transfer shall be clean and free of laitance. If $\mu$ is assumed equal to $1.0\lambda$, interface shall be roughened to a full amplitude of approximately 1/4 inch.

10. When shear is transferred between as-rolled steel and concrete using headed studs or welded reinforcing bars, steel shall be clean and free of paint.

(i) **Special Provisions for Deep Flexural Members.** [11.8] Provisions of this section shall apply for members with $l_n/d$ less than 5 that are loaded on one face and supported on the opposite face so that the compression struts can develop between the loads and the supports. See also Section 2612 (k) 6.

1. The design of simple supported deep flexural members for shear shall be based on Formulas (11-1) and (11-2), where shear strength $V_c$ shall be in accordance with Section 2611 (i) 5 or 2611 (i) 6, and shear strength $V_s$ shall be in accordance with Section 2611 (i) 7.

2. The design of continuous deep flexural members for shear shall be based on Section 2611 (b) through 2611 (f), or on methods satisfying equilibrium and strength requirements. In either case the design shall also satisfy Section 2611 (i) 3, 2611 (i) 8 and 2611 (i) 9.

3. Shear strength $V_n$ for deep flexural members shall not be taken greater than $8\sqrt{f'_c}b_wd$ when $l_n/d$ is less than 2. When $l_n/d$ is between 2 and 5,

$$V_n = \frac{2}{3}\left(10 + \frac{l_n}{d}\right)\sqrt{f'_c}b_wd \qquad (11\text{-}28)$$

4. Critical section for shear measured from face of support shall be taken at a distance $0.15l_n$ for uniformly loaded beams and $0.50a$ for beams with concentrated loads, but not greater than $d$.

5. Unless a more detailed calculation is made in accordance with Section 2611 (i) 6,

$$V_c = 2\sqrt{f'_c}b_wd \qquad (11\text{-}29)$$



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6. Shear strength $V_c$ may be computed by

$$V_c = \left(3.5 - 2.5\frac{M_u}{V_u d}\right)\left(1.9\sqrt{f'_c} + 2500\rho_w \frac{V_u d}{M_u}\right) b_w d \quad \ldots\ldots(11\text{-}30)$$

except that the term

$$\left(3.5 - 2.5\frac{M_u}{V_u d}\right)$$

shall not exceed 2.5, and $V_c$ shall not be taken greater than $6\sqrt{f'_c}\,b_w d$. $M_u$ is factored moment occurring simultaneously with $V_u$ at the critical section defined in Section 2611 (i) 4.

7. Where factored shear force $V_u$ exceeds shear strength $\phi V_c$, shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength $V_s$ shall be computed by

$$V_s = \left[\frac{A_v}{s}\left(\frac{1 + \frac{l_n}{d}}{12}\right) + \frac{A_{vh}}{s_2}\left(\frac{11 - \frac{l_n}{d}}{12}\right)\right] f_y d \quad \ldots\ldots(11\text{-}31)$$

where $A_v$ is area of shear reinforcement perpendicular to flexural tension reinforcement within a distance $s$, and $A_{vh}$ is area of shear reinforcement parallel to flexural reinforcement within a distance $s_2$.

8. Area of shear reinforcement $A_v$ shall be not less than $0.0015\, b_w s$, and $s$ shall not exceed $d/5$ nor 18 inches.

9. Area of horizontal shear reinforcement $A_{vh}$ shall be not less than $0.0025\, b_w s_2$, and $s_2$ shall not exceed $d/3$ nor 18 inches.

10. Shear reinforcement required at the critical section defined in Section 2611 (i) 4 shall be used throughout the span.

(j) **Special Provisions for Brackets and Corbels.** [11.9] Provisions of Section 2611 (j) shall apply to brackets and corbels with a shear span-to-depth ratio $a/d$ not greater than unity, and subject to a horizontal tensile force $N_{uc}$ not larger than $V_u$. Distance $d$ shall be measured at face of support.

2. Depth at outside edge of bearing area shall not be less than $0.5d$.

3. Section at face of support shall be designed to resist simultaneously a shear $V_u$, a moment $[V_u a + N_{uc}(h\text{-}d)]$, and a horizontal tensile force $N_{uc}$.

A. In all design calculations in accordance with Section 2611 (j), strength reduction factor $\phi$ shall be taken equal to 0.85.

B. Design of shear-friction reinforcement $A_{vf}$ to resist shear $V_u$ shall be in accordance with Section 2611 (h).



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For normal-weight concrete, shear strength $V_n$ shall not be taken greater than $0.2f'_c b_w d$ nor 800 $b_w d$ in pounds. For "all lightweight" or "sand-lightweight" concrete, shear strength $V_n$ shall not be taken greater than $(0.2 = 0.07\ a/d) f'_c b_w d$ nor $(800 - 280\ a/d)\ b_w d$ in pounds.

C. Reinforcement $A_f$ to resist moment $[V_u a + N_{uc}\ (h-d)]$ shall be computed in accordance with Sections 2610 (c) and 2610 (d).

D. Reinforcement $A_n$ to resist tensile force $N_{uc}$ shall be determined from $N_{uc} \leq \phi A_n f_y$. Tensile force $N_{uc}$ shall not be taken less than 0.2 $V_u$ unless special provisions are made to avoid tensile forces. Tensile force $N_{uc}$ shall be regarded as a live load even when tension results from creep, shrinkage or temperature change.

E. Area of primary tension reinforcement $A_s$ shall be made equal to the greater of $(A_f + A_n)$ or $(2A_{vf}/3 + A_n)$.

4. Closed stirrups or ties parallel to $A_s$, with a total area $A_h$ not less than 0.5 $(A_s - A_n)$, shall be uniformly distributed within two thirds of the effective depth adjacent to $A_s$.

5. Ratio $\rho = A_s/bd$ shall not be less than $0.04\ (f'_c/f_y)$.

6. At front face of bracket or corbel, primary tension reinforcement $A_s$ shall be anchored by one of the following: (1) by a structural weld to a transverse bar of at least equal size; weld to be designed to develop specified yield strength $f_y$ of $A_s$ bars; (2) by bending primary tension bars $A_s$ back to form a horizontal loop; or (3) by some other means of positive anchorage.

7. Bearing area of load on bracket or corbel shall not project beyond straight portion of primary tension bar $A_s$, nor project beyond interior face of transverse anchor bar (if one is provided).

(k) **Special Provisions for Walls.** [11.10] 1. Design for shear forces perpendicular to face of wall shall be in accordance with provisions for slabs in Section 2611 (l). Design for horizontal shear forces in plane of wall shall be in accordance with Section 2611 (k) 2 through 8.

2. Design of horizontal section for shear in plane of wall shall be based on Formulas (11-1) and (11-2), where shear strength $V_c$ shall be in accordance with Section 2611 (k) 5 or 2611 (k) 6 and shear strength $V_s$ shall be in accordance with Section 2611 (k) 9.

3. Shear strength $V_n$ at any horizontal section for shear in plane of wall shall not be taken greater than $10\sqrt{f'_c}hd$.

4. For design for horizontal shear forces in plane of wall, $d$ shall be taken equal to $0.8\ l_w$. A larger value of $d$, equal to the distance from extreme compression fiber to center of force of all reinforcement in tension may be used when determined by a strain compatibility analysis.

5. Unless a more detailed calculation is made in accordance with Section 2611 (k) 6, shear strength $V_c$ shall not be taken greater than $2\sqrt{f'_c}hd$ for walls subject to $N_u$ in compression, or $V_c$ shall not be taken greater than the value given in Section 2611 (d) 2 C for walls subject to $N_u$ in tension.

6. Shear strength $V_c$ may be computed by *Formulas* (11-32) and (11-33), where $V_c$ shall be the lesser of *Formula* (11-32) or (11-33).



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$$V_c = 3.3\sqrt{f'_c}hd + \frac{N_u d}{4l_w} \quad \text{(11-32)}$$

or

$$V_c = \left[0.6\sqrt{f'_c} + \frac{l_w\left(1.25\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd \quad \text{(11-33)}$$

where $N_u$ is negative for tension. When $(M_u/V_u - l_w/2)$ is negative, Formula (11-33) shall not apply.

7. Sections located closer to wall base than a distance $l_w/2$ or one half the wall height, whichever is less, may be designed for the same $V_c$ as that computed at a distance $l_w/2$ or one half the height.

8. When factored shear force $V_u$ is less than $\phi V_c/2$, reinforcement shall be provided in accordance with Section 2611 (k) 9 or in accordance with Section 2614. When $V_u$ exceeds $\phi V_c/2$, wall reinforcement for resisting shear shall be provided in accordance with Section 2611 (k) 9.

9. **Design of shear reinforcement for walls.** A. Where factored shear force $V_u$ exceeds shear strength $\phi V_c$, horizontal shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength $V_s$ shall be computed by

$$V_s = \frac{A_v f_y d}{s_2} \quad \text{(11-34)}$$

where $A_v$ is area of horizontal shear reinforcement within a distance $s_2$ and distance $d$ is in accordance with Section 2611 (k) 4. Vertical shear reinforcement shall be provided in accordance with Section 2611 (k) 9 D.

B. Ratio $\rho_h$ of horizontal shear reinforcement area to gross concrete area of vertical section shall be not less than 0.0025.

C. Spacing of horizontal shear reinforcement $s_2$ shall not exceed $l_w/5$, $3h$ nor 18 inches.

D. Ratio $\rho_n$ of vertical shear reinforcement area to gross concrete area of horizontal section shall be not less than

$$\rho_n = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_h - 0.0025) \quad \text{(11-35)}$$

nor 0.0025, but need not be greater than the required horizontal shear reinforcement.

E. Spacing of vertical shear reinforcement $s_1$ shall not exceed $l_w/3$, $3h$ nor 18 inches.



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(l) **Special Provisions for Slabs and Footings.** [11.11] 1. Shear strength of slabs and footings in the vicinity of concentrated loads or reactions is governed by the more severe of two conditions:

A. Beam action for slab or footing, with a critical section extending in a plane across the entire width and located at a distance $d$ from face of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Section 2611 (b) through (f).

B. Two-way action for slab or footing, with a critical section perpendicular to plane of slab and located so that its perimeter $b_o$ is a minimum, but need not approach closer than $d/2$ to perimeter of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Section 2611 (l) 2 through 4.

2. Design of slab or footing for two-way action shall be based on Formula (11-1), where shear strength $V_n$ shall not be taken greater than shear strength $V_c$, computed in accordance with Sections 2611 (l) 2 A or 2611 (l) 2 B unless shear reinforcement is provided in accordance with Section 2611 (l) 3 or 4.

A. For nonprestressed slabs and footings:

$$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\,b_o d \qquad (11\text{-}36)$$

but not greater than $4\sqrt{f'_c}\,b_o d$. $\beta_c$ is the ratio of long side to short side of concentrated load or reaction area and $b_o$ is perimeter of critical section defined in Section 2611 (l) 2.

B. At columns of two-way prestressed slabs and footings that meet requirements of Section 2618 (j) 3:

$$V_c = (3.5\sqrt{f'_c} + 0.3f_{pc})b_o d + V_p \qquad (11\text{-}37)$$

where $b_o$ is perimeter of critical section defined in Section 2611 (l) 1 B, $f_{pc}$ is average value of $f_{pc}$ for the two directions, and $V_p$ is vertical component of all effective prestress forces crossing the critical section. If shear strength is computed by Formula (11-37), the following shall be satisfied; otherwise, Formula (11-36) shall apply:

(i) No portion of column cross section shall be closer to a discontinuous edge than 4 times the slab thickness, and

(ii) $f'_c$ in Formula (11-37) shall not be taken greater than 5000 psi, and

(iii) $f_{pc}$ in each direction shall not be less than 125 psi nor be taken greater than 500 psi.

3. Shear reinforcement consisting of bars or wires may be used in slabs and footings in accordance with the following provisions:

A. Shear strength $V_n$ shall be computed by Formula (11-2), where shear strength $V_c$ shall be in accordance with Section 2611 (l) 3 D, and shear strength $V_s$ shall be in accordance with Section 2611 (l) 3 E.



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B. Shear strength $V_n$ shall not be taken greater than $6\sqrt{f'_c}\,b_o d$, where $b_o$ is perimeter of critical section defined in Section 2611 (l) 3 C.

C. Shear strength shall be investigated at the critical section defined in Section 2611 (l) 1 B and at successive sections more distance from the support.

D. Shear strength $V_c$ at any section shall not be taken greater than $2\sqrt{f'_c}\,b_o d$, where $b_o$ is perimeter of critical section defined in Section 2611 (l) 3 C.

E. Where factored shear force $V_u$ exceeds shear strength $\phi V_c$ as given in Section 2611 (l) 3 D, required area $A_v$ and shear strength $V_s$ of shear reinforcement shall be calculated in accordance with Section 2611 (f) and anchored in accordance with Section 2612 (n).

4. Shear reinforcement consisting of steel I- or channel-shaped sections (shearheads) may be used in slabs. Provisions of Sections 2611 (l) 4 A through 2611 (l) 4 J shall apply where shear due to gravity load is transferred at interior column supports. Where moment is transferred to columns, Section 2611 (m) 2 E shall apply.

A. Each shearhead shall consist of steel shapes fabricated by welding with a full penetration weld into identical arms at right angles. Shearhead arms shall not be interrupted within the column sections.

B. Shearhead shall not be deeper than 70 times the web thickness of the steel shape.

C. Ends of each shearhead arm may be cut at angles not less than 30 degrees with the horizontal, provided the plastic moment strength of the remaining tapered section is adequate to resist the shear force attributed to that arm of the shearhead.

D. All compression flanges of steel shapes shall be located with $0.3d$ of compression surface of slab.

E. Ratio $\alpha_v$ between the stiffness for each shearhead arm and that for surrounding composite cracked slab section of width $(c_2 + d)$ shall be not less than 0.15.

F. Plastic moment strength $M_p$ required for each arm of the shearhead shall be computed by

$$\phi M_p = \frac{V_u}{2\eta}\left[h_v + \alpha_v\left(l_v - \frac{c_1}{2}\right)\right] \qquad (11\text{-}38)$$

where $\phi$ is strength reduction factor for flexure, $\eta$ is number of arms, and $l_v$ is minimum length of each shearhead arm required to comply with requirements of Sections 2611 (l) 4 G and 2611 (l) 4 H.

G. Critical slab section for shear shall be perpendicular to plane of slab and shall cross each shearhead arm three fourths the distance $[l_v - (c_1/2)]$ from column face to end of shearhead arm. Critical section shall be located so that its perimeter $b_o$ is a minimum, but need not approach closer than $d/2$ to perimeter of column section.

H. Shear strength $V_n$ shall not be taken greater than $4\sqrt{f'_c}\,b_o d$, on the critical section defined in Section 2611 (l) 4 G. When shearhead reinforcement is



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provided; shear strength $V_n$ shall not be taken greater than $7\sqrt{f'_c}\,b_o d$ on the critical section defined in Section 2611 (l) 1 B.

I. A shearhead may be assumed to contribute a moment resistance $M_v$ to each slab column strip computed by

$$M_v = \frac{\phi\alpha_r V_u}{2\eta}\left(l_v - \frac{c_1}{2}\right) \qquad (11\text{-}39)$$

where $\phi$ is the strength reduction factor for flexure, $\eta$ is the number of arms and $l_v$ is the length of each shearhead arm actually provided. However, $M_v$ shall not be taken larger than the smaller of:

(i) Thirty percent of total factored moment required for each slab column strip.

(ii) Change in column strip moment over length $l_v$.

(iii) Value of $M_p$ computed by Formula (11-38).

J. When unbalanced moments are considered, shearhead must have adequate anchorage to transmit $M_p$ to column.

5. **Openings in slabs.** When openings in slabs are located at a distance less than 10 times the slab thickness from a concentrated load or reaction area, or when openings in flat slabs are located within column strips as defined in Section 2613, the critical slab section for shear defined in Sections 2611 (l) 1 B and 2611 (l) 4 G shall be modified as follows:

A. For slabs without shearheads, that part of the perimeter of the critical section that is enclosed by straight lines, projecting from the centroid of the load or reaction area and tangent to the boundaries of the openings, shall be considered ineffective.

B. For slabs with shearheads, the ineffective portion of the perimeter shall be one half of that defined in A.

(m) **Transfer of Moments to Columns.** [11.12] 1. **General.** A. When gravity load, wind, earthquake or other lateral forces cause transfer of moment at connections of framing elements to columns, shear resulting from moment transfer shall be considered in design of lateral reinforcement in columns.

B. Lateral reinforcement not less than that required by Formula (11-14) shall be provided within connections of framing elements to columns, except for connections not part of a primary seismic load-resisting system that are restrained on four sides by beams or slabs of approximately equal depth.

2. **Special provisions for slabs.** A. When gravity load, wind, earthquake or other lateral forces cause transfer of moment between slab and column, a fraction of the unbalanced moment shall be transferred by eccentricity of shear in accordance with Section 2611 (m) 2 C and D.

B. Fraction of unbalanced moment not transferred by eccentricity of shear shall be transferred by flexure in accordance with Section 2613 (d) 4.

C. A fraction of the unbalanced moment given by $\gamma_v M_u$ shall be considered to



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be transferred by eccentricity of shear about the centroid of the critical section defined by 2611 (l) 1 B where $M_u$ is the moment to be transferred and

$$\gamma_v = 1 - \frac{1}{1 + 2/3\sqrt{b_1/b_2}} \quad \text{.....(11-40)}$$

D. Shear stresses resulting from moment transfer by eccentricity of shear shall be assumed to vary linearly about centroid of critical section defined in Section *2611 (m) 2 C*. Maximum shear stress due to factored shear forces and moments shall not exceed $V_c$ computed in accordance with Formulas (11-41) or (11-42).

(i) For nonprestressed slabs:

$$v_c = \phi(2 + \frac{4}{\beta_c})\sqrt{f'_c} \quad \text{.....(11-41)}$$

but not greater than $\phi 4\sqrt{f'_c}$.

(ii) At columns of two-way prestressed slabs that meet requirements of Section *2618 (j) 3:*

$$v_c = \phi(3.5\sqrt{f'_c} + 0.3f_{pc} + v_p/b_o d) \quad \text{.....(11-42)}$$

$b_o$ is perimeter of critical section defined in Section 2611 (l) 1 B and $V_p$ is vertical component of all effective prestress forces crossing the critical section. If permissible shear stress is computed by Formula (11-42), the following shall be satisfied; otherwise, Formula (11-41) shall apply:

(1) $f'_c$ in Formula (11-42) shall not be taken greater than 5000 psi, and

(2) $f_{pc}$ in each direction shall not be less than 125 psi, nor be taken greater than 500 psi.

E. When shear reinforcement consisting of steel I- or channel-shaped sections (shearheads) is provided, the sum of shear stresses due to vertical load acting on the critical section defined by Section 2611 (l) 4 G and moment transferred by eccentricity of shear about centroid of the critical section defined in Section 2611 (l) 1 B shall not exceed $\phi 4\sqrt{f'_c}$.

## Development and Splices of Reinforcement [Chapter 12]

**Sec. 2612.** (a) **Notations.** [12.0]

$a$ = depth of equivalent rectangular stress block as defined in Section 2610 (c) 7.

$A_b$ = area of an individual bar, square inches.

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A_v$ = area of shear reinforcement within a distance $s$, square inches.

$A_w$ = area of an individual wire to be developed or spliced, square inches.

$b_w$ = web width, or diameter of circular section, inches.



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$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$d_b$ = nominal diameter of bar, wire or prestressing strand, inches.

$f'_c$ = specified compressive strength of concrete, psi.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

$f_{ct}$ = average splitting tensile strength of lightweight aggregate concrete, psi.

$f_{ps}$ = stress in prestressed reinforcement at nominal strength, ksi.

$f_{se}$ = effective stress in prestressed reinforcement (after allowance for all prestress losses), ksi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$h$ = overall thickness of member, inches.

$l_a$ = additional embedment length at support or at point of inflection, inches.

$l_d$ = development length, inches.

= $l_{db}$ × applicable modification factors.

$l_{db}$ = basic development length, inches.

$l_{dh}$ = development length of standard hook in tension, measured from critical section to outside end of hook [straight embedment length between critical section and start of hook (point of tangency) plus radius of bend and one bar diameter], inches.

= $l_{hb}$ × applicable modification factors.

$l_{hb}$ = basic development length of standard hook in tension, inches.

$M_n$ = nominal moment strength at section, inch-pounds.

$= A_s f_y (d - a/2)$.

$s$ = spacing of stirrups or ties, inches.

$s_w$ = spacing of wire to be developed or spliced, inches.

$V_u$ = factored shear force at section.

$\beta_b$ = ratio of area of reinforcement cut off to total area of tension reinforcement at section.

(b) **Development of Reinforcement—General.** [12.1] Calculated tension or compression in reinforcement at each section of reinforced concrete members shall be developed on each side of that section by embedment length, hook or mechanical device, or a combination thereof. Hooks may be used in developing bars in tension only.

(c) **Development of Deformed Bars and Deformed Wire in Tension.** [12.2] Development length $l_d$, in inches, for deformed bars and deformed wire in tension shall be computed as the product of the basic development length and the applicable modification factor or factors as defined in this section, but $l_d$ shall be not less than *12 inches except in computation of lap splices by Section 2612 (p) and development of web reinforcement by Section 2612 (n).*



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Basic development length shall be:

No. 11 bar and smaller ..... $0.04A_b f_y/\sqrt{f'_c}$*

but not less than ..... $0.0004 d_b f_y$†

No. 14 bar ..... $0.085 f_y/\sqrt{f'_c}$‡

No. 18 bar ..... $0.11 f_y/\sqrt{f'_c}$‡

Deformed wire ..... $0.03 d_b f_y/\sqrt{f'_c}$

*Constant carries the unit of 1/inch.

†Constant carries the unit of inch2/pound.

‡Constant carries the unit of inch.

Basic development length shall be multiplied by applicable factor or factors for:

Top reinforcement§ ..... 1.4

Reinforcement with $f_y$ greater than 60,000 psi ..... $2 - \frac{60{,}000}{f_y}$

Lightweight aggregate concrete.

When $f_{ct}$ is specified and concrete is proportioned in accordance with Section 2604 (c) ..... $6.7\sqrt{f'_c}/f_{ct}$ but not less than 1.0

When $f_{ct}$ is not specified

"all-lightweight" concrete ..... 1.33

"sand-lightweight" concrete ..... 1.18

Linear interpolation may be applied when partial sand replacement is used.

Basic development length, modified by appropriate factors *for lightweight aggregate concrete noted above,* may be multiplied by applicable factor or factors for:

Reinforcement being developed in length under consideration and spaced laterally at least 6 inches on center with at least 3 inches clear from face of member to edge bar, measured in direction of spacing ..... 0.8

Reinforcement in a flexural member in excess of that required by analysis ..... $(A_s \text{ required})/(A_s \text{ provided})$

Reinforcement enclosed within spiral reinforcement not less than 1/4-inch diameter and not more than 4-inch pitch ..... 0.75

(d) **Development of Deformed Bars in Compression.** [12:3] Development length $l_d$, in inches, for deformed bars in compression shall be computed as the product of the basic development length and applicable modification factors as defined in this section, but $l_d$ shall be not less than 8 inches.

§Top reinforcement is horizontal reinforcement so placed that more than 12 inches of concrete is cast in the member below the reinforcement.



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Basic development length shall be . . . . . $0.02 d_b f_y / \sqrt{f'_c}$
but not less than . . . . . $0.0003 d_b f_y$†

Basic development length may be multiplied by applieable factors for:

Reinforcement in excess of that required by analysis . . . . . ($A_s$ required)/($A_s$ provided)

Reinforcement enclosed within spiral reinforcement not less than 1/4-inch diameter and not more than 4-inch pitch . . . . . 0.75

(e) **Development of Bundled Bars.** [12.4] Development length of individual bars within a bundle, in tension or compression, shall be that for the individual bar, increased 20 percent for 3-bar bundle, and 33 percent for 4-bar bundle.

(f) **Development of Standard Hooks in Tension.** [12.5] 1. Development length $l_{dh}$ in inches for deformed bars in tension terminating in a standard hook shall be computed as the product of the basic development length $l_{hb}$ of Section 2612 (f) 2 and the applicable modification factor or factors of Section 2612 (f) 3, but $l_{dh}$ shall not be less than $8d_b$ nor less than 6 inches.

2. Basic development length $l_{hb}$ for a hooked bar with $f_y$ equal to 60,000 psi shall be . . . . . $1200\, d_b / \sqrt{f'_c}$

3. Basic development length $l_{hb}$ shall be multiplied by applicable factor or factors for:

A. Bar yield strength. Bars with $f_y$ other than 60,000 psi. . . . . $f_y/60{,}000$

B. Concrete cover. For No. 11 bar and smaller, side cover (normal to plane of hook) but not less than 2 1/2 inches; for 90-degree hook, cover on bar extension beyond hook not less than 2 inches *for No. 6 bar and larger and 1 1/2 inches cover for No. 5 bar and smaller* . . . . . 0.7

C. Ties or stirrups. For No. 11 bar and smaller, hook enclosed vertically or horizontally within ties or stirrup ties spaced along the full development length $l_{dh}$ not greater than $3d_b$, where $d_b$ is diameter of hooked bar . . . 0.8

D. Excessive reinforcement. Where anchorage or development for $f_y$ is not specifically required, reinforcement in excess of that required by analysis . . . . . ($A_s$ required)/($A_s$ provided)

E. Lightweight aggregate concrete . . . . . 1.3

4. For bars being developed by a standard hook at discontinuous ends of members with side cover and top (or bottom) cover over hook less than 2 1/2 inches, hooked bar shall be enclosed within ties or stirrups spaced along the full development length $l_{dh}$ not greater than $3d_b$, where $d_b$ is diameter of hooked bar. For this case, factor of Section 2612 (f) shall not apply.

5. Hooks shall not be considered effective in developing bars in compression.

(g) **Mechanical Anchorage.** [12.6] Any mechanical device capable of developing the strength of reinforcement without damage to concrete may be used as anchorage.

Test results showing adequacy of such mechanical devices shall be presented to the building official.



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Development of reinforcement may consist of a combination of mechanical anchorage plus additional embedment length of reinforcement between the point of maximum bar stress and the mechanical anchorage.

(h) **Development of Welded Deformed Wire Fabric in Tension.** [12.7] Development length $l_d$, in inches, of welded deformed wire fabric measured from point of critical section to end of wire shall be computed as the product of either of the basic development lengths noted in this section and applicable modification factor or factors of Section 2612 (c), but $l_d$ shall be not less than 8 inches except in computation of lap splices by Section 2612 (s) and development of web reinforcement by Section 2612 (n).

Basic development length of welded deformed wire fabric, with at least one cross wire within the development length not less than 2 inches from point of critical section, shall be

$$0.03 d_b (f_y - 20{,}000)/\sqrt{f'_c} *$$

*The 20,000 has units of psi.

but not less than

$$0.20 \frac{A_w}{s_w} \frac{f_y}{\sqrt{f'_c}}$$

Basic development length of welded deformed wire fabric, with no cross wires within the development length, shall be determined as for deformed wire.

(i) **Development of Welded Smooth Wire Fabric in Tension.** [12.8] Yield strength of welded smooth wire fabric shall be considered developed by embedment of two cross wires with the closer cross wire not less than 2 inches from point of critical section. However, development length $l_d$ measured from point of critical section to outermost cross wire shall be not less than

$$0.27 \frac{A_w}{s_w} \frac{f_y}{\sqrt{f'_c}}$$

modified by ($A_s$ required)/($A_s$ provided) for reinforcement in excess of that required by analysis and by factor of Section 2612 (c) for lightweight aggregate concrete, but $l_d$ shall be not less than 6 inches except in computation of lap splices by Section 2612 (t).

(j) **Development of Prestressing Strand.** [12.9] Three- or seven-wire pretensioning strand shall be bonded beyond the critical section for a development length, in inches, not less than

$$\left(f_{ps} - \frac{2}{3} f_{se}\right) d_b \dagger$$

†Expression in parenthesis used as a constant without units.

where $d_b$ is strand diameter in inches, and $f_{ps}$ and $f_{se}$ are expressed in kips per square inch.



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Investigation may be limited to cross sections nearest each end of the member that are required to develop full design strength under specified factored loads.

Where bonding of a strand does not extend to end of member, and design includes tension at service load in precompressed tensile zone as permitted by Section 2618 (e) 2, development length specified above shall be doubled.

(k) **Development of Flexural Reinforcement—General.** [12.10] 1. Tension reinforcement may be developed by bending across the web to be anchored or made continuous with reinforcement on the opposite face of member.

2. Critical sections for development of reinforcement in flexural members are at points of maximum stress and at points within the span where adjacent reinforcement terminates or is bent. Provisions of Section 2612 (l) 3 must be satisfied.

3. Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of member or $12d_b$, whichever is greater, except at supports of simple spans and at free end of cantilevers.

4. Continuing reinforcement shall have an embedment length not less than the development length $l_d$ beyond the point where bent or terminated tension reinforcement is no longer required to resist flexure.

5. Flexural reinforcement shall not be terminated in a tension zone unless one of the following conditions is satisfied:

A. Shear at the cutoff point does not exceed two thirds that permitted, including shear strength of shear reinforcement provided.

B. Stirrup area in excess of that required for shear and torsion is provided along each terminated bar or wire over a distance from the termination point equal to three fourths the effective depth of member. Excess stirrup area $A_v$ shall be not less than $60b_w s/f_y$. Spacing $s$ shall not exceed $d/8\beta_b$ where $\beta_b$ is the ratio of area of reinforcement cut off to total area of tension reinforcement at the section.

C. For No. 11 bar and smaller, continuing reinforcement provides double the area required for flexure at the cutoff point and shear does not exceed three fourths that permitted.

6. Adequate end anchorage shall be provided for tension reinforcement in flexural members where reinforcement stress is not directly proportional to moment; such as: sloped, stepped or tapered footings; brackets; deep flexural members; or members in which tension reinforcement is not parallel to compression face.

(l) **Development of Positive Moment Reinforcement.** [12.11] 1. At least one third the positive moment reinforcement in simple members and one fourth the positive moment reinforcement in continuous members shall extend along the same face of member into the support. In beams, such reinforcement shall extend into the support at least 6 inches.

2. When a flexural member is part of a primary lateral load-resisting system, positive moment reinforcement required to be extended into the support by



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Section 2612 (l) 1 shall be anchored to develop the specified yield strength $f_y$ in tension at the face of support.

3. At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that $l_d$ computed for $f_y$ by Section 2612 (c) satisfies Formula (12-1), except Formula (12-1) need not be satisfied for reinforcement terminating beyond center line of simple supports by a standard hook or a mechanical anchorage at least equivalent to a standard hook.

$$l_d \leq \frac{M_n}{V_u} + l_a \qquad (12\text{-}1)$$

**WHERE:**

$M_n$ = is nominal strength assuming all reinforcement at the section to be stressed to the specified yield strength $f_y$.

$V_u$ = is factored shear force at the section.

$l_a$ = at a support shall be the embedment length beyond center of support.

$l_a$ = at a point of inflection shall be limited to the effective depth or member of $12d_b$, whichever is greater.

Value of $M_n/V_u$ may be increased 30 percent when the ends of reinforcement are confined by a compressive reaction.

(m) **Development of Negative Moment Reinforcement.** [12.12] Negative moment reinforcement in a continuous, restrained or cantilever member, or in any member of a rigid frame, shall be anchored in or through the supporting member by embedment length, hooks or mechanical anchorage.

Negative moment reinforcement shall have an embedment length into the span as required by Section 2612 (b) and 2612 (k) 3.

At least one third the total tension reinforcement provided for negative moment at a support shall have an embedment length beyond the point of inflection not less than effective depth of member, $12\,d_b$, or 1/16 the clear span, whichever is greater.

(n) **Development of Web Reinforcement.** [12.13] Web reinforcement shall be carried as close to compression and tension surfaces of member as cover requirements and proximity of other reinforcement will permit.

Ends of single leg, simple U- or multiple U-stirrups shall be anchored by one of the following means:

1. A standard hook plus an embedment of $0.5l_d$. The $0.5l_d$ embedment of a stirrup leg shall be taken as the distance between middepth of member $d/2$ and start of hook (point of tangency).

2. Embedment $d/2$ above or below middepth on the compression side of the



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member for a full development length $l_d$ but not less than $24d_b$; or for deformed bars or deformed wire, 12 inches.

3. For No. 5 bar and D31 wire, and smaller, bending around longitudinal reinforcement through at least 135 degrees and, in addition, for stirrups with design stress exceeding 40,000 psi, an embedment of $0.33l_d$ shall be provided. The $0.33l_d$ embedment of a stirrup leg shall be taken as the distance between middepth of member $d/2$ and start of hook (point of tangency).

4. For each leg of welded smooth wire fabric forming simple U-stirrups, either:

A. Two longitudinal wires spaced at a 2-inch spacing along the member at the top of the U.

B. One longitudinal wire located not more than $d/4$ from the compression face and a second wire closer to the compression face and spaced not less than 2 inches from the first wire. The second wire may be located on the stirrup leg beyond a bend, or on a bend with an inside diameter of bend not less than $8d_b$.

Between anchored ends, each bend in the continuous portion of a simple U-stirrup or multiple U-stirrups shall enclose a longitudinal bar.

Longitudinal bars bent to act as shear reinforcement, if extended into a region of tension, shall be continuous with longitudinal reinforcement and, if extended into a region of compression, shall be anchored beyond middepth $d/2$ as specified for development length in Section 2612 (c) for that part of $f_y$ required to satisfy Formula (11-19).

Pairs of U-stirrups or ties so placed as to form a closed unit shall be considered properly spliced when lengths of laps are $1.7l_d$. In members at least 18 inches deep, such splices with $A_b f_y$ not more than 9000 pounds per leg may be considered adequate if stirrup legs extend the full available depth of member.

5. For each end of a single-leg stirrup of welded smooth or deformed wire fabric, two longitudinal wires at a minimum spacing of 2 inches and with the inner wire at least the greater of $d/4$ or 2 inches from middepth of member $d/2$. Outer longitudinal wire at tension face shall not be farther from the face than the portion of primary flexural reinforcement closest to the face.

(o) **Splices of Reinforcement.** [12.14] 1. **General.** Splices of reinforcement shall be made only as required or permitted on approved plans or specifications, or as authorized by the *building official*.

2. **Lap splices.** A. Laps splices shall not be used for bars larger than No. 11, except as provided in Sections 2612 (q) 1 and 2615 (i) 2 D.

B. Lap splices of bundled bars shall be based on the lap splice length required for individual bars within a bundle, increased 20 percent for a 3-bar bundle and 33 percent for a 4-bar bundle. Individual bar splices within a bundle shall not overlap.

C. Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than one fifth the required lap splice length, nor 6 inches.



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3. **Welded splices and mechanical connections.** A. Welded splices and other mechanical connections may be used.

B. Except as provided in this code, all welding shall conform to *U.B.C. Standard No. 26-8*.

C. A full welded splice shall have bars butted and welded to develop in tension at least 125 percent of specified yield strength $f_y$ of the bar.

D. A full mechanical connection shall develop in tension or compression, as required, at least 125 percent of specified yield strength $f_y$ of the bar.

E. Welded splices and mechanical connections not meeting requirements of Section 2612 (o) 3 C or D may be used in accordance with Section 2612 (p) 4.

(p) **Splices of Deformed Bars and Deformed Wire in Tension.** [12.15] 1. Minimum length of lap for tension lap splices shall be as required for Class A, B or C splice, but not less than 12 inches, where:

Class A splice ..... $1.0l_d$

Class B splice ..... $1.3l_d$

Class C splice ..... $1.7l_d$

where $l_d$ is the tensile development length for the specified yield strength $f_y$ in accordanee with Section 2612 (c).

2. Lap spliees of deformed bars and deformed wire in tension shall conform to Table No. 26-G.

3. Welded splices or mechanical connections used where area of reinforcement provided is less than twice that required by analysis shall meet requirements of Section 2612 (o) 3 C and D.

4. Welded splices or mechanical connections used where area of reinforcement provided is at least twice that required by analysis shall meet the following:

A. Splices shall be staggered at least 24 inches and in such manner as to develop at every section at least twice the calculated tensile force at that section but not less than 20,000 psi for total area of reinforcement provided.

B. In computing tensile force developed at each section, spliced reinforcement may be rated at the specified splice strength. Unspliced reinforcement shall be rated at that fraction of $f_y$ defined by the ratio of the shorter actual development length to $l_d$ required to develop the specified yield strength $f_y$.

C. Splices in "tension tie members" shall be made with a full welded splice or full mechanical connection in accordance with Section 2612 (o) 3 C and D and splices in adjacent bar shall be staggered at least 30 inches.

(q) **Splices of Deformed Bars in Compression.** [12.16] 1. **Lap Splice.** Minimum length of lap for compression lap splices shall be the development length in compression computed in accordance with Section 2612 (d) but not less than $0.0005\, f_y d_b$, nor $(0.0009 f_y - 24)\, d_b$ for $f_y$ greater than 60,000 psi, nor 12 inches. For $f'_c$ less than 3000 psi, length of lap shall be increased by one third.

Where bars of different size are lap spliced in compression, splice length shall



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be the larger of: development length of larger bar, or splice length of smaller bar. Bar sizes No. 14 and 18 may be lap spliced to No. 11 and smaller bars.

In tied reinforeed compression members, where ties throughout the lap splice length have an effective area not less than $0.0015hs$, lap splice length may be multiplied by 0.83, but lap length shall be not less than 12 inches. Tie legs perpendicular to dimension $h$ shall be used in determining effective area.

In spirally reinforced compression members, lap splice length of bars within a spiral may be multiplied by 0.75, but lap length shall be not less than 12 inches.

2. **End bearing splices.** In bars required for compression only, compressive stress may be transmitted by bearing of square cut ends held in concentric contact by a suitable deviee.

Bar ends shall terminate in flat surfaces within 1 1/2 degrees of a right angle to the axis of the bars and shall be fitted within 3 degrees of full bearing after assembly.

End bearing splices shall be used only in members containing closed ties, closed stirrups or spirals.

3. **Welded splices.** Welded splices or mechanical connections used in compression shall meet requirements of Seetion 2612 (o) 3 C and D.

(r) **Special Splice Requirements for Columns.** [12.17] 1. Where factored load stress in longitudinal bars in a column, ealeulated for various loading combinations, varies from $f_y$ in compression to one-half $f_y$ or less in tension, lap splices, butt welded splices, mechanical connections or end bearing splices may be used. Total tensile strength provided in eaeh face of the column by splices alone or by splices in combinations with continuing unspliced bars at specified yield strength $f_y$ shall be at least twice the calculated tension in that face of the column but not less than required by Section 2612 (r) 3.

2. Where faetored load stress in longitudinal bars in a column, calculated for any loading combination, exceeds one-half $f_y$ in tension, lap splices designed to develop the specified yield strength $f_y$ in tension, or full-welded splices or full mechanical conneetions in accordance with Seetion 2612 (o) 3 C and D.

3. At horizontal eross sections of columns where spliees are loeated, a minimum tensile strength in each face of the column equal to one fourth the area of vertieal reinforcement in that face multiplied by $f_y$ shall be provided.

(s) **Splices of Welded Deformed Wire Fabric in Tension.** [12.18] Minimum length of lap for lap splices of welded deformed wire fabric measured between the ends of each fabric sheet shall be not less than $1.7l_d$ nor 8 inches, and the overlap measured between outermost cross wires of eaeh fabrie sheet shall be not less than 2 inehes; $l_d$ shall be the development length for the specified yield strength $f_y$ in accordance with Section 2612 (h).

Lap splices of welded deformed wire fabric, with no cross wires within the lap spliee length, shall be determined as for deformed wire.

(t) **Splices of Welded Smooth Wire Fabric in Tension.** [12.19] Minimum



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length of lap for lap splices of welded smooth wire fabric shall be in accordance with the following:

1. When area of reinforcement provided is less than twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each fabric sheet shall be not less than one spacing of cross wires plus 2 inches, nor less than 1.5 $l_d$, nor 6 inches, $l_d$ shall be the development length for the specified yield strength $f_y$ in accordance with Section 2612 (i).

2. When area of reinforcement provided is at least twice that required by analysis at splice location; length of overlap measured between outermost cross wires of each fabric sheet shall be not less than 1.5 $l_d$, nor 2 inches, $l_d$ shall be the development length for the specified yield strength $f_y$ in accordance with Section 2612 (i).

## Slab Systems with Multiple Square or Rectangular Panels [Chapter 13]

**Sec. 2613.** (a) **Notations.** [13.0]

$c_2$ = size of rectangular or equivalent rectangular column, capital or bracket measured transverse to the direction of the span for which moments are being determined, inches.

$C$ = cross-sectional constant to define torsional properties. See Formula (13-7).

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$E_{cb}$ = modulus of elasticity of beam concrete.

$E_{cc}$ = modulus of elasticity of column concrete.

$E_{cs}$ = modulus of elasticity of slab concrete.

$h$ = overall thickness of member, inches.

$I_b$ = moment of inertia about centroidal axis of gross section of beam as defined in Section 2613 (c) 4.

$I_c$ = moment of inertia of gross section of column.

$I_s$ = moment of inertia about centroidal axis of gross section of slab.

= $h^3/12$ times width of slab defined in notations $\alpha$ and $\beta_t$.

$K_b$ = flexural stiffness of beam; moment per unit rotation.

$K_c$ = flexural stiffness of column; moment per unit rotation.

$K_{ec}$ = *flexural stiffness of equivalent column; moment per unit rotation. See Formula (13-6).*

$K_s$ = flexural stiffness of slab; moment per unit rotation.

$K_t$ = torsional stiffness of torsional member; moment per unit rotation.

$l_n$ = length of clear span in direction that moments are being determined, measured face-to-face of supports.

$l_1$ = length of span in direction that moments are being determined, measured center-to-center of supports.



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$l_2$ = length of span transverse to $l_1$, measured center-to-center of supports. See also Section 2613 (h) 2 C and D.

$M_o$ = total factored static moment.

$w_u$ = factored load per unit area.

$w_d$ = factored dead load per unit area.

$w_l$ = factored live load per unit area.

$x$ = shorter overall dimension of rectangular part of cross section.

$y$ = longer overall dimension of rectangular part of cross section.

$\alpha$ = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by center lines of adjacent panels (if any) on each side of the beam.

$$= \frac{E_{cb}I_b}{E_{cs}I_s}$$

$\alpha_c$ = ratio of flexural stiffness of columns above and below the slab to combined flexural stiffness of the slabs and beams at a joint taken in the direction of the span for which moments are being determined.

$$= \frac{\Sigma K_c}{\Sigma(K_s + K'_b)}$$

$\alpha_{min}$ = minimum $\alpha_c$ to satisfy Section 2613 (h) 10 A.

$\alpha_1$ = $\alpha$ in direction of $l_1$.

$\alpha_2$ = $\alpha$ in direction of $l_2$.

$\beta_a$ = ratio of dead load per unit area to live load per unit area (in each case without load factors).

$\beta_t$ = ratio of torsional stiffness of edge beam section to flexural stiffness of a width of slab equal to span length of beam, center-to-center of supports.

$$= \frac{E_{cb}C}{2E_{cs}I_s}$$

$\delta_s$ = factor defined by Formula (13-5). See Section 2613 (h) 10.

$\gamma_f$ = fraction of unbalanced moment transferred by flexure at slab-column connections. See Section 2613 (d) 6.

(b) **Scope.** [13.1] 1. The provisions of this section shall apply for design of slab systems reinforced for flexure in more than one direction with or without beams between supports.

2. A slab system may be supported on columns or walls. If supported by columns, no portion of a column capital or bracket shall be considered for structural purposes that lies outside the largest right circular cone, right pyramid, or tapered wedge whose planes are oriented no greater than 45 degrees to the column.

3. Solid slabs and slabs with recesses or pockets made by permanent or



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removable fillers between ribs or joists in two directions are included within the scope of this section.

4. Minimum thickness of slabs designed in accordance with this section shall be as required by Section 2609 (f) 3.

(c) **Definitions.** [13.2] 1. Column strip is a design strip with a width on each side of a column center line equal to $0.25l_2$ or $0.25l_1$, whichever is less. Column strip includes beams, if any.

2. Middle strip is a design strip bounded by two column strips.

3. A panel is bounded by column, beam or wall center lines on all sides.

4. For monolithic or fully composite construction, a beam includes that portion of slab on each side of the beam extending a distance equal to the projection of the beam above or below the slab, whichever is greater, but not greater than four times the slab thickness.

(d) **Design Procedures.** [13.3] 1. A slab system may be designed by any procedure satisfying conditions of equilibrium and geometric compatibility if shown that the design strength at every section is at least equal to the required strength considering Sections 2609 (c) and 2609 (d) and that all serviceability conditions, including specified limits on deflections, are met.

A. For gravity loads, a slab system, including the slab and beams (if any) between supports and supporting columns or walls forming orthogonal frames, may be designed by either the direct design method of Section 2613 (h) or the equivalent frame method of Section 2613 (i).

B. For lateral loads, analysis of unbraced frames shall take into account effects of cracking and reinforcement on stiffness of frame members.

C. Results of the gravity load analysis may be combined with results of the lateral load analysis.

*2. A slab system, including the slab and beams (if any) between supports, and supporting columns or walls may be designed by either the direct design method [Section 2613 (h)] or the equivalent frame method [Section 2613 (i)].*

3. The slab and beams (if any) between supports shall be proportioned for factored moments prevailing at every section.

4. When gravity load, wind, earthquake or other lateral forces cause transfer of moment between slab and column, a fraction of the unbalanced moment shall be transferred by flexure in accordance with Section 2613 (b) 4.

The fraction of unbalanced moment not transferred by flexure shall be transferred by eccentricity of shear in accordance with Section 2611 (m) 2.

5. A fraction of the unbalanced moment given by $\gamma_f M_u$ shall be considered to be transferred by flexure within an effective slab width between lines that are one and one-half slab or drop panel thickness ($1.5h$) outside opposite faces of the column or capital, where $M_u$ is the moment to be transferred and

$$\gamma_f = \frac{1}{1 + 2/3\sqrt{b_1/b_2}} \qquad \text{.....(13-1)}$$



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Concentration of reinforeement over the column by closer spacing or additional reinforeement may be used to resist moment on the effective slab width.

6. Design for transfer of load from slab to supporting columns or walls through shear and torsion shall be in accordance with Section 2611.

(e) **Slab Reinforcement.** [13.4] 1. Area of reinforcement in each direction for two-way slab systems shall be determined from moments at critical sections but shall be not less than required by Section 2607 (m).

Spacing of reinforcement at critical sections shall not exceed two times the slab thickness, except for portions of slab area that may be of cellular or ribbed construction. In the slab over cellular spaces, reinforcement shall be provided as required by Section 2607 (m).

2. Positive moment reinforcement perpendicular to a discontinuous edge shall extend to the edge of slab and have embedment, straight or hooked, at least 6 inches in spandrel beams, columns or walls.

3. Negative moment reinforcement perpendicular to a discontinuous edge shall be bent, hooked or otherwise anchored; in spandrel beams, columns or walls, to be developed at face of support according to provisions of Section 2612.

4. Where a slab is not supported by a spandrel beam or wall at a discontinuous edge or where a slab cantilevers beyond the support, anchorage of reinforcement may be within the slab.

5. In slabs with beams between supports with a value of $\alpha$ greater than 1.0, special top and bottom slab reinforcement shall be provided at exterior corners in accordance with the following:

A. The special reinforcement in both top and bottom of slab shall be sufficient to resist a moment equal to the maximum positive moment (per foot of width) in the slab.

B. Direction of moment shall be assumed parallel to the diagonal from the corner in the top of the slab and perpendicular to the diagonal in the bottom of the slab.

C. The special reinforcement shall be provided for a distance in each direction from the corner equal to one fifth the longer span.

D. In either the top or bottom of the slab, the special reinforcement may be placed in a single band in the direction of the moment or in two bands parallel to the sides of the slab.

6. Where a drop panel is used to reduce amount of negative moment reinforcement over the column of a flat slab, size of drop panel shall be in accordance with the following:

A. Drop panel shall extend in each direction from center line of support a distance not less than one sixth the span length measured from center-to-center of supports in that direction.

B. Projection of drop panel below the slab shall be at least one fourth the slab thickness beyond the drop.

C. In computing required slab reinforcement, thickness of drop panel below the



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slab shall not be assumed greater than one fourth the distance from edge of drop panel to edge of column or column capital.

(f) **Details of Reinforcement in Slabs Without Beams.** In addition to the other requirements of Section 2613 (e), reinforcement in slabs without beams shall have minimum bend point locations and extensions for reinforcement as prescribed in Figure No. 26-1.

Where adjacent spans are unequal, extension of negative reinforcement beyond the face of support as prescribed in Figure No. 26-1 shall be based on requirements of longer span. Bent bars may be used only when depth-span ratio permits use of bends 45 degrees or less.

For slabs in frames not braced against sidesway and for slabs resisting lateral loads, lengths of reinforcement shall be determined by analysis but shall be not less than those prescribed in Figure No. 26-1.

(g) **Openings in Slab Systems.** [13.5] 1. Openings of any size may be provided in slab systems if shown by analysis that the design strength is at least equal to the required strength considering Section 2609 (c) and (d), and that all serviceability conditions, including the specified limits on deflections, are met.

2. In lieu of special analysis as required by Section 2613 (g) 1, openings may be provided in slab systems without beams when in accordance with the following:

A. Openings of any size may be located in the area common to intersecting middle strips, provided total amount of reinforcement required for the panel without the opening is maintained.

B. In the area common to intersecting column strips, not more than one eighth the width of column strip in either span shall be interrupted by openings. An amount of reinforcement equivalent to that interrupted by an opening shall be added on the sides of the opening.

C. In the area common to one column strip and one middle strip, not more than one fourth the reinforcement in either strip shall be interrupted by openings. An amount of reinforcement equivalent to that interrupted by an opening shall be added on the sides of the opening.

D. Shear requirements of Section 2611 (l) 5 shall be satisfied.

(h) **Direct Design Method.** [13.6] 1. Slab systems within the following limitations may be designed by the direct design method:

A. There shall be a minimum of three continuous spans in each direction.

B. Panels shall be rectangular with a ratio of longer to shorter span center-to-center supports within a panel not greater than 2.

C. Successive span lengths center-to-center supports in each direction shall not differ by more than one third the longer span.

D. Columns may be offset a maximum of 10 percent of the span (in direction of offset) from either axis between center lines of successive columns.

E. All loads shall be due to gravity only and uniformly distributed over an entire panel. Live load shall not exceed three times dead load.



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F. For a panel with beams between supports on all sides, the relative stiffness of beams in two perpendicular directions

$$\frac{\alpha_1 l_2^2}{\alpha_2 l_1^2} \quad \text{.....(13-2)}$$

shall be not less than 0.2 nor greater than 5.0.

G. Moment redistribution as permitted by Section 2608 (e) shall not be applied for slab systems designed by the direct design method. See Section 2613 (h) 7.

H. Variations from the limitations of this section may be considered acceptable if demonstrated by analysis that requirements of Section 2613 (d) 1 are satisfied.

2. **Total factored static moment for a span.** A. Total factored static moment for a span shall be determined in a strip bounded laterally by center line of panel on each side of center line of supports.

B. Absolute sum of positive and average negative factored moments in each direction shall be not less than

$$M_o = \frac{w_u l_2 l_n^2}{8} \quad \text{.....(13-3)}$$

C. Where the transverse span of panels on either side of the center line of supports varies, $l_2$ in Formula (13-3) shall be taken as the average of adjacent transverse spans.

D. When the span adjacent and parallel to an edge is being considered, the distance from edge to panel center line shall be substituted for $l_2$ in Formula (13-3).

E. Clear span $l_n$ shall extend from face to face of columns, capitals, brackets or walls. Value of $l_n$ used in Formula (13-3) shall be not less than $0.65 l_1$. Circular or regular polygon-shaped supports shall be treated as square supports with the same area.

3. **Negative and positive factored moments.** Negative factored moments shall be located at face of rectangular supports. Circular or regular polygon-shaped supports shall be treated as square supports with the same area.

In an interior span, total static moment $M_o$ shall be distributed as follows:

| | |
|---|---|
| Negative factored moment | 0.65 |
| Positive factored moment | 0.35 |



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In an end span, total factored static moment $M_o$ shall be distributed as follows:

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Exterior Edge Unrestrained | Slab with Beams Between All Supports | Slab Without Beams Between Interior Supports | | Exterior Edge Fully Restrained |
| | | | Without Edge Beam | With Edge Beam | |
| Interior negative factored moment | 0.75 | 0.70 | 0.70 | 0.70 | 0.65 |
| Positive factored moment | 0.63 | 0.57 | 0.52 | 0.50 | 0.35 |
| Exterior negative factored moment | 0 | 0.16 | 0.26 | 0.30 | 0.65 |

Negative moment sections shall be designed to resist the larger of the two interior negative factored moments determined for spans framing into a common support unless an analysis is made to distribute the unbalanced moment in accordance with stiffness of adjoining elements.

Edge beams or edges of slab shall be proportioned to resist in torsion their share of exterior negative factored moments.

For moment transfer between slab and an edge column in accordance with Section 2613 (d) 4, column strip nominal moment strength provided shall be used as the transfer moment for gravity load.

4. **Factored moments in column strips.** Column strips shall be proportioned to resist the following percentage of interior negative factored moments:

| $l_2/l_1$ | 0.5 | 1.0 | 2.0 |
|---|---|---|---|
| $(\alpha_1 l_2/l_1) = 0$ | 75 | 75 | 75 |
| $(\alpha_1 l_2/l_1) \geq 1.0$ | 90 | 75 | 45 |

Linear interpolations shall be made between values shown.

Column strips shall be proportioned to resist the following percentage of exterior negative factored moments:

| $l_2/l_1$ | | 0.5 | 1.0 | 2.0 |
|---|---|---|---|---|
| $(\alpha_1 l_2/l_1) = 0$ | $\beta_t = 0$ | 100 | 100 | 100 |
| | $\beta_t \geq 2.5$ | 75 | 75 | 75 |
| $(\alpha_1 l_2/l_1) \geq 1.0$ | $\beta_t = 0$ | 100 | 100 | 100 |
| | $\beta_t \geq 2.5$ | 90 | 75 | 45 |



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Linear interpolations shall be made between values shown...

Where supports consist of columns or walls extending for a distance equal to or greater than three fourths the span length $l_2$ used to compute $M_o$, negative moments shall be considered to be uniformly distributed across $l_2$.

Column strips shall be proportioned to resist the following percentage of positive factored moments:

| $l_2/l_1$ | 0.5 | 1.0 | 2.0 |
|---|---|---|---|
| $(\alpha_1 l_2/l_1) = 0$ | 60 | 60 | 60 |
| $(\alpha_1 l_2/l_1) \geq 1.0$ | 90 | 75 | 45 |

Linear interpolations shall be made between values shown.

For slabs with beams between supports, the slab portion of column strips shall be proportioned to resist that portion of column strip moments not resisted by beams.

5. **Factored moments in beams.** Beams between supports shall be proportioned to resist 85 percent of column strip moments if $(\alpha_1 l_2/l_1)$ is equal to or greater than 1.0. For values of $(\alpha_1 l_2/l_1)$ between 1.0 and zero, proportion of column strip moments resisted by beams shall be obtained by linear interpolation between 85 and zero percent. In addition to moments calculated for uniform loads according to Section 2613 (h) 2 B and this paragraph, beams shall be proportioned to resist all moments caused by concentrated or linear loads applied directly to beams, including weight of projecting beam stem above or below the slab.

6. **Factored moments in middle strips.** That portion of negative and positive factored moments not resisted by column strips shall be proportionately assigned to corresponding half middle strips. Each middle strip shall be proportioned to resist the sum of the moments assigned to its two half middle strips. A middle strip adjacent to and parallel with an edge supported by a wall shall be proportioned to resist twice the moment assigned to the half middle strip corresponding to the first row of interior supports.

7. **Modification of factored moments.** Negative and positive factored moments may be modified by 10 percent, provided the total static moment for a panel in the direction considered is not less than that required by Formula (13-3).

8. **Factored shear in slab systems with beams.** Beams with $(\alpha_1 l_2/l_1)$ equal to or greater than 1.0 shall be proportioned to resist shear caused by factored loads on tributary areas bounded by 45-degree lines drawn from the corners of the panels and the center lines of the adjacent panels parallel to the long sides.

Beams with $(\alpha_1 l_2/l_1)$ less than 1.0 may be proportioned to resist shear obtained by linear interpolation, assuming beams carry no load at $\alpha = 0$. In addition to shears calculated according to this section, beams shall be proportioned to resist shears caused by factored loads applied directly on beams.

Slab shear strength may be computed on the assumption that load is distributed to supporting beams in accordance with the preceding paragraph. Resistance to total shear occurring on a panel shall be provided.



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Shear strength shall satisfy requirements of Section 2611.

9. **Factored moments in columns and walls.** Columns and walls built integrally with a slab system shall resist moments caused by factored loads on the slab system.

At an interior support, supporting elements above and below the slab shall resist the moment specified by Formula (13-4) in direct proportion to their stiffnesses unless a general analysis is made.

$$M = 0.07[(w_d + 0.5w_l)l_2 l^2_n - w'_d l'_2 (l'_n)^2] \quad \text{(13-4)}$$

where $w'_d$, $l'_2$ and $l'_n$ refer to shorter span.

10. **Provisions for effects of pattern loadings.** Where ratio $\beta_a$ of dead load to live load is less than 2; one of the following conditions shall be satisfied:

A. Sum of flexural stiffnesses of the columns above and below the slab shall be such that $\alpha_c$ is not less than $\alpha_{min}$ specified in Table No. 26-E:

B. If $\alpha_c$ for the columns above and below the slab is less than $\alpha_{min}$ specified in Table No. 26-E, positive factored moments in panels supported by such columns shall be multiplied by the coefficient $\delta_s$ determined from Formula (13-5).

$$\delta_s = 1 + \frac{2-\beta_a}{4+\beta_a}\left(1 - \frac{\alpha_c}{\alpha_{min}}\right) \quad \text{(13-5)}$$

where $\beta_a$ is ratio of dead load to live load; per unit area (in each case without load factors).

(i) **Equivalent Frame Method.** [13.7] 1. Design of slab systems by the equivalent frame method shall be based on assumptions given in Section 2613 (i) 2 through 6, and all sections of slabs and supporting members shall be proportioned for moments and shears thus obtained.

Where metal column capitals are used, account may be taken of their contributions to stiffness and resistance to moment and to shear.

Change in length of columns and slabs due to direct stress, and deflections due to shear, may be neglected.

2. **Equivalent frame.** The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building. Each frame shall consist of a row of columns or supports and slab-beam strips, bounded laterally by the center line of panel on each side of the center line of columns or supports. Frames adjacent and parallel to an edge shall be bounded by that edge and the center line of adjacent panel.

Columns or supports shall be assumed to be attached to slab-beam strips by torsional members [Section 2613 (i) 5] transverse to the direction of the span for which moments are being determined and extending to bounding lateral panel center lines on each side of a column.

Each equivalent frame may be analyzed in its entirety, or for vertical loading, each floor and the roof (slab-beams) may be analyzed separately with far ends of



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columns considered fixed. Where slab-beams are analyzed separately, it may be assumed in determining moment at a given support that the slab-beam is fixed at any support two panels distant therefrom, provided the slab continues beyond that point.

3. **Slab-beams.** Moment of inertia of slab-beams at any cross section outside of joints or column capitals may be based on the gross area of concrete. Variation in moment of inertia along axis of slab-beams shall be taken into account.

Moment of inertia of slab-beams from center of column to face of column, bracket or capital shall be assumed equal to the moment of inertia of the slab-beam at face of column, bracket or capital divided by the quantity $(1 - c_2/l_2)^2$ where $c_2$ and $l_2$ are measured transverse to the direction of the span for which moments are being determined.

4. **Columns.** Moment of inertia of columns at any cross section outside of joints or column capitals may be based on the gross area of concrete. Variation in moment of inertia along axis of columns shall be taken into account. Moment of inertia of columns from top to bottom of the slab-beam at a joint shall be assumed infinite.

5. **Torsional members.** Torsional members shall be assumed to have a constant cross section throughout their length consisting of the larger of:

A. A portion of slab having a width equal to that of the column, bracket or capital in the direction of the span for which moments are being determined.

B. For monolithic or fully composite construction, the portion of slab specified in A above plus that part of the transverse beam above and below the slab.

C. Transverse beam as defined in Section 2613 (c) 4.

Stiffness $K_t$ of an attached torsional member shall be calculated by the following expression:

$$K_t = \Sigma \frac{9E_{cs}C}{l_2\left(1 - \frac{c_2}{l_2}\right)^3} \qquad (13\text{-}6)$$

where $c_2$ and $l_2$ relate to the transverse spans on each side of column. The constant $C$ in Formula (13-6) may be evaluated for the cross section by dividing it into separate rectangular parts and carrying out the following summation:

$$C = \Sigma\left(1 - 0.63\,\frac{x}{y}\right)\frac{x^3y}{3} \qquad (13\text{-}7)$$

Where beams frame into columns in the direction of the span for which moments are being determined, value of $K_t$ as computed by Formula (13-6) shall be multiplied by the ratio of moment of inertia of slab with such beam to moment of inertia of slab without such beam.

6. **Arrangement of live load.** When loading pattern is known, the equivalent frame shall be analyzed for that load.



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When live load is variable but does not exceed three fourths the dead load, or the nature of live load is such that all panels will be loaded simultaneously, maximum factored moments may be assumed to occur at all sections with full factored live load on entire slab system.

For loading conditions other than those defined in the preceding paragraph, maximum positive factored moment near midspan of a panel may be assumed to occur with three fourths the full factored live load on the panel and on alternate panels; and maximum negative factored moment in the slab at a support may be assumed to occur with three fourths the full live load on adjacent panels only. Factored moments shall not be taken less than those occurring with full factored live load on all panels.

7. **Factored moments.** At interior supports, critical section for negative factored moment (in both column and middle strips) shall be taken at face of rectilinear supports, but not greater than $0.175l_1$ from center of a column.

At exterior supports provided with brackets or capitals, critical section for negative factored moment in the span perpendicular to an edge shall be taken at a distance from face of supporting element not greater than one half the projection of bracket or capital beyond face of supporting element.

Circular or regular polygon-shaped supports shall be treated as square supports with the same area for location of critical section for negative design moment.

Slab systems within limitations of Section 2613 (h) 1, when analyzed by the equivalent frame method, may have resulting computed moments reduced in such proportion that the absolute sum of the positive and average negative moments used in design need not exceed the value obtained from Formula (13-3).

Moments at critical seetions across the slab-beam strip of each frame may be distributed to column strips, beams and middle strips as provided in Section 2613 (h) 4, 5 and 6 if the requirement of Section 2613 (h) 1 F is satisfied.

## Walls [Chapter 14]

**Sec. 2614.** (a) **Notations.** [14.0]

$A_g$ = gross area of section, square inches.
$f'_c$ = speeified eompressive strength of eoncrete, psi.
$h$ = overall thickness of member, inches.
$k$ = effective length factor.
$l_c$ = vertieal distance between supports, inches.
$M_u$ = *factored moment at section, inch-lb. See Section 2614 (i) 2.*
$M_n$ = *nominal moment strength at section, inch-lb.*
$M_{cr}$ = *cracking moment 5* $\sqrt{f'_c}$*1g/y*$_t$ *for regular concrete.*
$P_{nw}$ = nominal axial load strength of wall designed by Section 2614 (e).
$P_u$ = *factored axial load at midheight of wall, including tributary wall weight.*
$\phi$ = strength reduction factor. See Section 2609 (d).



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$\rho$ = *ratio of nonprestressed tension reinforcement.*

$\rho_b$ = *reinforcement ratio producing balanced strain conditions. See Formula (8-1).*

(b) **Scope.** [14.1] Provisions of Section 2614 shall apply for design of walls subjected to axial load, with or without flexure.

Cantilever retaining walls are designed according to flexural design provisions of Section 2610 with minimum horizontal reinforcement according to Section 2614 (d) 3.

(c) **General.** [14.2] Walls shall be designed for eccentric loads and any lateral or other loads to which they are subjected. Walls subject to axial loads shall be designed in accordance with Sections 2614 (c), 2614 (d) and either 2614 (e) or (f). Design for shear shall be in accordance with Section 2611 (k).

Unless demonstrated by a detailed analysis, horizontal length of wall to be considered as effective for each concentrated load shall not exceed center-to-center distance between loads, nor width of bearing plus four times the wall thickness.

Compression members built integrally with walls shall conform to Section 2610 (i) 2.

Walls shall be anchored to intersecting elements such as floors, roofs or to columns, pilasters, buttresses, and intersecting walls and footings.

Quantity of reinforcement and limits of thickness required by Sections 2614 (d) and (f) may be waived where structural analysis shows adequate strength and stability.

(d) **Minimum Reinforcement.** [14.3] 1. Minimum vertical and horizontal reinforcement shall be in accordance with Sections 2614 (d) 2 and 3 unless a greater amount is required for shear by Sections 2611 (k) 8 and 9.

2. Minimum ratio of vertical reinforcement area to gross concrete area shall be:

A. 0.0012 for deformed bars not larger than No. 5 with a specified yield strength not less than 60,000 psi, or

B. 0.0015 for other deformed bars, or

C. 0.0012 for welded wire fabric (smooth or deformed) not larger than W31 or D31.

3. Minimum ratio of horizontal reinforcement area to gross concrete area shall be:

A. 0.0020 for deformed bars not larger than No. 5 with a specified yield strength not less than 60,000 psi, or

B. 0.0025 for other deformed bars, or

C. 0.0020 for welded wire fabric (smooth or deformed) not larger than W31 or D31.



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4. Walls more than 10 inches thick, except basement walls, shall have reinforcement for each direction placed in two layers parallel with faces of wall in accordance with the following:

A. One layer consisting of not less than one half and not more than two thirds of total reinforcement required for each direction shall be placed not less than 2 inches nor more than one-third the thickness of wall from exterior surface.

B. The other layer, consisting of the balance of required reinforcement in that direction, shall be placed not less than 3/4 inch nor more than one-third the thickness of wall from interior surface.

5. Vertical and horizontal reinforcement shall not be spaced farther apart than three times the wall thickness, nor 18 inches.

6. Vertical reinforcement need not be enclosed by lateral ties if vertical reinforcement area is not greater than 0.01 times gross concrete area, or where vertical reinforcement is not required as compression reinforcement.

7. In addition to the minimum reinforcement required by Section 2614 (d) 1 and 2, not less than two No. 5 bars shall be provided around all window and door openings. Such bars shall be extended to develop the bar beyond the corners of the openings but not less than 24 inches.

8. The minimum requirements for horizontal and vertical steel of Section 2614 (d) 2 and 2614 (d) 3 may be interchanged for precast panels which are not restrained along vertical edges to inhibit temperature expansion or contraction.

(e) **Walls Designed as Compression Members.** [14.4] Except as provided in Section 2614 (f), walls subject to axial load or combined flexure and axial load shall be designed as compression members in accordance with provisions of Section 2610 (c), (d), (k), (l), (m), (p) and Section 2614 (c) and (d).

(f) **Empirical Design Method.** [14.5] 1. Walls of solid rectangular cross section may be designed by the empirical provisions of Section 2614 (f) if resultant of all factored loads is located within the middle third of the overall thickness of wall and all limits of Section 2614 (c), (d) and (f) are satisfied.

2. Design axial load strength $\phi P_{nw}$ of a wall satisfying limitations of Section 2614 (f) 1 shall be computed by Formula (14-1) unless designed in accordance with Section 2614 (e).

$$\phi P_{nw} = 0.55\,\phi f'_c A_g \left[1 - \left(\frac{k l_c}{32h}\right)^2\right] \quad \text{.....(14-1)}$$

where $\phi = 0.70$ and effective length factor $k$ shall be:

For walls braced top and bottom against lateral translation and

A. Restrained against rotation at one or both ends (top and/or bottom) 0.8

B. Unrestrained against rotation at both ends 1.0

For walls not braced against lateral translation 2.0



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3. Minimum thickness of walls designed by empirical design method.

A. Thickness of bearing walls shall not be less than 1/25 the unsupported height or length, whichever is shorter, nor less than 4 inches.

B. Thickness of exterior basement walls and foundation walls shall not be less than 7 1/2 inches.

(g) **Nonbearing Walls.** [14.6] Thickness of nonbearing walls shall not be less than 4 inches, nor less than 1/30 the least distance between members that provide lateral support.

(h) **Walls as Grade Beams.** [14.7] 1. Walls designed as grade beams shall have top and bottom reinforcement as required for moment in accordance with provisions of Section 2610 (e) through (h). Design for shear shall be in accordance with provisions of Section 2611.

2. Portions of grade beam walls exposed above grade shall also meet requirements of Section 2614 (d).

*(i) **Alternate Design Slender Walls.** When flexural tension controls design of walls, the requirements of Section 2610 (k) 1 may be satisfied by complying with the limitations and procedures set forth in this section.*

*1. **Limitations.***

*A. Vertical service load stress at the location of maximum moment does not exceed $0.04 f'_c$.*

*B. The reinforcement ratio* $\rho$ does not exceed $.6 \rho_b$.

*C. Sufficient reinforcement is provided so that the nominal moment capacity times the $\phi$ factor is greater that $M_{cr}$.*

*D. Distribution of concentrated load does not exceed the width of bearing plus a width increasing at a slope of two vertical to one horizontal down to the design flexural section.*

*2. **Design strength.** The required factored moment, $M_u$ at the midheight cross section for combined axial and lateral factored loads, including the $P$-$\Delta$ moments, shall be as set forth in the Formula (14-2).*

$$M_u \leq \phi M_n \quad \text{(14-2)}$$

*Unless a more comprehensive analysis is used, the $P$-$\Delta$ moment shall be calculated using the maximum potential deflection, $\Delta_n$, as defined in 2614 (i) 3.*

*3. **Deflection design.** The midheight deflection $\Delta_s$, under service lateral and vertical loads (without load factors), shall be limited by the relation*

$$\Delta_s = \frac{l_c}{150} \quad \text{(14-3)}$$

*Unless a more comprehensive analysis is used, the midheight deflection shall be computed with the following formula:*

$$\Delta_s = \Delta_{cr} + \left(\frac{M_s - M_{cr}}{M_n - M_{cr}}\right)(\Delta_n - \Delta_{cr}) \quad \text{(14-4)}$$



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*WHERE:*

$$\Delta_{cr} = \frac{5M_{cr}\,l_c^2}{48\,E_c\,I_g}$$

$$\Delta_n = \frac{5M_n l_c^2}{48\,E_c\,I_{cr}}$$

$$I_{cr} = nA_{se}(d-c)^2 + \frac{bc^3}{3}$$

$M_s$ = *the maximum moment in the wall resulting from the application of the unfactored load combinations.*

$$A_{se} = \frac{P_u + A_s f_y}{f_y}$$

## Footings [Chapter 15]

**Sec. 2615.** (a) **Notations.** [15.0]

$A_g$ = gross area of section, square inches.
$d_p$ = diameter of pile at footing base.
$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.
$\beta$ = ratio of long side to short side of footing.
$\phi$ = strength reduction factor. See Section 2609 (d).

(b) **Scope.** [15.1] Provisions of this section shall apply for design of isolated footings and, where applicable, to combined footings and mats.

Additional requirements for design of combined footings and mats are given in Section 2615 (k).

(c) **Loads and Reactions.** [15.2] Footings shall be proportioned to resist the factored loads and induced reactions, in accordance with the appropriate design requirements of this code and as provided in this section.

*External forces and moments* applied to footings shall be transferred to supporting soil without exceeding permissible soil pressures.*

For footings on piles, computations for moments and shears may be based on the assumption that the reaction from any pile is concentrated at pile center.

Base area of footing or number and arrangement of piles shall be determined from the external forces and moments* (transmitted by footing to soil or piles) and permissible soil pressure or permissible pile capacity selected through principles of soil mechanics.

**External forces and moments are those resulting from unfactored loads (D, L, W and E) specified in Chapter 23.*



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(d) **Footings Supporting Circular or Regular Polygon-shaped Columns or Pedestals.** [15.3] Circular or regular polygon-shaped concrete columns or pedestals may be treated as square members with the same area for location of critical sections for moment, shear and development of reinforcement in footings.

(e) **Moment in Footings.** [15.4] 1. External moment on any section of a footing shall be determined by passing a vertical plane through the footing and computing the moment of the forces acting over entire area of footing on one side of that vertical plane.

2. Maximum factored moment for an isolated footing shall be computed as prescribed in Section 2615 (e) 1 at critical sections located as follows:

A. At face of column, pedestal or wall, for footings supporting a concrete column, pedestal or wall.

B. Halfway between middle and edge of wall, for footings supporting a masonry wall.

C. Halfway between face of column and edge of steel base, for footings supporting a column with steel base plates.

3. In one-way footings, and two-way square footings, reinforcement shall be distributed uniformly across entire width of footing.

4. In two-way rectangular footings, reinforcement shall be distributed as follows:

A. Reinforcement in long direction shall be distributed uniformly across entire width of footing.

B. For reinforcement in short direction, a portion of the total reinforcement given by *Formula* (15-1) shall be distributed uniformly over a band width (centered on center line of column or pedestal) equal to the length of short side of footing. Remainder of reinforcement required in short direction shall be distributed uniformly outside center band width of footing.

$$\frac{\text{Reinforcement in band width}}{\text{Total reinforcement in short direction}} = \frac{2}{(\beta + 1)} \qquad (15\text{-}1)$$

(f) **Shear in Footings.** [15.5] 1. Computation of shear in footings shall be in accordance with Section 2611 (l).

2. Location of critical section for shear in accordance with Section 2611 shall be measured from face of column, pedestal or wall, for footings supporting a column, pedestal or wall. For footings supporting a column or pedestal with steel base plates, the critical section shall be measured from location defined in Section 2615 (e) 2 C.

3. Computation of shear on any section through a footing supported on piles shall be in accordance with the following:

A. Entire reaction from any pile whose center is located $d_p/2$ or more outside the section shall be considered as producing shear on that section.



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B. Reaction from any pile whose center is located $d_p/2$ or more inside the section shall be considered as producing no shear in that section.

C. For intermediate positions of pile center, the portion of the pile reaction to be considered as producing shear on the section shall be based on straight-line interpolation between full value at $d_p/2$ outside the section and zero value at $d_p/2$ inside the section.

(g) **Development of Reinforcement in Footings.** [15.6] 1. Computation of development of reinforcement in footings shall be in accordance with Section 2612.

2. Calculated tension or compression in reinforcement at each section shall be developed on each side of that section by proper embedment length, end anchorage, hooks (tension only), or combinations thereof.

3. Critical sections for development of reinforcement shall be assumed at the same locations as defined in Section 2615 (e) 2 for maximum factored moment, and at all other vertical planes where changes of section or reinforcement occur. See also Section 2612 (k) 6.

(h) **Minimum Footing Depth.** [15.7] Depth of footing above bottom reinforcement shall be not less than 6 inches for footings on soil, nor less than 12 inches for footings on piles.

(i) **Transfer of Force at Base of Column, Wall or Reinforced Pedestal.** [15.8] 1. Forces and moments at base of column, wall or pedestal shall be transferred to supporting pedestal or footing by bearing on concrete and by reinforcement, dowels and mechanical connectors.

A. Bearing on concrete at contact surface between supported and supporting member shall not exceed concrete bearing strength for either surface as given by Section 2610 (p).

B. Reinforcement, dowels or mechanical connectors between supported and supporting members shall be adequate to transfer:

(i) All compressive force that exceeds concrete bearing strength of either member.

(ii) Any computed tensile force across interface.

In addition, reinforcement, dowels or mechanical connectors shall satisfy Section 2615 (i) 2 or 2615 (i) 3.

C. If calculated moments are transferred to supporting pedestal or footing, reinforcement, dowels or mechanical connectors shall be adequate to satisfy Section 2612 (s).

D. Lateral forces shall be transferred to supporting pedestal or footing in accordance with shear-friction provisions of Section 2611 (h) or by other appropriate means.

2. In cast-in-place construction, reinforcement required to satisfy Section 2615 (i) 1 shall be provided either by extending longitudinal bars into supporting pedestal or footing, or by dowels.



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A. For cast-in-place columns and pedestals, area of reinforcement across interface shall be not less than 0.005 times gross area of supported member.

B. For cast-in-place walls, area of reinforcement across interface shall be not less than minimum vertical reinforcement given in Section 2614 (d) 2.

C. Diameter of dowels, if used, shall not exceed diameter of longitudinal bars by more than 0.15 inch.

D. At footings, No. 14 and No. 18 longitudinal bars, in compression only, may be lap spliced with dowels to provide reinforcement required to satisfy Section 2615 (i) 1. Dowels shall not be larger than No. 11 bar and shall extend into supported member a distance not less than the development length of No. 14 or No. 18 bars or the splice length of the dowels, whichever is greater, and into the footing a distance not less than the development length of the dowels.

E. If a pinned or rocker connection is provided in cast-in-place construction, connection shall conform to Sections 2615 (i) 1 and 2615 (i) 3.

3. In precast construction, reinforcement required to satisfy Section 2615 (i) 1 may be provided by anchor bolts or suitable mechanical connectors.

A. Connection between precast columns or pedestals and supporting member shall have a tensile strength not less than $200\ A_g$, in pounds, where $A_g$ is area of supported member.

B. Connection between precast wall and supporting member shall have a tensile strength not less than $50\ A_g$, in pounds, where $A_g$ is cross-sectional area of wall.

C. Anchor bolts and mechanical connectors shall be designed to reach their design strength prior to anchorage failure or failure of surrounding concrete.

(j) **Sloped or Stepped Footings.** [15.9] In sloped or stepped footings, angle of slope or depth and location of steps shall be such that design requirements are satisfied at every section.

Sloped or stepped footings designed as a unit shall be constructed to assure action as a unit.

(k) **Combined Footings and Mats.** [15.10] 1. Footings supporting more than one column, pedestal or wall (combined footings or mats) shall be proportioned to resist the factored loads and induced reactions in accordance with appropriate design requirements of this code.

2. The direct design method of Section 2613 shall not be used for design of combined footings and mats.

3. Distribution of soil pressure under combined footings and mats shall be consistent with properties of the soil and the structure and with established principles of soil mechanics.

*(l) **Plain Concrete Pedestals and Footings.** 1. Stresses due to factored loads in plain concrete pedestals and footings on soil shall be computed assuming a linear stress distribution in the concrete.*

*2. For plain concrete pedestals and footings with concrete cast against soil,*



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*effective thickness used in computing stresses shall be taken as overall thickness minus 3 inches.*

*3. Stresses due to factored loads in plain concrete pedestals and footings on soil shall not exceed the following:*

| | |
|---|---|
| *Flexure—extreme fiber stress in tension* | $5\phi\sqrt{f'_c}$ |
| *Shear—Beam action* | $2\phi\sqrt{f'_c}$ |
| *—Two-way action* | $4\phi\sqrt{f'_c}$ |

*4. Maximum compressive stress in plain concrete pedestals shall not exceed concrete bearing strength as given in Section 2610 (p). Where concrete bearing strength is exceeded, reinforcement shall be provided and the pedestal designed as a reinforced concrete member.*

*5. Plain concrete shall not be used for footings on piles.*

*6. Overall thickness of plain concrete footings shall not be less than 8 inches.*

## Precast Concrete [Chapter 16]

**Sec. 2616.** (a) **Scope.** [16.1] 1. Provisions of this section shall apply only to design of precast concrete members *manufactured under plant-controlled conditions.*

*2. All provisions of this code shall apply to precast concrete members, except as specifically modified in this section.*

(b) **Design.** [16.2] 1. Design of precast members shall consider all loading and restraint conditions from initial fabrication to completion of the structure, including form removal, storage, transportation and erection.

2. In precast construction that does not behave monolithically, effects at all interconnected and adjoining details shall be considered to assure proper performance of the structural system.

3. Effects of initial and long-time deflections shall be considered including effects on interconnected elements.

4. Design of joints and bearings shall include effects of all forces to be transmitted, including shrinkage, creep, temperature, elastic deformation, wind and earthquake.

5. All details shall be designed to provide for manufacturing and erection tolerances and temporary erection stresses.

(c) **Precast Wall Panels.** [16.3] 1. Precast bearing and nonbearing walls shall be designed in accordance with provisions of Section 2614. *Design shall include effects of temperature and shrinkage.*

2. Where precast panels are designed to span horizontally to columns or isolated footings, the ratio of height to thickness shall not be limited, provided the effect of deep beam action, lateral buckling, *vertical buckling (including $p$-$\Delta$ effects)* and deflections are provided for in the design. See Section 2610 (h) *and 2610 (k).*



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(d) **Details.** [16.4] 1. All details of reinforcement, connections, bearing seats, inserts, anchors, concrete cover, openings, lifting devices, fabrication and erection tolerances shall be shown on the shop drawings.

2. When approved by the *building official,* embedded items (such as dowels or inserts) that either protrude from concrete or remain exposed for inspection may be embedded while concrete is in a plastic state, provided:

A. Embedded items are not required to be hooked or tied to reinforcement within plastic concrete.

B. Embedded items are maintained in correct position while concrete remains plastic, and

C. Embedded items are properly anchored to develop required factored loads.

(e) **Identification and Marking.** [16.5] Each precast member or element shall be marked to indicate location in the structure, top surface and date of fabrication. Identification marks shall correspond to the placing plans.

(f) **Transportation, Storage and Erection.** [16.6] During curing, form removal, storage, transportation and erection, precast members shall not be overstressed, warped or otherwise damaged or have camber adversely affected.

Precast members shall be adequately braced and supported during erection to ensure proper alignment and structural integrity until permanent connections are completed.

## Composite Concrete Flexural Members [Chapter 17]

**Sec. 2617.** (a) **Notations.** [17.0]

$b_v$ = width of cross section at contact surface being investigated for horizontal shear.

$d$ = distance from extreme compression fiber to centroid of tension reinforcement for entire composite section, inches.

$V_{nh}$ = nominal horizontal shear strength.

$V_u$ = factored shear force at section.

$\phi$ = strength reduction factor. See Section 2609 (d).

(b) **Scope.** [17.1] Provisions of this section shall apply for design of composite concrete flexural members defined as precast or cast-in-place concrete elements or both constructed in separate placements but so interconnected that all elements respond to loads as a unit.

All provisions of this code shall apply to composite concrete flexural members, except as specifically modified in this section.

(c) **General.** [17.2] 1. An entire composite member or portions thereof may be used in resisting shear and moment.

2. Individual elements shall be investigated for all critical stages of loading.

3. If the specified strength, unit weight or other properties of the various elements are different, properties of the individual elements or the most critical values, shall be used in design.



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4. In strength computations of composite members, no distinction shall be made between shored and unshored members.

5. All elements shall be designed to support all loads introduced prior to full development of design strength of composite members.

6. Reinforcement shall be provided as required to control cracking and to prevent separation of individual elements of composite members.

7. Composite members shall meet requirements for control of deflections in accordance with Section 2609 (f).

(d) **Shoring.** [17.3] When used, shoring shall not be removed until supported elements have developed design properties required to support all loads and limit deflections and cracking at time of shoring removal.

(e) **Vertical Shear Strength.** [17.4] 1. When an entire composite member is assumed to resist vertical shear, design shall be in accordance with requirements of Section 2611 as for a monolithically cast member of the same cross-sectional shape.

2. Shear reinforcement shall be fully anchored into interconnected elements in accordance with Section 2612 (n).

3. Extended and anchored shear reinforcement may be included as ties for horizontal shear.

(f) **Horizontal Shear Strength.** [17.5] 1. In a composite member, full transfer of horizontal shear forces shall be assured at contact surfaces of interconnected elements.

*2. Full transfer of horizontal shear forces may be assumed when all of the following are satisfied:*

*A. Contact surfaces are clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inch,*

*B. Minimum ties are provided in accordance with Section 2617 (g),*

*C. Web members are designed to resist total vertical shear, and*

*D. All shear reinforcement is fully anchored into all interconnected elements.*

*3. If all requirements of Section 2617 (f) 2 are not satisfied, horizontal shear shall be investigated in accordance with Section 2617 (f) 4 or 5.*

4. Unless calculated in accordance with Section 2617 (f) 5, design of cross sections subject to horizontal shear shall be based on

$$V_u \leq \phi V_{nh} \qquad (17\text{-}1)$$

where $V_u$ is factored shear force at section considered and $V_{nh}$ is nominal horizontal shear strength in accordance with the following:

A. When contact surfaces are clear, free of laitance and intentionally roughened, shear strength $V_{nh}$ shall not be taken greater than than $80b_v d$.

B. When minimum ties are provided in accordance with Section 2617 (g) and contact surfaces are clean and free of laitance, but not intentionally roughened, shear strength $V_{nh}$ shall not be taken greater than $80b_v d$.



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C. When minimum ties are provided in accordance with Section 2617 (g) and contact surfaces are clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inch, shear strength $V_{nh}$ shall not be taken greater than $350b_v d$.

D. When factored shear force $V_u$ at section considered exceeds $\phi(350b_v d)$, design for horizontal shear shall be in accordance with Section 2611 (h).

5. Horizontal shear may be investigated by computing the actual compressive or tensile force in any segment, and provisions made to transfer that force as horizontal shear to the supporting element. The factored horizontal shear force shall not exceed horizontal shear strength $\phi V_{nh}$ as given in Section 2617 (f) 4 A through D.

6. When tension exists across any contact surface between interconnected elements, shear transfer by contact may be assumed only when minimum ties are provided in accordance with Section 2617 (g).

(g) **Ties for Horizontal Shear.** [17.6] 1. When ties are provided to transfer horizontal shear, tie area shall be not less than that required by Section 2611 (f) 5 C and tie spacing shall not exceed four times the least dimension of supported element, nor 24 inches.

2. Ties for horizontal shear may consist of single bars or wire, multiple leg stirrups or vertical legs of welded wire fabric (smooth or deformed).

3. All ties shall be fully anchored into interconnected elements in accordance with Section 2612 (n).

## Prestressed Concrete [Chapter 18]

**Sec. 2618.** (a) **Notations.** [18.0]

$A$ = area of that part of cross section between flexural tension face and center of gravity of gross section, square inches.

$A_c$ = area of concrete at cross section considered, square inches.

$A_{ps}$ = area of prestressed reinforcement in tension zone, square inches.

$A_s$ = area of nonprestressed tension reinforcement, square inches.

$A'_s$ = area of compression reinforcement, square inches.

$b$ = width of compression face of member, inches.

$d$ = distance from extreme compression fiber to centroid of nonprestressed tension reinforcement, inches.

$d'$ = distance from extreme compression fiber to centroid of compression reinforcement, inches.

$d_p$ = distance from extreme compression fiber to centroid of prestressed reinforcement.

$D$ = dead loads or related internal moments and forces.

$e$ = base of Napierian logarithms.

$f'_c$ = specified compressive strength of concrete, psi.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi; or *square root of compressive strength of concrete at time of initial prestress, psi.*



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$f'_{ci}$ = compressive strength of concrete at time of initial prestress, psi.

$f_{pc}$ = average compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses), psi.

$f_{ps}$ = stress in prestressed reinforcement at nominal strength, psi.

$f_{pu}$ = specified tensile strength of prestressing tendons, psi.

$f_{py}$ = specified yield strength of prestressing tendons, psi.

$f_r$ = modulus of rupture of concrete, psi.

$f_{se}$ = effective stress in prestressed reinforcement (after allowance for all prestress losses), psi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$h$ = overall thickness of member, inches.

$K$ = wobble friction coefficient per foot of prestressing tendon.

$l$ = *length of prestressing tendon element from jacking end to any point x, feet. See Formulas (18-1) and (18-2);* or length of span of two-way flat plates in direction parallel to that of the reinforcement being determined, inches. See Formula (18-8).

$L$ = live loads or related internal moments and forces.

$N_c$ = tensile force in concrete due to unfactored dead load plus live load $(D + L)$.

$P_s$ = prestressing tendon force at jacking end.

$P_x$ = prestressing tendon force at any point $x$.

$\alpha$ = total angular change of prestressing tendon profile in radians from tendon jacking end to any point $x$.

$\beta_1$ = factor defined in Section 2610 (c) 7.

$\gamma_p$ = factor for type of prestressing tendon.

= 0.55 for $f_{py}/f_{pu}$ not less than 0.80.

= 0.40 for $f_{py}/f_{pu}$ not less than 0.85.

= 0.28 for $f_{py}/f_{pu}$ not less than 0.90.

$\mu$ = curvature friction coefficient.

$\rho$ = ratio of nonprestressed tension reinforcement.

$= A_s/bd$.

$\rho'$ = ratio of compression reinforcement.

$= A_s/bd$.

$\rho'$ = ratio of compression reinforcement.

$= A'_s/bd$.

$\rho_p$ = ratio of prestressed reinforcement.

$= A_{ps}/bd_p$.

$\phi$ = strength reduction factor. See Section 2609 (d).

$\omega = \rho f_y/f'_c$.

$\omega' = \rho' f_y/f'_c$.



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$\omega_p = \rho_p f_{ps}/f'_c$

$\omega_w$, $\omega_{pw}$, $\omega'_w$

= reinforcement indices for flanged sections computed as for $\omega$, $\omega_p$, and $\omega'$ except that $b$ shall be the web width, and reinforcement area shall be that required to develop compressive strength of web only.

(b) **Scope.** [18.1] Provisions of this section shall apply to members prestressed with wire, strands or bars conforming to provisions for prestressing tendons in Section 2603 (f) 4.

All provisions of this code not specifically excluded, and not in conflict with provisions of this section, shall apply to prestressed concrete.

The following provisions of this code shall not apply to prestressed concrete, except as specifically noted: Sections 2607 (g) (last paragraph), 2608 (e), 2608 (k) 2 through 2608 (k) 4, 2608 (l); 2610 (d) 2 and 3, 2610 (f), 2610 (j) 1, 2610 (j) 2; 2613 and 2614 (d), (f) and (g).

(c) **General.** [18.2] 1. Prestressed members shall meet the strength requirements specified in this code.

2. Design of prestressed members shall be based on strength and on behavior at service conditions at all load stages that may be critical during the life of the structure from the time prestress is first applied.

3. Stress concentrations due to prestressing shall be considered in design.

4. Provisions shall be made for effects on adjoining construction of elastic and plastic deformations, deflections, changes in length and rotations due to prestressing. Effects of temperature and shrinkage shall also be included.

5. Possibility of buckling in a member between points where concrete and prestressing tendons are in contact and of buckling in thin webs and flanges shall be considered.

6. In computing section properties prior to bonding of prestressing tendons, effect of loss of area due to open ducts shall be considered.

(d) **Design Assumptions.** [18.3] 1. Strength design of prestressed members for flexure and axial loads shall be based on assumptions given in Section 2610 (c), except Section 2610 (c) 4 shall apply only to reinforcement conforming to Section 2603 (f) 2.

2. For investigation of stresses at transfer of prestress, at service loads and at cracking loads, straight-line theory may be used with the following assumptions:

A. Strains vary linearly with depth through entire load range.

B. At cracked sections, concrete resists no tension.

(e) **Permissible Stresses in Concrete—Flexural Members.** [18.4] 1. Stresses in concrete immediately after prestress transfer (before time-dependent prestress losses) shall not exceed the following:

A. Extreme fiber stress in compression ..... $0.60f'_{ci}$

B. Extreme fiber stress in tension except as permitted in ..... $3\sqrt{f'_{ci}}$



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C. Extreme fiber stress in tension at ends of simply supported members ..... $6\sqrt{f'_{ci}}$

Where computed tensile stresses exceed these values, bonded auxiliary reinforcement (nonprestressed or prestressed) shall be provided in the tensile zone to resist the total tensile force in concrete computed with the assumption of an uncraeked section.

2. Stresses in concrete at service loads (after allowance for all prestress losses) shall not exceed the following:

A. Extreme fiber stress in compression ..... $0.45f'_c$

B. Extreme fiber stress in tension in precompressed tensile zone ..... $6\sqrt{f'_c}$

C. Extreme fiber stress in tension in precompressed tensile zone of members (except two-way slab systems) where analysis based on transformed cracked sections and on bilinear moment-deflection relationships show that immediate and long-time deflections comply with requirements of Section 2609 (f) 4, and where cover requirements comply with Section 2607 (h) 3 B ..... $12\sqrt{f'_c}$

3. Permissible stresses in concrete of Section 2618 (e) 1 and 2 may be exceeded if shown by test or analysis that performance will not be impaired.

(f) **Permissible Stress in Prestressing Tendons.** [18.5] Tensile stress in prestressing tendons shall not exceed the following:

1. Due to tendon jacking force ..... $0.94f_{py}$ but not greater than the lesser of $0.80f_{pu}$ and the maximum value recommended by manufacturer of prestressing tendons or anchorages.

2. Immediately after prestress transfer ..... $0.82f_{py}$ but not greater than $0.74f_{pu}$.

3. Posttensioning tendons, at anchorages and couplers, immediately after tendon anchorage ..... $0.70f_{pu}$

(g) **Loss of Prestress.** [18.6] 1. To determine effective prestress $f_{se}$, allowance for the following sources of loss of prestress shall be considered:

A. Anchorage seating loss.

B. Elastic shortening of concrete.

C. Creep of concrete.

D. Shrinkage of concrete.

E. Relaxation of tendon stress.

F. Friction loss due to intended or unintended curvature in posttensioning tendons.

2. **Friction loss in posttensioning tendons.** A. Effect of friction loss in posttensioning tendons shall be computed by

$$P_s = P_x e^{(Kl_x + \mu\alpha)} \quad (18\text{-}1)$$



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When ($Kl = \mu\alpha$) is not greater than 0.3, effect of friction loss may be computed by

$$P_x = P_x(1 + Kl + \mu\alpha) \quad \text{(18-2)}$$

B. Friction loss shall be based on experimentally determined wobble $K$ and curvature $\mu$ friction coefficients and shall be verified during tendon stressing operations.

C. Values of wobble and curvature coefficients used in design, and acceptable ranges of tendon jacking forces and tendon elongations shall be shown on design drawings.

D. Where loss of prestress in member may occur due to connection of member to adjoining construction, such loss of prestress shall be allowed for in design.

(h) **Flexural Strength.** [18.7] 1. Design moment strength of flexural members shall be computed by the strength design methods of this code. For prestressing tendons, $f_{ps}$ shall be substituted for $f_y$ in strength computations.

2. In lieu of a more accurate determination of $f_{ps}$ based on strain compatibility, the following approximate values of $f_{ps}$ shall be used if $f_{se}$ is not less than $0.5\,f_{pu}$.

A. For members with bonded prestressing tendons:

$$f_{ps} = f_{pu}\left(1 - \frac{\gamma_p}{\beta_1}\left[\rho_p \frac{f_{pu}}{f'_c} + \frac{d'}{d_p}(\omega - \omega')\right]\right). \quad \text{(18-3)}$$

If any compression reinforcement is taken into account when calculating $f_{ps}$ by Formula (18-3), the term

$$\left[\rho_p \frac{f_{pu}}{f'_c} + \frac{d'}{d_p}(\omega - \omega')\right]$$

shall be taken not less than 0.17 and $d'$ shall be no greater than $0.15\,d_p$.

B. For members with unbonded prestressing tendons and with a span-to-depth ratio of 35 or less:

$$f_{ps} = f_{se} + 10{,}000 + \frac{f'_c}{100\rho_p} \quad \text{(18-4)}$$

but $f_{ps}$ in Formula (18-4) shall not be taken greater than $f_{py}$, nor $(f_{se} + 60{,}000)$.

C. For members with unbonded prestressing tendons and with a span-to-depth ratio greater than 35:

$$f_{ps} = f_{se} + 10{,}000 + \frac{f'_c}{300\rho_p} \quad \text{(18-5)}$$

but $f_{ps}$ in Formula (18-5) shall not be taken greater than $f_{py}$, nor $(f_{se} + 30{,}000)$.

3. Nonprestressed reinforcement conforming to Section 2603 (f) 2, if used with prestressing tendons, may be considered to contribute to the tensile force and may be included in moment strength computations at a stress equal to the specified



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yield strength $f_y$. Other nonprestressed reinforcement may be included in strength computations only if a strain compatibility analysis is made to determine stresses in such reinforcement.

(i) **Limits for Reinforcement of Flexural Members.** [18.8] 1. Ratio of prestressed and nonprestressed reinforcement used for computation of moment strength of a member, except as provided in Section 2618 (i) 2, shall be such that $\omega_p[\omega_p + d/d_p(\omega - \omega')]$, or $[\omega_{pw} + d/d_p(\omega_w - \omega'_w)]$ is not greater than $0.36\,\beta_1$.

2. When a reinforcement ratio in exeess of that specified in Section 2618 (i) 1 is provided, design moment strength shall not exceed the moment strength based on the compression portion of the moment couple.

3. Total amount of prestressed and nonprestressed reinforcement shall be adequate to develop a factored load at least 1.2 times the cracking load computed on the basis of the modulus of rupture $f_r$ specified in Section 2609 (f) 2 C, except for flexural members with shear and flexural strength at least twice that required by Section 2609 (c).

(j) **Minimum Bonded Reinforcement.** [18.9] 1. A minimum area of bonded reinforcement shall be provided in all flexural members with unbonded prestressing tendons as required by Section 2618 (j) 2 and 3.

2. Except as provided in Section 2618 (j) 3, minimum area of bonded reinforcement shall be computed by

$$A_s = 0.004A \qquad (18\text{-}6)$$

A. Bonded reinforcement required by Formula (18-6) shall be uniformly distributed over precompressed tensile zone as close as practicable to extreme tension fiber.

B. Bonded reinforcement shall be required regardless of service load stress conditions.

*One-way, unbonded, posttensioned slabs and beams shall be designed to carry the dead load of the slab or beam plus 25 percent of the unreduced superimposed live load by some method other than the primary unbonded posttensioned reinforcement. Design shall be based on the strength method of design with a load factor and capacity reduction factor of one. All reinforcement other than the primary unbonded reinforcement provided to meet other requirements of this section may be used in the design.*

*C. Maximum spacing limitations of Sections 2607 (g) 1 and 2608 (k), Item No. 5 B, for bonded reinforcement in slabs are not applicable to spacing of bonded reinforcement in members with unbonded tendons.*

3. For two-way flat plates, defined as solid slabs of uniform thickness, minimum area and distribution of bonded reinforcement shall be as follows:

A. Bonded reinforcement shall not be required in positive moment areas where computed tensile stress in concrete at service load (after allowance for prestress losses) does not exceed $2\sqrt{f'_c}$.

B. In positive moment areas where computed tensile stress in concrete at



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service load exceeds $2\sqrt{f'_c}$, minimum area of bonded reinforcement shall be computed by

$$A_s = \frac{N_c}{0.5f_y} \quad \text{.....(18-7)}$$

where design yield strength $f_y$ shall not exeeed 60,000 psi. Bonded reinforcement shall be uniformly distributed over preeompressed tensile zone as close as practieable to extreme tension fiber.

C. In negative moment areas at column supports, minimum area of bonded reinforcement in each direction shall be computed by

$$A_s = 0.00075hl \quad \text{.....(18-8)}$$

where $l$ is length of span in direction parallel to that of the reinforcement being determined. Bonded reinforcement required by Formula (18-8) shall be distributed within a slab width between lines that are $1.5h$ outside opposite faces of the column support. At least four bars or wires shall be provided in each direction. Spacing of bonded reinforcement shall not exceed 12 inches.

4. Minimum length of bonded reinforcement required by Section 2618 (j) 2 and 3 shall be as follows:

A. In positive moment areas, minimum length of bonded reinforcement shall be one third the clear span length and centered in positive moment area.

B. In negative moment areas, bonded reinforcement shall extend one sixth the clear span on each side of support.

C. Where bonded reinforcement is provided for design moment strength in accordance with Section 2618 (h) 3, or for tensile stress conditions in accordance with Section 2618 (j) 3, minimum length also shall conform to provisions of Section 2612.

(k) **Frames and Continuous Construction.** [18.10] 1. Frames and continuous construction of prestressed concrete shall be designed for satisfactory performance at service load conditions and for adequate strength.

2. Performance at service load conditions shall be determined by elastic analysis, considering reactions, moments, shears, and axial forces produced by prestressing, creep, shrinkage, temperature change, axial deformation, restraint of attached structural elements and foundation settlement.

3. Moments to be used to compute required strength shall be the sum of the moments due to reactions induced by prestressing (with a load factor of 1.0) and the moments due to factored loads including redistribution as permitted in Section 2618 (k) 4.

4. **Redistribution of negative moments due to gravity loads in continuous prestressed flexural members.** A. Where bonded reinforcement is provided at supports in accordance with Section 2618 (j) 2, negative moments calculated by



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elastic theory for any assumed loading arrangement may be increased or decreased by not more than

$$20\left[1 - \frac{\omega_p + \frac{d}{d_p}(\omega - \omega')}{0.36\beta_1}\right] \text{percent}$$

B. The modified negative moments shall be used for calculating moments at sections within spans for the same loading arrangement.

C. Redistribution of negative moments shall be made only when the section at which moment is reduced is so designed that $\omega_p$, $[\omega_p + d/d_p(\omega - \omega')]$, or $[\omega_{pw} + d/d_p(\omega_w - \omega'_w)]$, whichever is applicable, is not greater than $0.24\beta_1$.

(l) **Compression Members—Combined Flexure and Axial Loads.** [18.11] 1. Prestressed concrete members subject to combined flexure and axial load, with or without nonprestressed reinforcement, shall be proportioned by the strength design methods of this code for members without prestressing. Effects of prestress, creep, shrinkage and temperature change shall be included.

2. **Limits for reinforcement of prestressed compression members.** A. Members with average prestress $f_{pc}$ less than 225 psi shall have minimum reinforcement in accordance with Sections 2607 (k) and 2609 (j) 1 and 2 for columns, or Section 2614 (d) for walls.

B. Except for walls, members with average prestress $f_{pc}$ equal to or greater than 225 psi shall have all prestressing tendons enclosed by spirals or lateral ties in accordance with the following:

(i) Spirals shall conform to Section 2607 (k) 2.

(ii) Lateral ties shall be at least No. 3 in size or welded wire fabric of equivalent area, and spaced vertically not to exceed 48 tie bar or wire diameters or least dimension of compression member.

(iii) Ties shall be located vertically not more than half a tie spacing above top of footing or slab in any story, and shall be spaced as provided herein to not more than half a tie spacing below lowest horizontal reinforcement in members supported above.

(iv) Where beams or brackets frame into all sides of a column, ties may be terminated not more than 3 inches below lowest reinforcement in such beams or brackets.

C. For walls with average prestress $f_{pc}$ equal to or greater than 225 psi, minimum reinforcement required by Section 2614 (d) may be waived where structural analysis shows adequate strength and stability.

(m) **Slab Systems.** [18.12] 1. Factored moments and shears in prestressed slab systems reinforced for flexure in more than one direction shall be determined in accordance with provisions of Section 2613 (i), excluding Sections 2613 (i) 7 D and E), or by more detailed design procedures.



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2. Moment strength of prestressed slabs at every section shall be at least equal to the required strength considering Sections 2609 (c), 2609 (d), 2618 (k) 3 and 2618 (k) 4. Shear strength of prestressed slabs at columns shall be at least equal to the required strength considering Sections 2609 (c), 2609 (d), 2611 (b), 2611 (l) 2 and 2611 (m) 2 D.

3. At service load conditions, all serviceability limitations, including specified limits on deflections, shall be met, with appropriate consideration of the factors listed in Section 2618 (k) 2.

4. For normal live loads and load uniformly distributed, spacing of prestressing tendons or groups of tendons in one direction shall not exceed eight times the slab thickness, nor 5 feet. Spacing of tendons also shall provide a minimum average prestress, after allowance for all prestress losses, of 125 psi on the slab section tributary to the tendon or tendon group. A minimum of two tendons shall be provided in each direction through the critical shear section over columns. Special consideration of tendon spacing shall be provided for slabs with concentrated loads.

5. In slabs with unbonded prestressing tendons, bonded reinforcement shall be provided in accordance with Sections 2618 (j) 3 and 4.

(n) **Tendon Anchorage Zones.** [18.13] 1. Reinforcement shall be provided where required in tendon anchorage zones to resist bursting, splitting and spalling forces induced by tendon anchorages. Regions of abrupt change in section shall be adequately reinforced.

2. End blocks shall be provided where required for support bearing or for distribution of concentrated prestressing forces.

3. Posttensioning anchorages and supporting concrete shall be designed to resist maximum jacking force for strength of concrete at time of prestressing.

4. Posttensioning anchorage zones shall be designed to develop the guaranteed ultimate tensile strength of prestressing tendons using a strength reduction factor $\phi$ of 0.90 for concrete.

(o) **Corrosion Protection for Unbonded Prestressing Tendons.** [18.14] 1. Unbonded tendons shall be completely coated with suitable material to ensure corrosion protection.

2. Tendon wrapping shall be continuous over entire length to be unbonded, and shall prevent intrusion of cement paste or loss of coating materials during concrete placement.

(p) **Posttensioning Ducts.** [18.15] 1. Ducts for grouted or unbonded tendons shall be mortar-tight and nonreactive with concrete, tendons or filler materials.

2. Ducts for grouted single wire, strand or bar tendons shall have an inside diameter at least 1/4 inch larger than tendon diameter.

3. Ducts for grouted multiple wire, strand or bar tendons shall have an inside cross-sectional area at least two times net area of tendons.

4. Ducts shall be maintained free of water if members to be grouted are exposed to temperatures below freezing prior to grouting.



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(q) **Grout for Bonded Prestressing Tendons.** [18.16] 1. Grout shall consist of portland cement and water; or portland cement, sand and water.

2. Materials for grout shall conform to the following:

A. Portland cement shall conform to Section 2603 (c).

B. Water shall conform to Section 2603 (e).

C. Sand, if used, shall conform to *U.B.C. Standard No. 24-21* except that gradation may be modified as necessary to obtain satisfactory workability.

D. Admixtures conforming to Section 2603 (g) and known to have no injurious effects on grout, steel or concrete may be used. Calcium chloride shall not be used.

3. **Selection of group proportions.** A. Proportions of materials for grout shall be based on either of the following:

(i) Results of tests on fresh and hardened grout prior to beginning grouting operations, or

(ii) Prior documented experience with similar materials and equipment and under comparable field conditions.

B. Cement used in the work shall correspond to that on which selection of grout proportions was based.

C. Water content shall be minimum necessary for proper pumping of grout; however, water-cement ratio shall not exceed 0.45 by weight.

D. Water shall not be added to increase grout flowability that has been decreased by delayed use of grout.

4. **Mixing and pumping grout.** A. Grout shall be mixed in equipment capable of continuous mechanical mixing and agitation that will produce uniform distribution of materials, passed through screens, and pumped in a manner that will completely fill tendon ducts.

B. Temperature of members at time of grouting shall be above 35°F. and shall be maintained above 35°F. until field-cured 2-inch cubes of grout reach a minimum compressive strength of 800 psi.

C. Grout temperatures shall not be above 90°F. during mixing and pumping.

(r) **Protection for Prestressing Tendons.** [18.17] Burning or welding operations in vicinity of prestressing tendons shall be carefully performed so that tendons are not subject to excessive temperatures, welding sparks or ground currents.

(s) **Application and Measurement of Prestressing Force.** [18.18] 1. Prestressing force shall be determined by both of the following methods:

A. Measurement of tendon elongation. Required elongation shall be determined from average load-elongation curves for prestressing tendons used.

B. Observation of jacking force on a calibrated gauge or load cell or by use of a calibrated dynamometer.

Cause of any difference in force determination between A and B that exceeds 5 percent shall be ascertained and corrected.



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2. Where transfer of force from bulkheads of pretensioning bed to concrete is accomplished by flame cutting prestressing tendons, cutting points and cutting sequence shall be predetermined to avoid undesired temporary stresses.

3. Long lengths of exposed pretensioned strand shall be cut near the member to minimize shock to concrete.

4. Total loss of prestress due to unreplaced broken tendons shall not exceed 2 percent of total prestress.

(t) **Posttensioning Anchorages and Couplers.** [18.19] 1. Anchorages and couplers for bonded and unbonded prestressed tendons shall develop at least 95 percent of the specified breaking strength of the tendons, when tested in an unbonded condition, without exceeding anticipated set.

For bonded tendons, anchorages and couplers shall be located so that 100 percent of the specified breaking strength of the tendons shall be developed at critical sections after tendons are bonded in the member.

2. Couplers shall be placed in areas approved by the *building official* and enclosed in housing long enough to permit necessary movements.

3. In unbonded construction subject to repetitive loads, special attention shall be given to the possibility of fatigue in anchorages and couplers.

4. Anchorages, couplers and end fittings, shall be permanently protected against corrosion.

## Shells and Folded Plates [Chapter 19]

**Sec. 2619.** (a) **Notations.** [19.0]

$f'_c$ = specified compressive strength of concrete, psi.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

$f_y$ = specified yield strength of nonprestressed reinforcement, psi.

$E_c$ = modulus of elasticity of concrete, psi. See Section 2608 (f).

$h$ = thickness of shell or folded plate, inches.

$\phi$ = strength reduction factor.

(b) **Scope and Definitions.** [19.1] Provisions of Section 2619 shall apply to thin-shell and folded-plate concrete structures, including ribs and edge members.

All provisions of Chapter 26 not specifically excluded, and not in conflict with provisions of Section 2619, shall apply to thin-shell structures.

**THIN SHELLS** are three-dimensional spatial structures made up of one or more curved slabs or folded plates whose thicknesses are small compared to their other dimensions. Thin shells are characterized by their three-dimensional load-carrying behavior which is determined by the geometry of their forms, by the manner in which they are supported and by the nature of the applied load.

**FOLDED PLATES** are a special class of shell structures formed by joining flat, thin slabs along their edges so as to create a three-dimensional spatial structure.

**RIBBED SHELLS** are spatial structures with material placed primarily along



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certain preferred rib lines, with the area between the ribs filled with thin slabs or left open.

**AUXILIARY MEMBERS** are ribs or edge beams which serve to strengthen, stiffen and/or support the shell; usually, auxiliary members act jointly with the shell.

**ELASTIC ANALYSIS** is an analysis of deformations and internal forces based on equilibrium, compatibility of strains and assumed elastic behavior and representing to suitable approximation the three-dimensional action of the shell together with its auxiliary members.

**INELASTIC ANALYSIS** is an analysis of deformations and internal forces based on equilibrium, nonlinear stress-strain relations for concrete and reinforcement, consideration of cracking and time-dependent effects and compatibility of strains. The analysis shall represent to suitable approximation the three-dimensional action of the shell together with its auxiliary members.

**EXPERIMENTAL ANALYSIS** is an analysis procedure based on the measurement of deformations and/or strains of the structure or its model; experimental analysis may be based on either elastic or inelastic behavior.

(c) **Analysis and Design.** [19.2] 1. Elastic behavior shall be an accepted basis for determining internal forces and displacements of thin shells. This behavior may be established by computations based on an analysis of the uncracked concrete structure in which the material is assumed linearly elastic, homogeneous and isotropic. Poisson's ratio of concrete may be assumed equal to zero.

2. Inelastic analysis may be used where it can be shown that such methods provide a safe basis for design.

3. Equilibrium checks of internal resistances and external loads shall be made to ensure consistency of results.

4. Experimental or numerical analysis procedures may be used where it can be shown that such procedures provide a safe basis for design.

5. Approximate methods of analysis not satisfying compatibility of strains either within the shell or between the shell and auxiliary members may be used where it can be shown that such methods provide a safe basis for design.

6. In prestressed shells, the analysis must also consider behavior under loads induced during prestressing, at cracking load and at factored load. Where prestressing tendons are draped within a shell, design shall take into account force components on the shell resulting from tendon profile not lying in one plane.

7. The thickness $h$ of a thin shell and its reinforcement shall be proportioned for the required strength and serviceability. All elements shall be proportioned by the same method, using either the strength design method of Section 2608 (b) or the alternate design method of Section *2626*.

8. Shell design shall investigate and preclude the possibility of general or local instability.

9. Auxiliary members shall be designed according to the applicable provisions of this code. The design method selected for shell elements under Section 2619 (c) 7 shall also be used for auxiliary members. A portion of the shell equal to the



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flange width specified in Section 2608 (k) may be assumed to aet with the auxiliary member. In such portions of the shell, the reinforcement perpendicular to the auxiliary member shall be at least equal to that required for the flange of a T-beam by Section 2608 (k) 5.

(d) **Design Strength of Materials.** [19.3] 1. Speeified compressive strength of conerete $f'_c$ at 28 days shall be not less thàn 3000 psi.

2. Specified yield strength of nonprestressed reinforeement $f_y$ shall not exeeed 60,000 psi.

(e) **Shell Reinforcement.** [19.4] 1. Shell reinforcement shall be provided to resist tensile stresses from internal membrane forces, to resist bending and twisting moments, to control shrinkage and temperature cracking and as special reinforcement as shell boundaries, load attachments and shell openings.

2. Membrane reinforcement shall be provided in two or more directions in all parts of the shell.

3. The area of shell reinforcement at any section as measured in two orthogonal directions shall not be less than the slab shrinkage or temperature reinforeement required by Section 2607 (m).

4. Reinforcement required to resist shell membrane forces shall be provided so that the design strength in every direction shall be at lcast equal to the eomponent of the principal membrane forces in the same direetion due to faetored loads.

5. The area of shell tension reinforcement shall be limited so that the reinforcement will yield before crushing of concrete in eompression can take place.

6. In regions of high tension, membrane reinforeement shall, if practical, be placed in the general directions of the principal tensile membrane forces. Where this is not praetieal, membrane reinforcement may be placed in two or more component directions.

7. If the direction of reinforcement varies more than 10 degrees from the direction of principal tensile membrane force, the amount of reinforcement may have to be increased to limit the width of possible cracks at service load levels.

8. Where the magnitude of the principal tensile membrane stress within the shell varies greatly over the area of the shell surfaee, reinforcement resisting the total tension may be concentrated in the regions of largest tensile stress where it can be shown that this provides a safe basis for design. However, the ratio of shell reinforeement in any portion of the tensile zone shall be not less than 0.0035 based on the overall thickness of the shell.

9. Reinforcement required to resist shell bending moments shall be proportioned with due regard to the simultaneous action of membrane axial forces at the same location. Where shell reinforcement is required in only one face to resist bending moments, equal amounts shall be placed near both surfaces of the shell even though a reversal of bending moments is not indicated by the analysis.

10. Shell reinforeement in any direction shall not be spaced farther apart than 18 inches, nor five times the shell thickness. Where the principal membrane tensile stress on the gross concrete area due to faetored loads exceeds $4\ \phi\ \sqrt{f'_c}$,



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reinforcement shall not be spaced farther apart than three times the shell thickness.

11. Shell reinforcement at the junction of the shell and supporting members or edge members shall be anchored in or extended through such members in accordance with the requirements of Section 2612, except that the minimum development length shall be 1.2 $d$ but not less than 18 inches.

12. Splice development lengths of shell reinforcement shall be governed by the provisions of Section 2612, except that the minimum splice length of tension bars shall be 1.2 times the value required by Section 2612 but not less than 18 inches. The number of splices in principal tensile reinforcement shall be kept to a practical minimum. Where splices are necessary, they shall be staggered at least $ld$ with not more than one third of the reinforcement spliced at any section.

(f) **Construction.** [19.5] 1. When removal of formwork is based on a specific modulus of elasticity of concrete because of stability or deflection considerations, the value of the modulus of elasticity $E_c$ shall be determined from flexural tests of field-cured beam specimens. The number of test specimens, the dimensions of test beam specimens and test procedures shall be specified.

2. *The tolerances for the shape of the shell shall be specified.* If construction results in deviations from the shape greater than the specified tolerances, an analysis of the effect of the deviations shall be made and any required remedial actions shall be taken to ensure safe behavior.

## Strength Evaluation of Existing Structures [Chapter 20]

**Sec. 2620.** (a) **Notations.** [20.0]

$a$ = maximum deflection under test load of member relative to a line joining the ends of the span, or of the free end of cantilever relative to its support, inches.

$D$ = dead loads, or related internal moments and forces.

$h$ = overall thickness of member, inches.

$l_t$ = span of member under load test (shorter span of flat slabs and of slabs supported on four sides). Span of member, except as provided in Section 2620 (e) 9, is distance between centers of supports or clear distance between supports plus depth of member, whichever is smaller, inches.

$L$ = live loads, or related internal moments and forces.

(b) **Strength Evaluation—General.** [20.1] If doubt develops concerning the safety of a structure or member, the building official may order a structural strength investigation by analyses or by means of load tests, or by a combination of analyses and load tests.

(c) **Analytical Investigations—General.** [20.2] If strength evaluation is by analysis, a thorough field investigation shall be made of dimensions and details of members, properties of materials and other pertinent conditions of the structure as actually built.



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Analyses based on investigation required by this subsection shall satisfy the building official that the load factors meet requirements and intent of this code. See Section 2620 (g).

(d) **Load Tests—General.** [20.3] If strength evaluation is by load tests, a qualified engineer acceptable to the building official shall control such tests.

A load test shall not be made until that portion of the structure to be subject to load is at least 56 days old. When the owner of the structure, the contractor and all involved parties mutually agree, the test may be made at an earlier age.

When only a portion of the structure is to be load tested, the questionable portion shall be load tested in such a manner as to adequately test the suspected source of weakness.

Forty-eight hours prior to application of test load, a load to simulate effect of that portion of the dead loads not already acting shall be applied and shall remain in place until all testing has been completed.

(e) **Load Tests of Flexural Members.** [20.4] 1. When flexural members, including beams and slabs, are load tested, the additional provisions of this subsection shall apply.

2. Base readings (datum for deflection measurements) shall be made immediately prior to application of test load.

3. That portion of the structure selected for loading shall be subject to a total load, including dead loads already acting, equivalent to $0.85\ (1.4D + 1.7L)$. Determination of $L$ shall include live load reductions as permitted by Section 2306.

4. Test load shall be applied in not less than four approximately equal increments without shock to the structure and in such a manner as to avoid arching of loading materials.

5. After test load has been in position for 24 hours, initial deflection readings shall be taken.

6. Test load shall be removed immediately after initial deflection readings, and final deflection readings shall be taken 24 hours after removal of the test load.

7. If the portion of the structure tested shows visible evidence of failure, the portion tested shall be considered to have failed the test and no retesting of the previously tested portion shall be permitted.

8. If the portion of the structure tested shows no visible evidence of failure, the following criteria shall be taken as indication of satisfactory behavior:

A. If measured maximum deflection $a$ of a beam, floor or roof is less than $l_t^2/20{,}000h$.

B. If measured maximum deflection $a$ of a beam, floor or roof exceeds $l_t^2/20{,}000h$, deflection recovery within 24 hours after removal of the test load shall be at least 75 percent of the maximum deflection for nonprestressed concrete, or 80 percent for prestressed concrete.

9. In Sections 2620 (c) 8 A and B, $l_t$ for cantilevers shall be taken as two times



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the distance from support to cantilever end, and deflection shall be adjusted for any support movement.

10. Nonprestressed concrete construction failing to show 75 percent recovery of deflection as required by Section 2620 (e) 8 B may be retested not earlier than 72 hours after removal of the first test load. The portion of the structure tested shall be considered satisfactory if:

A. The portion of the structure tested shows no visible evidence of failure in the retest, and

B. Deflection recovery caused by second test load is at least 80 percent of the maximum deflection in the second test.

11. Prestressed concrete construction shall not be retested.

(f) **Members Other Than Flexural Members.** [20.5] Members other than flexural members preferably shall be investigated by analysis.

(g) **Provision for Lower Load Rating.** [20.6] If structure under investigation does not satisfy conditions or criteria of Section 2620 (c); (e) 8 or (e) 10, the building official may approve a lower load rating for that structure based on results of the load test or analysis.

(h) **Safety.** [20.7] Load tests shall be conducted in such a manner as to provide for safety of life and structure during the test.

No safety measures shall interfere with load test procedures or affect results.

### *Shotcrete*

***Sec. 2621.*** *(a) **General.** Shotcrete shall be defined as mortar or concrete pneumatically projected at high velocity onto a surface. Except as specified in this section, shotcrete shall conform to the regulations of this chapter for plain concrete or reinforced concrete.*

*(b) **Proportions and Materials.** Shotcrete proportions shall be selected that allow suitable placement procedures using the delivery equipment selected and shall result in finished in-place hardened shotcrete meeting the strength requirements of this code.*

*(c) **Aggregate.** Coarse aggregate, if used, shall not exceed 3/4 inch.*

*(d) **Reinforcement.** The maximum size of reinforcement shall be No. 5 bars unless it can be demonstrated by preconstruction tests that adequate encasement of larger bars can be achieved. When No. 5 or smaller bars are used, there shall be a minimum clearance between parallel reinforcement bars of 2 1/2 inches. When bars larger than No. 5 are permitted, there shall be a minimum clearance between parallel bars equal to six diameters of the bars used. When two curtains of steel are provided, the curtain nearest the nozzle shall have a spacing equal to 12 bar diameters and the remaining curtain shall have a minimum spacing of six bar diameters.*

*Lap splices in reinforcing bars shall be by the noncontact lap splice method with at least 2 inches clearance between bars. The building official may permit the use of contact lap splices when necessary for the support of the reinforcing*



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*provided it can be demonstrated by means of preconstruction testing, that adequate encasement of the bars at the splice can be achieved and provided that the splices are placed so that a line through the center of the two spliced bars is perpendicular to the surface of the shotcrete work.*

*Shatcrete shall not be applied to spirally tied columns.*

*(e) **Preconstruction Tests.** When required by the building official a test panel shall be shot, cured, cored or sawn, examined and tested prior to commencement of the project. The sample panel shall be representative of the project and simulate job conditions as closely as possible. The panel thickness and reinforcing shall reproduce the thickest and most congested area specified in the structural design. It shall be shot at the same angle, using the same nozzleman and with the same concrete mix design that will be used on the project.*

*(f) **Rebound.** Any rebound or accumulated loose aggregate shall be removed fram the surfaces to be covered prior to placing the initial or any succeeding layers of shotcrete. Rebound shall not be reused as aggregate.*

*(g) **Joints.** Except where permitted herein, unfinished work shall not be allowed to stand for more than 30 minutes unless all edges are sloped to a thin edge. Before placing additional material adjacent to previously applied work, sloping and square edges shall be cleaned and wetted.*

*(h) **Damage.** An in-place shotcrete which exhibits sags or sloughs, segregation, honeycombing, sand pockets or other obvious defects shall be removed and replaced.*

*(i) **Curing.** During the curing periods specified herein, shotcrete shall be maintained above 40°F. and in moist condition. In initial curing, shotcrete shall be kept continuously moist for 24 hours after placement is complete. Final curing shall continue for seven days after shotcreting, for three days if high-early-strength cement is used, or until the specified strength is obtained. Final curing shall consist of a fog spray or an approved moisture-retaining cover or membrane. In sections of a depth in excess of 12 inches, final curing shall be the some as that for initial curing.*

*(j) **Strength Test.** Strength test for shotcrete shall be made in accordance with U.B.C. Standard No. 26-10 by an appraved agency on specimens which are representative of work and which have been water soaked for at least 24 hours prior to testing. When the maximum size aggregate is larger than 3/8 inch, specimens shall consist of not less than three 3-inch-diameter cores or 3 inch cubes. When the maximum size aggregate is 3/8 inch or smaller, specimens shall consist of not less than three 2-inch-diameter cores or 2-inch cubes. Specimens shall be taken in accordance with one of the following:*

*1. From the inplace work: taken at least once each shift nor less than one for each 50 cubic yards of shotcrete; or*

*2. From test panels: made not less than once each shift nor less than one for each 50 cubic yards of shotcrete placed. When the maximum size aggregate is larger than 3/8 inch, the test panels shall have a minimum dimension of 18 by 18 inches. When the maximum size aggregate is 3/8 inch or smaller, the test panels*



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*shall have a minimum dimension of 12 by 12 inches. Panels shall be gunned in the same position as the work, during the course of the work and by nozzlemen doing the work. The condition under which the panels are cured shall be the same as the work.*

*The average of three cores from a single panel shall be equal to or exceed 0.85 $f'_c$ with no single core less than 0.75 $f'_c$. The average of three cubes taken from a single panel must equal or exceed $f'_c$ with no individual cube less than 0.88 $f'_c$. To check testing accuracy, locations represented by erratic core strengths may be retested.*

*(k) **Inspections.** 1. **During placement.** When shotcrete is used for columns and beams, a special inspector is required by Section 306 (a) 12. The special inspector shall provide continuous inspection of the placement of the reinforcement and shotcreting and shall submit a statement indicating compliance with the plans and specifications.*

*2. **Visual examination for structural soundness of in-place shotcrete.** Completed shotcrete work shall be checked visually for reinforcing bar embedment, voids, rock pockets, sand streaks and similar deficiencies by examining a minimum of three 3-inch cores taken from three areas chosen by the design engineer which represent the worst congestion of reinforcing bars occurring in the project. Extra reinforcing bars may be added to noncongested areas and cores may be taken from these areas. The cores shall be examined by the special inspector and a report submitted to the building official prior to final approval of the shotcrete.*

***EXCEPTION:** Shotcrete work fully supported on earth, minor repairs and when, in the opinion of the building official, no special hazard exists.*

*(l) **Equipment.** The equipment used in preconstruction testing shall be the same equipment used in the work requiring such testing, unless substitute equipment is approved by the building official.*

## Plain Concrete

***Sec. 2622.** (a) **General.** Plain concrete, other than fill, shall have a minimum ultimate compressive strength at 28 days of 2000 pounds per square inch, and material proportioning and placing shall conform to the requirements of this chapter. Concrete made with lightweight aggregates may be used with strengths less than 2000 pounds per square inch if it has been shown by tests or experience to have sufficient strength and durability.*

*Provisions shall be made to care for temperature and shrinkage stresses either by use of reinforcement or by means of joints.*

*Plain concrete construction shall conform to the detailed minimum requirements specified in this chapter.*

*Plain concrete shall not be used in Seismic Zone No. 2, 3 or 4.*

***EXCEPTION:** Plain concrete may be used for footings of Group R, Division 3 Occupancies constructed in accordance with Section 2517.*

*(b) **Wall Thickness.** Except where justifying data are submitted, the thickness of plain concrete walls shall be not less than 6 inches and the ratio of unsupported height or length (whichever is the lesser) to thickness shall be not greater than 22.*



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*(c) **Design.** Plain concrete walls shall be designed to withstand all vertical and horizontal loads as specified in Chapter 23.*

*(d) **Stresses.** The allowable working stresses in plain concrete walls shall not exceed the following percentages of ultimate strength:*

1. *Compression—$.25f'_c$*
2. *Tension—$1.6\sqrt{f'_c}$*
3. *Shear—$.02f'_c$*

## Minimum Slab Thickness

***Sec. 2623.** The minimum thickness of concrete floor slabs supported directly on the ground shall be not less than 3 1/2 inches.*

## Anchorage to Concrete

***Sec. 2624.** (a) **Service Load Design.** Bolts and headed stud anchors shall be solidly cast in concrete and the service load shear and tension shall not exceed the values set forth in Table No. 26-F.*

*For combined tension and shear:*

$$(P_s/P_t)^{5/3} + (V_s/V_t)^{5/3} \leq 1$$

***WHERE:***

$P_s$ = *Applied service tension load.*

$P_t$ = *Table No. 26-F service tension load.*

$V_s$ = *Applied service shear load.*

$V_t$ = *Table No. 26-F service shear load.*

*(b) **Strength Design.** The factored loads on embedded anchor bolts and headed studs shall not exceed the design strengths determined by Subsection 2624 (c).*

*In addition to the load factors in Section 2609 (c), a multiplier of 2 shall be used if special inspection is not provided or of 1.3 if it is provided. When anchors are embedded in the tension zone of a member, the load factors in Section 2609 (c) shall have a multiplier of 3 if special inspection is not provided or of 2 if it is provided.*

*(c) **Strength of Anchors.** The strength of concrete anchors shall be taken as the average of ten tests, approved by the building official, for each concrete strength and anchor size or calculated as the minimum of $P_s$ or $\phi P_c$ in tension and $V_s$ or $\phi V_c$ in shear when:*

$P_s = 0.9 A_b f'_s$

$\phi P_c = \phi\lambda\sqrt{f'_c}(2.8A_s + 4A_t)$, *when edge distance is less than embedment length, reduce proportionately. For multiple edge distances less than the embedment length, use multiple reductions.*

$V_s = .75 A_b f'_s$

$\phi V_c = \phi 800 A_b \lambda\sqrt{f'_c}$ *when loaded toward an edge greater than 10 diameters away.*



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$\phi V_c = \phi 2\ \pi d_e^2 \lambda \sqrt{f'_c}$ when loaded toward an edge less than 10 diameters away.

For groups of anchors the concrete design shear strength shall be taken as the smallest of:

1. The strength of the weakest stud times the number of studs.
2. The strength of the row of studs nearest the free edge in the direction of shear times the number of rows.
3. The strength of the row farthest from the free edge in the direction of shear.

For shear loading toward an edge less than 10 diameters away, or tension or shear not toward an edge less than 4 diameters away, reinforcing sufficient to carry the load shall be provided to prevent failure of the concrete in tension. In no case shall the edge distance be less than one-third the above. The bearing area of headed anchors shall be at least one and one-half times the shank area for anchors of not over 120,000 psi yield strength.

When tension and shear act simultaneously both the following shall be met:

$$(1/\phi)\ [(P_u/P_c)^2 + (V_u/V_c)^2] \leq 1$$

$$(P_u/P_s)^2 + (V_u/V_s)^2 \leq 1$$

**WHERE:**

$A_b$ = Area (in square inches) of bolt or stud. Must be used with the corresponding steel properties to determine the weakest part of the assembly in tension. In shear the insert leg need not be checked.

$A_s$ = The sloping area (in square inches) of an assumed failure surface. The surface to be that of a cone or truncated pyramid radiating at a 45 degree slope from the bearing edge of the anchor or anchor group to the surface.

For thin sections with anchor groups the failure surface shall be assumed to follow the extension of this slope through to the far side rather than truncate as in $A_t$.

$A_t$ = The area (in square inches) of the flat bottom of the truncated pyramid of an assumed concrete failure surface. When anchors in a group are closer together than twice their embedded length, the failure surface pyramid is assumed to truncate at the anchor bearing edge rather than form separate cones.

$d_e$ = Distance from the anchor axis to the free edge.

$f'_c$ = Concrete strength, 6000 psi limit for design.

$f'_s$ = Ultimate tensile strength (in psi) of the bolt, stud or insert leg wires. For A307 bolts or A108 studs may be assumed to be 60,000.

$P_u$ $V_u$ = Tensile, shear strength required due to factored loads (in pounds).

$\lambda$ = 1 for normal weight, 0.75 for "all lightweight" and 0.85 for "sand lightweight" concrete.

$\phi$ = Strength reduction factor = 0.65.



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*EXCEPTION: When the anchor is attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to reinforcing steel which is designed to distribute forces and avert sudden local failure $\phi$ may be taken as 0.85.*

## Reinforced Concrete Structures Resisting Forces Induced by Earthquake Motions [Appendix A]

**Sec. 2625.** (a) **Notations.** [A.0]

$A_{ch}$ = cross-sectional area of a structural member measured out-to-out of transverse reinforcement, square inches.

$A_{cp}$ = area of concrete section, resisting shear, of an individual pier or horizontal wall segment, square inches.

$A_{cv}$ = net area of concrete section bounded by web thickness and length of section in the direction of shear force considered, square inches.

$A_g$ = gross area of section, square inches.

$A_j$ = effective cross-sectional area within a joint *[see Section 2625 (g) 3 A]*.

$A_{sh}$ = total cross-sectional area of transverse reinforcement (including cross-ties) within spacing, $s$, and perpendicular to dimension, $h_c$.

$A_v$ = total cross-sectional area of shear reinforcement within spacing, $s$, and perpendicular to longitudinal axis of structural member, square inches.

$b$ = effective compressive flange width of a structural member, inches.

$b_w$ = web width, or diameter of circular section, inches.

$d$ = effective depth of section.

$d_b$ = bar diameter.

$E$ = load effects of earthquake, or related internal moments and forces.

$f'_c$ = specified compressive strength of concrete, psi.

$f_y$ = specified yield strength of reinforcement, psi.

$f_{yh}$ = specified yield strength of transverse reinforcement, psi.

$h$ = overall thickness of structural member.

$h_c$ = cross-sectional dimension of column core measured center-to-center of confining reinforcement.

$h_w$ = height of entire wall (diaphragm) or of the segment of wall (diaphragm) considered.

$l_d$ = development length for a straight bar.

$l_{dh}$ = development length for a bar with a standard hook as defined in Formula (25-5).

$l_o$ = minimum length, measured from joint face along axis of structural member, over which transverse reinforcement must be provided, inches.

$l_w$ = length of entire wall (diaphragm) or of segment of wall (diaphragm) considered in direction of shear force.

$M_s$ = portion of slab moment balanced by support moment.



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$s$ = spacing of transverse reinforcement measured along the longitudinal axis of the structural member, inches.

$s_o$ = maximum spacing of transverse reinforcement, inches.

$V_c$ = nominal shear strength provided by concrete.

$V_e$ = design shear force determined from Section 2625 (h) 1 A or B.

$V_n$ = nominal shear strength.

$V_u$ = factored shear force at section.

$\alpha_c$ = coefficient defining the relative contribution of concrete strength to wall strength.

$\rho$ = ratio of nonprestressed tension reinforcement $= A_s/bd$.

$\rho_g$ = ratio of total reinforcement area to cross-sectional area of column.

$\rho_n$ = ratio of distributed shear reinforcement on a plane perpendicular to plane of $A_{cv}$.

$\rho_s$ = ratio of volume of spiral reinforcement to the core volume confined by the spiral reinforcement (measured out-to-out).

$\rho_v$ = $A_{sv}/A_{cv}$; where $A_{sv}$ is the projection on $A_{cv}$ of area of distributed shear reinforcement crossing the plane of $A_{cv}$.

$\phi$ = strength reduction factor.

(b) **Definitions.** [A.1] *For the purposes of this section, certain terms are defined as follows:*

**BASE OF STRUCTURE.** *See Section 2312 (b).*

**CONFINED CORE** is the area within the core defined by $h_c$.

**CROSSTIE** is a continuous bar having a 135-degree hook with at least a six-diameter extension at one end and a 90-degree hook with at least a six-diameter extension at the other end. The hooks shall engage peripheral longitudinal bars.

**DESIGN LOAD COMBINATIONS** are combinations of factored loads and forces specified in Sections *2609 (c) and 2625 (c) 4*.

**DEVELOPMENT LENGTH FOR A BAR WITH A STANDARD HOOK** is the shortest distance between the critical section (where the strength of the bar is to be developed) and a tangent to the outer edge of the 90-degree hook.

**FACTORED LOADS AND FORCES** are the specified loads and forces modified by the factors in Sections *2609 (c) and 2625 (c) 4*.

**HOOP** is a closed tie or continuous wound tie, the ends of which have 135-degree hooks with six-diameter extensions, that encloses the longitudinal reinforcement.

***IMRFS** is an intermediate moment-resisting space frame conforming to the provisions of Section 2625 (k).*

**LIGHTWEIGHT-AGGREGATE CONCRETE** is "all-lightweight" or "sanded-lightweight" aggregate concrete made with lightweight aggregates conforming to Section 2603 (d).



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*SEISMIC HOOK is a 135-degree bend with a six-bar-diameter, but not less than 3-inch, extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop.*

**SHELL CONCRETE** is concrete outside the transverse reinforcement confining the concrete.

*SMRSF is a special moment-resisting space frame conforming to provisions of Section 2625, as they apply to moment-resisting frames.*

**SPECIFIED LATERAL FORCES** are lateral forces corresponding to the appropriate distribution of the design base shear force prescribed by the governing code for earthquake-resistant design.

**STRUCTURAL DIAPHRAGMS** are structural members, such as floor and roof slabs, which transmit inertial forces to lateral-force resisting members.

**STRUCTURAL TRUSSES** are assemblages of reinforced concrete members subjected primarily to axial forces.

**STRUT** is an element of a structural diaphragm used to provide continuity around an opening in the diaphragm.

**TIE ELEMENTS** are elements which serve to transmit inertia forces and prevent separation of such building components as footings and walls.

(c) **General Requirements.** [A.2] 1. **Scope.** A. Section 2625 contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

B. The provisions of Sections 2601 through 2617 shall apply except as modified by the provisions of Section 2625.

C. *In Seismic Zones Nos. 0 and 1, the provisions of Section 2625 shall not apply.*

*D. In Seismic Zone No. 2, reinforced concrete frames resisting forces induced by earthquake motions shall be intermediate moment-resisting space frames proportioned to satisfy only Section 2625 (k) in addition to the requirements of Sections 2601 through 2618.*

*E. In Seismic Zones Nos. 3 and 4,* all structural reinforced concrete members shall satisfy Sections 2625 (c) through 2625 (i) in addition to the requirements of Section 2601 through 2617.

F. A reinforced concrete structural system not satisfying the requirements of this section may be used if it is demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure satisfying this section.

2. **Analysis and proportioning of structural members.** A. The interaction of all structural and nonstructural members which materially affect the linear and nonlinear response of the structure to earthquake motions shall be considered in the analysis.

B. Rigid members assumed not to be a part of the lateral-force-resisting system



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may be used, provided their effect on the response of the system is considered and accommodated in the structural design. Consequences of failure of structural and nonstructural members which are not a part of the lateral-force-resisting system shall also be considered.

C. Structural members below base of structure required to transmit to the foundation forces resulting from earthquake effects shall also comply with the requirements of Section 2625.

D. All structural members assumed not to be part of the lateral-force-resisting system shall conform to Section 2625 (i).

3. **Strength-reduction factors.** Strength-reduction factors shall be as given in Section 2609 (d), except for the following:

A. *The shear strength reduction factor for walls, for topping slabs used as diaphragms over precast concrete members and for structural members, except joints, where their nominal shear strength is less than the shear corresponding to development of their nominal flexural strength shall be 0.6.* The shear strength reduction factor for joints shall be 0.85.

B. The strength reduction factor for axial compression and flexure shall be 0.5 for all frame members with factored axial compressive forces exceeding $(A_g f'_c/10)$ if the transverse reinforcement does not conform to Section 2625 (e) 4.

*4. **Load factors.** For earthquake loading, the load factors given in Equations (9-2) and (9-3) shall be modified to:*

$$U = 1.4\,(D + L + E)$$

$$U = 0.9D \pm 1.4E$$

5. **Concrete in members resisting earthquake-induced forces.** A. Compressive strength $f'_c$ shall be not less than 3000 psi.

B. Compressive strength of lightweight-aggregate concrete used in design shall not exceed 4000 psi. Lightweight-aggregate concrete with higher design compressive strength may be used if demonstrated by experimental evidence that structural members made with that lightweight-aggregate concrete provide strength and toughness equal to or exceeding those of comparable members made with normal-weight aggregate concrete of the same strength. *In no case shall the compressive strength of lightweight concrete used in design exceed 6000 psi.*

6. **Reinforcement in members resisting earthquake-induced forces.** Reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary members shall comply with *U.B.C. Standard No. 26-4 for low alloy* A706. Billet steel A615 Grades 40 and 60 reinforcement may be used in these members if (1) the actual yield strength based on mill tests does not exceed the specified yield strength by more than 18,000 psi (retests shall not exceed this value by more than an additional 3000 psi), and (2) the ratio of the actual ultimate tensile stress to the actual tensile yield strength is not less than 1.25. Reinforcement required by design load combinations which include earthquake effect shall not be welded except as specified in Sections 2625 (d) 2 D and 2625 (e) 3 B. *When*



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*reinforcing bars are to be welded, the bars shall comply with Uniform Building Code Standard No. 26-4 for A 706 or A 615 bars. Welding shall comply with Uniform Building Code Standard No. 26-8. Welding of stirrups, ties, inserts or other similar elements to longitudinal reinforcing bars shall not be permitted.*

(d) **Flexural Members of Frames.** [A.3] 1. **Scope.** Requirements of Section 2625 (d) apply to frame members (1) resisting earthquake-induced forces, (2) proportioned primarily to resist flexure, and (3) satisfying the following conditions:

A. Factored axial compressive force on the member shall not exceed $(A_g f'_c/10)$.

B. Clear span for the members shall not be less than four times its effective depth.

C. The width-to-depth ratio shall not be less than 0.3.

D. The width shall not be (1) less than 10 inches, and (2) more than the width of the supporting member (measured on a plane perpendicular to the longitudinal axis of the flexural member) plus distances on each side of the supporting member not exceeding three fourths of the depth of the flexural member.

2. **Longitudinal reinforcement.** A. At any section of a flexural member and for the top as well as for bottom reinforcement, the amount of reinforcement shall not be less than $(200\, b_w d/f_y)$. The reinforcement ratio, $\rho$, shall not exceed 0.025. At least two bars shall be provided continuously both top and bottom.

B. Positive-moment strength at joint face shall be not less than one half of the negative-moment strength provided at that face of the joint. Neither the negative nor the positive-moment strength at any section along member length shall be less than one-fourth the maximum moment strength provided at face of either joint.

C. Lap splices of flexural reinforcement shall be permitted only if hoop or spiral reinforcement is provided over the lap length. Maximum spacing of the transverse reinforcement enclosing the lapped bars shall not exceed $d/4$ or 4 inches. Lap splices shall not be used (1) within the joints, (2) within a distance of twice the member depth from the face of joint, and (3) at locations where analysis indicates flexural yielding caused by inelastic lateral displacements of the frame.

D. Welded splices and mechanical connections conforming to Sections 2612 (o) 3 A through D may be used for splicing, provided not more than alternate bars in each layer of longitudinal reinforcement are spliced at a section and the center-to-center distance between splices of adjacent bars is 24 inches or more measured along the longitudinal axis of the frame member.

3. **Transverse reinforcement.** A. Hoops shall be provided in the following regions of frame members:

(i) Over a length equal to twice the member depth measured from the face of the supporting member toward midspan, at both ends of the flexural members.

(ii) Over lengths equal to twice the member depth on both sides of a section



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where flexural yielding may occur in conneetion with inelastic lateral displacements of the frame.

B. The first hoop shall be located not more than 2 inches from the face of a supporting member. Maximum spacing of the hoops shall not exceed (1) $d/4$, (2) eight times the diameter of the smallest longitudinal bars, (3) 24 times the diameter of the hoop bars, and (4) 12 inches.

C. Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to Section 2607 (k) 3 C.

D. Where hoops are not required, stirrups with 135-degree seismic hooks shall be spaced at no more than $d/2$ throughout the length of the member.

E. Hoops in flexural members may be made up of two pieces of reinforcement: a stirrup having 135-degree hooks with six-diameter extensions anchored in the confined core and a crosstie to make a closed hoop. Consecutive crossties shall have their 90-degree hooks at opposite sides of the flexural member. If the longitudinal reinforcing bars secured by the crossties are confined by a slab only on one side of the flexural frame member, the 90-degree hooks of the crossties shall all be placed on that side.

(e) **Frame Members Subjected to Bending and Axial Load.** [A.4] 1. **Scope.** The requirements of this section apply to all members *of the system resisting gravity loads by axial compression and to frame members which resist earthquake forces and have a factored axial compressive force exceeding* ($A_g f'_c/10$). Frame members shall satisfy the following conditions:

A. The shortest cross-sectional dimension, measured on a straight line passing through the geometric centroid, shall be not less than 12 inches.

B. The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall be not less than 0.4.

2. **Minimum flexural strength of columns.** A. Flexural strength of any column proportioned to resist a factored axial compressive force exceeding ($A_g f'_c/10$) shall satisfy Section 2625 (e) 2 B or C.

Lateral strength and stiffness of columns not satisfying Section 2625 (e) 2 B shall be ignored in determining the calculated strength and stiffness of the structure but shall conform to Section 2625 (i).

B. The flexural strengths of the columns shall satisfy Formula (25-1).

$$\Sigma M_c \geq (6/5)\Sigma M_g \quad \text{.....(25-1)}$$

**WHERE:**

$\Sigma M_c$ = sum of moments, at the center of the joint, corresponding to the design flexural strength of the columns framing into that joint. Column flexural strength shall be calculated for the factored axial force, consistent with the direction of the lateral forces considered, resulting in the lowest flexural strength.

$\Sigma M_g$ = sum of moments, at the center of the joint, corresponding to the design flexural strengths of the girders framing into that joint.



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Flexural strengths shall be summed such that the column moments oppose the beam moments. Formula (25-1) shall be satisfied for beam moments acting in both directions in the vertical plane of the frame considered.

C. If Section 2625 (e) 2.B is not satisfied at a joint, columns supporting reactions from that joint shall be provided with transverse reinforcement as specified in Section 2625 (c) 4 over their full height.

3. **Longitudinal reinforcement.** A. The reinforcement ratio $\rho_g$ shall be not less than 0.01 and shall not exceed 0.06.

*B. Lap splices are permitted only within the center half of the member length. They shall be proportioned as Class A tension splices in accordance with Section 2612 and shall have transverse reinforcement over the full lap splice length in accordance with Section 2625 (e) 4.* Welded splices and mechanical connections conforming to Sections 2612 (o) 3.A through D may be used for splicing the reinforcement at any section, provided not more than alternate longitudinal bars are spliced at a section and the distance between splices is 24 inches or more along the longitudinal axis of the reinforcement.

4. **Transverse reinforcement.** A. Transverse reinforcement as specified below shall be provided unless a larger amount is required by Section 2625 (h).

(i) The volumetric ratio of spiral or circular hoop reinforcement, $\rho_s$, shall not be less than that indicated by Formula (25-2).

$$\rho_s = 0.12 f'_c / f_{yh} \quad \text{.....(25-2)}$$

and shall be not less than that required by Formula (10-5).

(ii) The total cross-sectional area of rectangular hoop reinforcement shall not be less than that given by Formulas (25-3) and (25-4).

$$A_{sh} = 0.3\,(sh_c f'_c / f_{yh}) \left[ (A_g / A_{ch}) - 1 \right] \quad \text{.....(25-3)}$$

$$A_{sh} = 0.12\,(sh_c f'_c / f_{yh}) \quad \text{.....(25-4)}$$

(iii) Transverse reinforcement may be provided by single or overlapping hoops. Crossties of the same bar size and spacing as the hoops may be used. Each end of the crosstie shall engage a peripheral longitudinal reinforcing bar *and be secured to the peripheral hoop.* Consecutive crossties shall be alternated end for end along the longitudinal reinforcement.

(iv) If the design strength of member core satisfies the requirement of the specified loading combinations including earthquake effect, Formulas (25-3) and (10-5) need not be satisfied.

*(v) Any area of a column which, for architectural purposes, extends more than 4 inches beyond the confined core shall have minimum reinforcement as required for nonseismic columns as specified in Section 2625 (i).*

*(vi) Where the calculated point of contraflexure is not within the middle half of*



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*the member clear height, provide transverse reinforcement as specified in Section 2625 (e) 4 A (i) through 2625 (e) 4 (iii) over the full height of the member.*

B. Transverse reinforcement shall be spaced at distances not exceeding 4 inches.

C. Crossties or legs of overlapping hoops shall not be spaced more than 14 inches on center in the direction perpendicular to the longitudinal axis of the structural member.

D. Transverse reinforcement in amount specified in Sections 2625 (e) 4 A through C shall be provided over a length $l_o$ from each joint face and on both sides of any section where flexural yielding may occur in connection with inelastic lateral displacements of the frame. The length $l_o$ shall not be less than (1) the depth of the member at the joint face or at the section where flexural yielding may occur, (2) one sixth of the clear span of the member, and (3) 18 inches.

E. Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with transverse reinforcement as specified in Sections 2625 (e) 4 A through C over their full height beneath the level at which the discontinuity occurs if the factored axial compressive force in these members, including earthquake effect, exceeds $(A_g f'_c/10)$. *The special transverse reinforcement shall be placed above the discontinuity for at least the development length of the largest longitudinal reinforcement in the column in accordance with Section 2625 (g) 4. Where the column is supported on a wall the special transverse reinforcement shall be placed below the discontinuity for the same development length. Where the column terminates on a footing or mat special transverse reinforcement shall be placed below the top of the footing or mat for the same development length or the lead length of a standard hook.*

*F. At any section where the nominal strength, $\phi P_n$, of the column is less than the sum of the shears $V_e$ computed in accordance with Section 2625 (h) 1 for all the beams framing into the column above the level under consideration, transverse reinforcement as specified in Section 2625 (e) 4 A through 2625 (e) 4 C shall be provided. For beams framing into opposite sides of the column, the moment components may be assumed to be of opposite sign. For the determination of the nominal strength, $\phi P_n$, of the column, these moments may be assumed to result from the deformation of the frame in any one principal axis.*

(f) ***Shear* Walls, Diaphragms and Trusses.** [A.5] 1. **Scope.** The requirements of this section apply to *shear* walls and trusses serving as parts of the earthquake-force-resisting systems as well as to diaphragms, struts, ties, chords and collector members which transmit forces induced by earthquake.

2. **Reinforcement.** A. The reinforcement ratio, $\rho_v$, for shear walls shall be not less than 0.0025 along the longitudinal and transverse axes. Reinforcement spacing each way shall not exceed 18 inches. Reinforcement provided for shear strength shall be continuous and shall be distributed across the shear plane.

B. At least two curtains of reinforcement shall be used in a wall if the in-plane factored shear force assigned to the wall exceeds $2A_{cv}\sqrt{f'_c}$.



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C. Structural-truss members, struts, ties and collector members with compressive stresses exceeding $0.2 f'_c$ shall have special transverse reinforcement, as specified in Section 2625 (e) 4, over the total length of the member. The special transverse reinforcement may be discontinued at a section where the calculated compressive stress is less than $0.15 f'_c$. Stresses shall be calculated for the factored forces using a linearly elastic model and gross-section properties of the members considered.

D. All continuous reinforcement in shear walls, diaphragms, trusses, struts, ties, chords and collector members shall be anchored or spliced in accordance with the provisions for reinforcement in tension as specified in Section 2625 (g) 4. *Splices in horizontal reinforcement shall be staggered. Splices in two curtains where used shall not occur in the same location.*

3. **Boundary members for shear walls and diaphragms.** A. Boundary members shall be provided at boundaries and edges around openings of shear walls and diaphragms for which the maximum extreme fiber stress, corresponding to factored forces, including earthquake effect, exceeds $0.2 f'_c$ unless the entire wall or diaphragm member is reinforeed to satisfy Sections 2625 (e) 4 A through C. The boundary member may be discontinued where the calculated compressive stress is less than $0.15 f'_c$. Stresses may be ealculated for the factored forces using a linearly elastic model and gross-section properties.

B. Boundary members, where required, shall have transverse reinforcement as specified in Sections 2625 (e) 4 A through C.

C. Boundary members of *shear* walls shall be proportioned to carry all factored gravity loads on the wall, including tributary loads and self-weight, as well as the vertical force required to resist overturning moment calculated from factored forces related to earthquake effects.

D. Boundary members of structural diaphragms shall be proportioned to resist the sum of the compressive force acting in the plane of the diaphragm and the force obtained from dividing the factored moment at the section by the distance between the edges of the diaphragm at that section.

E. Transverse reinforcement in walls with boundary members shall be anchored within the confined core of the boundary member to develop the yield stress in tension of the transverse reinforeement.

*Reinforcement terminating at the edges of shear walls with a minimum edge reinforcement shall have a standard hook enclosing the edge reinforcement or the edge reinforcement shall be enclosed in "U" stirrups of the same size and spacing as transverse reinforcement.*

*F. Structural steel members conforming to Chapter 27 and encased monolithically in the walls at the edges may be used for boundary members, provided adequate shear transfer is provided between the steel and the concrete.*

4. **Construction joints.** All construction joints in walls and diaphragms shall conform to Seetion 2606 (d), and contact surfaees shall be roughened as specified in Section 2611 (h) 9.

5. ***Coupling Beams.*** *Horizontal members with clear span-to-effective-depth*



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*ratio ($l_n/d$) of less than four and factored shear force $V_u$ exceeding $4\sqrt{f'_c}\,b_w d$ and which interconnect shear walls shall be provided with special shear reinforcement as follows:*

*A. Symmetrical diagonal shear reinforcement shall be provided to extend diagonally across the full length of the member and located within the confined concrete core as specified in Section 2625 (d) 3.*

*B. The required area of one leg of the diagonal reinforcement $A_{vd}$ shall be not less than*

$$A_{vd} = \frac{V_u}{2f_y \sin\alpha}$$

***WHERE:***

$V_u$ = *factored shear force.*

$f_y$ = *yield stress of diagonal reinforcement.*

$\alpha$ = *angle between diagonal reinforcement and longitudinal axis of the member.*

*C. Flexural strength contribution by the diagonal reinforcement shall be included in the flexural capacity calculation of the member.*

*6. **Discontinuous walls.** Columns supporting discontinuous wall elements shall be reinforced in accordance with Section 2625 (e) 4 E.*

*7. A cast-in-place topping on a precast floor system may serve as the diaphragm, provided the cast-in-place topping acting alone is proportioned and detailed to resist the design forces.*

*8. Minimum thickness of diaphragms—Diaphragms used to resist prescribed lateral forces shall not be less than 2 inches thick. Topping slabs placed over precast floor and roof elements shall not be less than 2 1/2 inches thick.*

(g) **Joints of Frames.** [A.6] 1. **General requirements.** A. Forces in longitudinal beam reinforcement at the joint face shall be determined by assuming that the stress in the flexural tensile reinforcement is $1.25 f_y$.

B. Strength of joint shall be governed by the appropriate strength reduction factors specified in Section 2609 (d).

C. Beam longitudinal reinforcement terminated in a column shall be extended to the far face of the confined column core and anchored in tension according to Section 2625 (g) 4 and in compression according to Section 2612.

*D. Where longitudinal beam reinforcing bars extend through a joint, the column depth in the direction of loading shall not be less than 20 times the diameter of the largest longitudinal bar.*

2. **Transverse reinforcement.** A. Transverse hoop reinforcement as specified in Section 2625 (e) 4 shall be provided within the joint, unless the joint is confined by structural members as specified in Section 2625 (g) 2 B.

B. Within the depth of the shallowest framing member, transverse reinforcement equal to at least one half the amount required by Section 2625 (e) 4 A shall be



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provided where members frame into all four sides of the joint and where each member width is at least three fourths the column width.

C. Transverse reinforcement as required by Section 2625 (e) 4 shall be provided through the joint to provide confinement for longitudinal beam reinforcement outside the column core if such confinement is not provided by a beam framing into the joint.

3. **Shear strength.** A. The nominal shear strength of the joint shall be assumed not to exceed the forces specified below for normal-weight aggregate concrete.

| | |
|---|---|
| For confined joint | $20\sqrt{f'_c}\,A_j$ |
| For others | $15\sqrt{f'_c}\,A_j$ |

**WHERE:**

$A_j$ = *Minimum cross-sectional area within a joint in a plane parallel to the plane of reinforcement generating shear in the joint. Where a beam frames into a support of larger width, effective width of the joint shall not exceed the smaller of:*

*(i) Beam width plus overall depth of the joint.*

*(ii) Beam width plus that portion of the column concentric to the beam and projecting each side beyond the beam.*

A joint is considered to be confined if members frame into all vertical faces of the joint and if at least three quarters of each face of the joint is covered by the framing member.

B. For lightweight-aggregate concrete, the nominal shear strength of the joint shall not exceed three quarters of the limits given in Section 2625 (g) 3 A.

4. **Development length for reinforcement in tension.** A. The development length, $l_{dh}$, for a bar with a standard 90-degree hook in normal-weight aggregate concrete shall be not less than $8d_b$, 6 inches, and the length required by Formula (25-5).

$$l_{dh} = f_y d_b / 65\sqrt{f'_c} \qquad (25\text{-}5)$$

for bar sizes No. 3 through No. 11.

For lightweight-aggregate concrete, the development length for a bar with a standard 90-degree hook shall not be less than $10d_b$, 7.5 inches, and 1.25 times that required by Formula (25-5).

The 90-degree hook shall be located within the confined core of a column or of a boundary member.

B. For bar sizes No. 3 through No. 11, the development length, $l_d$, for a straight bar shall not be less that (1) 2.5 times the length required by Section 2625 (g) 4 A if the depth of the concrete cast in one lift beneath the bar does not exceed 12 inches, and (2) 3.5 times the length required by Section 2625 (g) 4 A if the depth of the concrete cast in one lift beneath the bar exceeds 12 inches.

C. Straight bars terminated at a joint shall pass through the confined core of a column or of a boundary member. Any portion of the straight embedment length not within the confined core shall be increased by a factor of 1.6.



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(h) **Shear-strength Requirements.** [A:7] 1. **Design forces:** A. **Frame members subjected primarily to bending.** The design shear force $V_e$ shall be determined from consideration of the statical forces on the portion of the member between faces of the joints. It shall be assumed that moments of opposite sign corresponding to probable strength act at the joint faces and that the member is loaded with the tributary gravity load along its span. *Probable strength is the nominal strength computed using an assumed tensile reinforcement stress of 1.25 $f_y$.*

B. **Frame members subjected to combined bending and axial load.** *The design shear force $V_e$ shall be determined from the consideration of the maximum forces that can be developed at the faces of the joints with the nominal moment strengths calculated for the factored axial compressive force resulting in the largest moment acting at the joint faces without strength reduction factors and assuming that the stress in tensile reinforcement is equal to at least 1.25$f_y$. The moment need not exceed the moments that can be resisted by the flexural members framing into the joint calculated in accordance with Section 2625 (h) 1.*

C. **Shear walls, diaphragms and trusses.** The design shear force $V_u$ shall be obtained from the lateral load analysis in accordance with the factored loads and combinations specified in Section 2609 (c).

2. **Transverse reinforcement in frame members.** A. For determining the required transverse reinforcement in frame members the quantity $V_c$ shall be assumed to be zero if the factored axial compressive force including earthquake effects is less than $(A_g f'_c/20)$.

B. Stirrups or ties required to resist shear shall be hoops over lengths of members as specified in Sections 2625 (d) 3, 2625 (e) 4 and 2625 (g) 2.

3. **Shear strength of shear walls and diaphragms.** A. The nominal shear strength, $V_n$, *for shear* walls and diaphragms shall be determined in accordance with Formula (25-6) or Formula (25-7).

*Where the ratio of $(h_w/l_w)$ is 2 or greater:*

$$V_n = A_{cv}(2\sqrt{f'_c} + \rho_n f_y) \quad \text{.....(25-6)}$$

*Where the ratio of $(h_w/l_w)$ is less than 2:*

$$V_n = A_{cv}(\alpha_c \sqrt{f'_c} + \rho_n f_y) \quad \text{.....(25-7)}$$

$\alpha_c$ varies linearly from 3.0 for $h_w/l_w = 1.5$ to 2.0 for $h_w/l_w = 2.0$

B. In Section 2625 (h) 3 A, value of ratio $(h_w/l_w)$ used for determining $V_n$ for segments of a wall or diaphragm shall be the largest of the ratios for the entire wall (diaphragm) and the segment of wall (diaphragm) considered.

C. Walls (diaphragms) shall have distributed shear reinforcement providing resistance in two orthogonal directions in the plane of the wall (diaphragm). If the ratio $(h_w/l_w)$ does not exceed 2.0, reinforcement ratio $\rho_v$ shall not be less than reinforcement ratio $\rho_n$.

$\rho_v$ = *reinforcement ratio on plane of* $A_{cv}$



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D. Nominal shear strength of all wall piers sharing a common lateral force shall not be assumed to exceed $8A_{cv}\sqrt{f'_c}$ where $A_{cv}$ is the total cross-sectional area and the nominal shear strength of any one of the individual wall piers shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ where $A_{cp}$ represents the cross-sectional area of the pier considered.

E. Nominal shear strength of horizontal wall segments shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ where $A_{cp}$ represents the cross-sectional area of a horizontal wall segment.

*(i) **Frame Members Not Part of the Lateral Force-resisting System.** [A.8] All frame members assumed not to be part of the lateral force-resisting system shall conform to the requirements of Section 2312 (h) 2 D. Such members shall satisfy the minimum reinforcement requirements of Sections 2607, 2610, 2611, 2625 (d) 2 A and 2625 (f) 2 A.*

*(j) **Inspection.** For moment frames resisting design seismic load in structures within Seismic Zones Nos. 3 and 4, a specially qualified inspector who will provide reports to the person responsible for the structural design shall provide continuous inspection of the placement of the reinforcement and concrete and shall submit a certificate indicating compliance with the plans and specifications.*

(k) **Requirements for Frames *in Seismic Zone No. 2.*** [A.9] 1. *In Seismic Zone No. 2*, structural frames proportioned to resist forces induced by earthquake motions shall satisfy the requirements of Section 2625 (k) in addition to the those of Sections 2601 through 2618.

2. Reinforcement details in a frame member shall satisfy Section 2625 (k) 4 if the factored compressive axial load for the member does not exceed $(A_g f'_c/10)$. If the factored compressive axial load is larger, frame reinforcement details shall satisfy Section 2625 (k) 5 unless the member has spiral reinforcement according to Formula (10-5). If a two-way slab system without beams is treated as part of a frame-resisting earthquake effect, reinforcement details in any span resisting moments caused by lateral force shall satisfy Section 2625 (k) 6.

3. Design shear strength of beams, columns and two-way slabs resisting earthquake effect shall not be less than either (1) the sum of the shear associated with development of nominal moment strengths of the member at each restrained end of the clear span and the shear calculated for gravity loads, or (2) the maximum shear obtained from design load combinations which include earthquake effect $E$ with $E$ assumed to be twice that prescribed in Section 2312.

4. **Beams.** A. The positive-moment strength at the face of the joint shall be not less than one-third the negative-moment strength provided at that face of the joint. Neither the negative- nor the positive-moment strength at any section along the length of the member shall be less than one-fifth the maximum moment strength provided at the face of either joint.

B. At both ends of the member, stirrups shall be provided over lengths equal to twice the member depth measured from the face of the supporting member toward mid-span. The first stirrup shall be located at not more than 2 inches from the face of the supporting member. Maximum stirrup spacing shall not exceed (1) $d/4$, (2)



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eight times the diameter of the smallest longitudinal bar enclosed, (3) 24 times the diameter of the stirrup bar, and (4) 12 inches.

C. Stirrups shall be placed at not more than d/2 throughout the length of the member.

5. **Columns.** A. Maximum tie spacing shall not exceed $s_o$ over a length $l_o$ measured from the joint face. Spacing $s_o$ shall not exceed (1) eight times the diameter of the smallest longitudinal bar enclosed, (2) 24 times the diameter of the tie bar, (3) one half of the smallest cross-sectional dimension of the frame member, and (4) 12 inches. Length $l_o$ shall not be less than (1) one sixth of the clear span of the member, (2) maximum cross-sectional dimension of the member, and (3) 18 inches.

B. The first tie shall be located at not more than $s_o/2$ from the joint face.

C. Joint reinforcement shall conform to Section 2611 (m) 1 B.

D. Tie spacing shall not exceed twice the spacings $s_o$.

6. **Two-way slabs without beams.** A. Factored slab moment at support related to earthquake effect shall be determined for load combinations defined by Formula (9-2) and (9-3). All reinforcement provided to resist $M_s$, the portion of slab moment balanced by support moment, shall be placed within the column strip defined in Section 2613 (c) 1.

B. The fraction, defined by Formula (13-1), of moment $M_s$ shall be resisted by reinforcement placed within the effective width specified in Section 2613 (d) 5.

C. Not less than one half of the reinforcement in the column strip at support shall be placed within the effective slab width specified in Section 2613 (d) 5.

D. Not less than one fourth of the top reinforcement at the support in the column strip shall be continuous throughout the span.

E. Continuous bottom reinforcement in the column strip shall be not less than one third of the top reinforcement at the support in the column strip.

F. Not less than one half of all bottom reinforcement at midspan shall be continuous and shall develop its yield strength at face of support as defined in Section 2613 (h) 2 E.

G. At discontinuous edges of the slab, all top and bottom reinforcement at support shall be developed at the face of support as defined in Section 2613 (h) 2 E.

## Alternate Design Method [Appendix B]

**Sec. 2626.** (a) **Notation.** [B.0] The following symbols and notations apply only to the provisions of this section:

$A_g$ = gross area of section, square inches.

$A_1$ = loaded area.

$A_2$ = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area.

$A_v$ = area of shear reinforcement within a distance $s$, square inches.

$b$ = width of compression face of member, inches.

$b_o$ = perimeter of critical section for slabs and footings, inches.



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$b_w$ = web width, or diameter of circular section; inches.

$d$ = distance from extreme compression fiber to centroid of tension reinforcement, inches.

$E_c$ = modulus of elasticity of concrete, psi. See Section 2608 (f).

$E_s$ = modulus of elasticity of reinforcement, psi. See Section 2608 (f).

$f'_c$ = specified compressive strength of concrete, psi. See Section 2604.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

$f_{ct}$ = average splitting tensile strength of lightweight aggregate concrete, psi. See Section 2604 (b).

$f_s$ = permissible tensile stress in reinforcement, psi.

$f_y$ = specified yield strength of reinforcement, psi. See Section 2603 (f).

$M$ = design moment.

$n$ = modular ratio of elasticity.

$= E_s/E_c$.

$N$ = design axial load normal to cross section occurring simultaneously with $V$; to be taken as positive for compression, negative for tension and to include effects of tension due to creep and shrinkage.

$s$ = spacing of shear reinforcement in direction parallel to longitudinal reinforcement; inches.

$v$ = design shear stress.

$v_c$ = permissible shear stress carried by concrete, psi.

$v_h$ = permissible horizontal shear stress, psi.

$V$ = design shear force at section.

$\beta_c$ = ratio of long side to short side of concentrated load or reaction area.

$\alpha$ = angle between inclined stirrups and longitudinal axis of member.

$\rho$ = ratio of tension reinforcement.

$= A_s/bd$.

$\phi$ = strength reduction factor. See Section 2626 (c).

(b) **Scope.** [B.1] Nonprestressed reinforced concrete members may be designed using service loads (without load factors) and permissible service load stresses in accordance with provisions of this section. For design of members not covered by this section, appropriate provisions of this code shall apply.

All applicable provisions of this code for nonprestressed concrete, except Section 2608 (e), shall apply to members designed by the alternate design method. Flexural members shall meet requirements for deflection control in Section 2609 (f) and requirements of Sections 2610 (e) through (h) of this code.

(c) **General.** [B.2] Load factors and strength reduction factors $\phi$ shall be taken as unity for members designed by the alternate design method.

Members may be proportioned for 75 percent of capacities required by other parts of the section when considering wind or earthquake forces combined with



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other loads, provided the resulting section is not less than that required for the combination of dead and live load.

When dead load reduces effects of other loads, members shall be designed for 85 percent of dead load in combination with the other loads.

(d) **Permissible Service Load Stresses.** [B.3] 1. Stresses in concrete shall not exceed the following:

| | |
|---|---|
| A. Flexure. | |
| Extreme fiber stress in compression | $0.45 f'_c$ |
| B. Shear.† | |
| Beams and one-way slabs and footings: | |
| Shear carried by concrete, $v_c$ | $1.1\sqrt{f'_c}$ |
| Maximum shear carried by concrete plus shear reinforcement | $v_c + 4.4\sqrt{f'_c}$ |
| Joists.* | |
| Shear carried by concrete, $v_c$ | $1.2\sqrt{f'_c}$ |
| Two-way slabs and footings: | |
| Shear carried by concrete, $v_c$‡ | $(1 + 2/\beta_c)\sqrt{f'_c}$ but not greater than $2\sqrt{f'_c}$ |
| C. Bearing on load area** | $0.3 f'_c$ |

†For more detailed calculation of shear stress carried by concrete $v_c$ and shear values for lightweight aggregate concrete, see Section 2626 (i).

*Designed in accordance with Section 2608 (l) of this code.

‡If shear reinforcement is provided, see Sections 2626 (l) 4 and 2626 (l) 5.

**When the supporting surface is wider on all sides than the loaded area, permissible bearing stress on the loaded area may be increased by $\sqrt{A_2/A_1}$ but not more than 2. When the supporting surface is sloped or stepped, $A_2$ may be taken as the area of the lower base of the largest frustum of a right pyramid or cone contained wholly within the support and having for its upper base the loaded area and having side slopes of 1 vertical to 2 horizontal.

2. Tensile stress in reinforcement $f_s$ shall not exceed the following:

| | |
|---|---|
| A. Grade 40 or Grade 50 reinforcement | 20,000 psi |
| B. Grade 60 reinforcement or greater and welded wire fabric (smoothed or deformed) | 24,000 psi |
| C. For flexural reinforcement, 3/8 inch or less in diameter, in one-way slabs of not more than 12-foot span but not greater than 30,000 psi | $0.50 f_y$ |

(e) **Development and Splices of Reinforcement.** [B.4] Development and splices of reinforcement shall be as required in Section 2612. In satisfying requirements of Section 2612 (l), $M_n$ shall be taken as computed moment capacity assuming all positive moment tension reinforcement at the section to be stressed to the permissible tensile stress $f_s$, and $V_u$ shall be taken as unfactored shear force at the section.



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(f) **Flexure.** [B.5] For investigation of stresses at service loads, straight-line theory (for flexure) shall be used with the following assumptions:

1. Strains vary linearly as the distance from the neutral axis, except for deep flexural members with overall depth-span ratios greater than 2/5 for continuous spans and 4/5 for simple spans, a nonlinear distribution of strain shall be considered. [See Section 2610 (h).]

2. Stress-strain relationship of concrete is a straight line under service loads within permissible service load stresses.

3. In reinforced concrete members, concrete resists no tension.

4. Modular ratio, $n = E_s/E_c$, may be taken as the nearest whole number (but not less than 6). Except in calculations for deflections, value of $n$ for lightweight concrete shall be assumed to be the same as for normal-weight concrete of the same strength.

5. In doubly reinforced flexural members, an effective modular ratio of $2\ E_s/E_c$ shall be used to transform compression reinforcement for stress computations. Compressive stress in such reinforcement shall not exceed permissible tensile stress.

(g) **Compression Members With or Without Flexure.** [B.6] Combined flexure and axial load capacity of compression members shall be taken as 40 percent of that computed in accordance with provisions in Section 2610.

Slenderness effects shall be included according to requirements of Section 2610 (k) and 2610 (l). In Formulas (10-7) and (10-8), the term $P_u$ shall be replaced by 2.5 times the design axial load, and $\phi$ shall be taken equal to 1.0.

Walls shall be designed in accordance with Section 2614 with flexure and axial load capacities taken as 40 percent of that computed using Section 2614. In Formula (14-1), $\phi$ shall be taken equal to 1.0.

(h) **Shear and Torsion.** [B.7] Design shear stress $v$ shall be computed by:

$$v = \frac{V}{b_w d} \qquad \text{.....(26-1)}$$

where $V$ is design shear force at section considered.

When the reaction, in direction of applied shear, introduces compression into the end regions of a member, sections located less than a distance $d$ from face of support may be designed for the same shear $v$ as that computed at a distance $d$.

Whenever applicable, effects of torsion, in accordance with provisions of Section 2611, shall be added. Shear and torsional moment strengths provided by concrete and limiting maximum strengths for torsion shall be taken as 55 percent of the values given in Section 2611.

(i) **Shear Stress Carried by Concrete.** 1. For members subject to shear and flexure only, shear stress carried by concrete $v_c$ shall not exceed $1.1\sqrt{f'_c}$ unless a more detailed calculation is made in accordance with Section 2626 (i) 4.



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2. For members subject to axial compression, shear stress carried by concrete $v_c$ shall not exceed $1.1\sqrt{f'_c}$ unless a more detailed calculation is made in accordance with Section 2626 (i) 5.

3. For members subject to significant axial tension, shear reinforcement shall be designed to carry total shear, unless a more detailed calculation is made using

$$v_c = 1.1\left(1 + 0.004\ \frac{N}{A_g}\right)\sqrt{f'_c} \quad \text{.....(26-2)}$$

where $N$ is negative for tension. Quantity $N/A_g$ shall be expressed in psi.

4. For members subject to shear and flexure only, $v_c$ may be computed by

$$v_c = \sqrt{f'_c} + 1300\,\rho_w \frac{Vd}{M} \quad \text{.....(26-3)}$$

but $v_c$ shall not exceed $1.9\sqrt{f'_c}$. Quantity $Vd/M$ shall not be taken greater than 1.0 where $M$ is design moment occurring simultaneously with $V$ at section considered.

5. For members subject to axial compression, $v_c$ may be computed by

$$v_c = 1.1\left(1 + 0.0006\ \frac{N}{A_g}\right)\sqrt{f'_c} \quad \text{.....(26-4)}$$

Quantity $N/A_g$ shall be expressed in psi.

6. Shear stresses carried by concrete $v_c$ apply to normal-weight concrete. When lightweight aggregate concrete is used, one of the following modifications shall apply:

A. When $f_{ct}$ is specified and concrete is proportioned in accordance with Section 2604 (c), $f_{ct}/6.7$ shall be substituted for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ shall not exceed $\sqrt{f'_c}$.

B. When $f_{ct}$ is not specified, the value of $\sqrt{f'_c}$ shall be multiplied by 0.75 for "all-lightweight" concrete and by 0.85 for "sand-lightweight" concrete. Linear interpolation may be applied when partial sand replacement is used.

7. In determining shear stress carried by concrete $v_c$, whenever applicable, effects of axial tension due to creep and shrinkage in restrained members shall be considered and effects of inclined flexural compression in variable depth members may be included.

(j) **Shear Stress Carried by Shear Reinforcement.** 1. **Types of shear reinforcement.** Shear reinforcement may consist of:

A. Stirrups perpendicular to axis of member.

B. Welded wire fabric with wires located perpendicular to axis of member making an angle of 45 degrees or more with longitudinal tension reinforcement.

C. Longitudinal reinforcement with bent portion making an angle of 30 degrees or more with longitudinal tension reinforcement.



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D. Combinations of stirrups and bent longitudinal reinforcement.

E. Spirals.

2. **Maximum yield strength.** Design yield strength of shear reinforcement shall not exceed 60,000 psi.

3. **Anchorage of shear reinforcement.** Stirrups and other bars or wires used as shear reinforcement shall extend to a distance $d$ from extreme compression fiber and shall be anchored at both ends according to Section 2612 (p) to develop design yield strength of reinforcement.

4. **Spacing limits for shear reinforcement.** Spacing of shear reinforcement placed perpendicular to axis of member shall not exceed $d/2$ nor 24 inches.

Inclined stirrups and bent longitudinal reinforcement shall be so spaced that every 45-degree line, extending toward the reaction from middepth of member $d/2$ to longitudinal tension reinforcement, shall be crossed by at least one line of shear reinforcement.

When $(v - v_c)$ exceeds $2\sqrt{f'_c}$, maximum spacing given by this subsection shall be reduced by one half.

5. **Minimum shear reinforcement.** A minimum area of shear reinforcement shall be provided in all reinforced concrete flexural members where design shear stress $v$ is greater than one half the permissible shear stress $v_c$ carried by concrete, except:

A. Slab and footings.

B. Concrete joist construction defined by Section 2608 (l) of this code.

C. Beams with total depth not greater than 10 inches, two and one-half times thickness of flange or one half the width of web, whichever is greater.

Minimum shear reinforcement requirements of this subsection may be waived if shown by test that required ultimate flexural and shear strength can be developed when shear reinforcement is omitted.

Where shear reinforcement is required by this subsection or by analysis, minimum area of shear reinforcement shall be computed by

$$A_v = 50 \frac{b_w s}{f_y} \qquad (26\text{-}5)$$

where $b_w$ and $s$ are in inches.

6. **Design of shear reinforcement.** Where design shear stress $v$ exceeds shear stress carried by concrete $v_c$, shear reinforcement shall be provided in accordance with this subsection.

When shear reinforcement perpendicular to axis of member is used,

$$A_v = \frac{(v - v_c)\, b_w s}{f_s} \qquad (26\text{-}6)$$

When inclined stirrups are used as shear reinforcement,

$$A_v = \frac{(v - v_c)\, b_w s}{f_s (\sin \alpha + \cos \alpha)} \qquad (26\text{-}7)$$



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When shear reinforcement consists of a single bar or a single group of parallel bars, all bent up at the same distance from the support,

$$A_v = \frac{(v - v_c)\, b_w d}{f_s \sin \alpha} \qquad (26\text{-}8)$$

where $(v - v_c)$ shall not exceed $1.6\sqrt{f'_c}$.

When shear reinforcement consists of a series of parallel bent-up bars or groups of parallel bent-up bars at different distances from the support, required area shall be computed by Formula (26-7).

Only the center three fourths of the inclined portion of any longitudinal bent bar shall be considered effective for shear reinforcement.

When more than one type of shear reinforcement is used to reinforce the same portion of a member, required area shall be computed as the sum of the various types separately. In such computations, $v_c$ shall be included only once.

Value of $(v - v_c)$ shall not exceed $4.4\sqrt{f'_c}$.

(k) **Shear Friction.** Where it is appropriate to consider shear transfer across a given plane such as an existing or potential crack, an interface between dissimilar materials, or an interface between two concretes cast at different times, shear friction provisions of Section 2611 (h) may be applied with limiting maximum stress for shear taken as 55 percent of that given in Section 2611 (h) 5. Permissible stress in shear friction reinforcement shall be that given in Section 2626 (d) 2.

(l) **Special Provisions for Slabs and Footings.** 1. Shear capacity of slabs and footings in the vicinity of concentrated loads or reactions is governed by the more severe of two conditions:

A. Beam action for slab or footing with a critical section extending in a plane across the entire width and located at a distance $d$ from face of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Section 2626 (h) through (j).

B. Two-way action for slab or footing with a critical section perpendicular to plane of slab and located so that its perimeter is a minimum but need not approach closer than $d/2$ to perimeter of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Sections 2626 (l) 2 and 2626 (l) 3.

2. Design shear stress $v$ shall be computed by

$$v = \frac{V}{b_o d} \qquad (26\text{-}9)$$

where $V$ and $b_o$ shall be taken at the critical section defined in Section 2626 (l) 1 B.

3. Design shear stress $v$ shall not exceed $v_c$ given by Formula (26-10) unless shear reinforcement is provided.

$$v_c = \left(1 + \frac{2}{\beta_c}\right)\sqrt{f'_c} \qquad (26\text{-}10)$$

but $v_c$ shall not exceed $2\sqrt{f'_c}$. $\beta_c$ is the ratio of long side to short side of concentrated load or reaction area. When lightweight aggregate concrete is used, the modifications of Section 2626 (i) 6 shall apply.



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4. If shear reinforcement consisting of bars or wires is provided in accordance with Section 2611 (l) 3, $v_c$ shall not exceed $\sqrt{f'_c}$, and $v$ shall not exceed $3\sqrt{f'_c}$.

5. If shear reinforcement consisting of steel I or channel shapes (shearheads) is provided in accordance with Section 2611 (l) 4 of this code, $v$ on the critical section defined in Section 2626 (l) 1 B shall not exceed $3.5\sqrt{f'_c}$ and $v$ on the critical section defined in Section 2611 (l) 4 G shall not exceed $2\sqrt{f'_c}$. In Formulas (11-38) and (11-39), design shear force $V$ shall be multiplied by 2 and substituted for $V_u$.

(m) **Special Provisions for Other Members.** For design of deep flexural members, brackets and corbels and walls, the special provisions of Section 2611 shall be used with shear strengths provided by concrete and limiting maximum strengths for shear taken as 55 percent of the values given in Section 2611. In Section 2611 (k) 6, the design axial load shall be multiplied by 1.2 if compression and 2.0 if tension and substituted for $N_u$.

(n) **Composite Concrete Flexural Members.** For design of composite concrete flexural members, permissible horizontal shear stress $v_h$ shall not exceed 55 percent of the horizontal shear strengths given in Section 2617 (f) 4.

## *Reinforced Gypsum Concrete*

*Sec. 2627. (a) **General.** Reinforced gypsum concrete shall conform to U.B.C. Standard No. 26-15.*

*Reinforced gypsum concrete shall develop the minimum ultimate compressive strength in pounds per square inch set forth in Table No. 26-H when dried to constant weight, with tests made on cylinders 2 inches in diameter and 4 inches long or on 2-inch cubes.*

*Tests, when required, shall follow the procedure set forth in U.B.C. Standard No. 47-17.*

*For special inspection, see Section 306.*

*(b) **Design.** The minimum thickness of reinforced gypsum concrete shall be 2 inches except the thickness may be reduced to 1 1/2 inches, provided all of the following conditions are satisfied:*

*1. The overall thickness including the formboard is not less than 2 inches.*

*2. The clear span of the gypsum concrete between supports does not exceed 2 feet 9 inches.*

*3. Diaphragm action is not required.*

*4. The design live load does not exceed 40 pounds per square foot.*

*(c) **Stresses.** The maximum allowable unit working stresses in reinforced gypsum concrete shall not exceed the values set forth in Table No. 26-I except as specified in Chapter 23. Bolt values shall not exceed those set forth in Table No. 26-J.*

*Allowable shear in poured-in-place reinforced gypsum concrete diaphragms using standard hot-rolled bulb tee subpurlins shall be determined by U.B.C. Standard No. 26-15. (See Table No. 26-15-A in the standard for values for commonly used roof systems.)*



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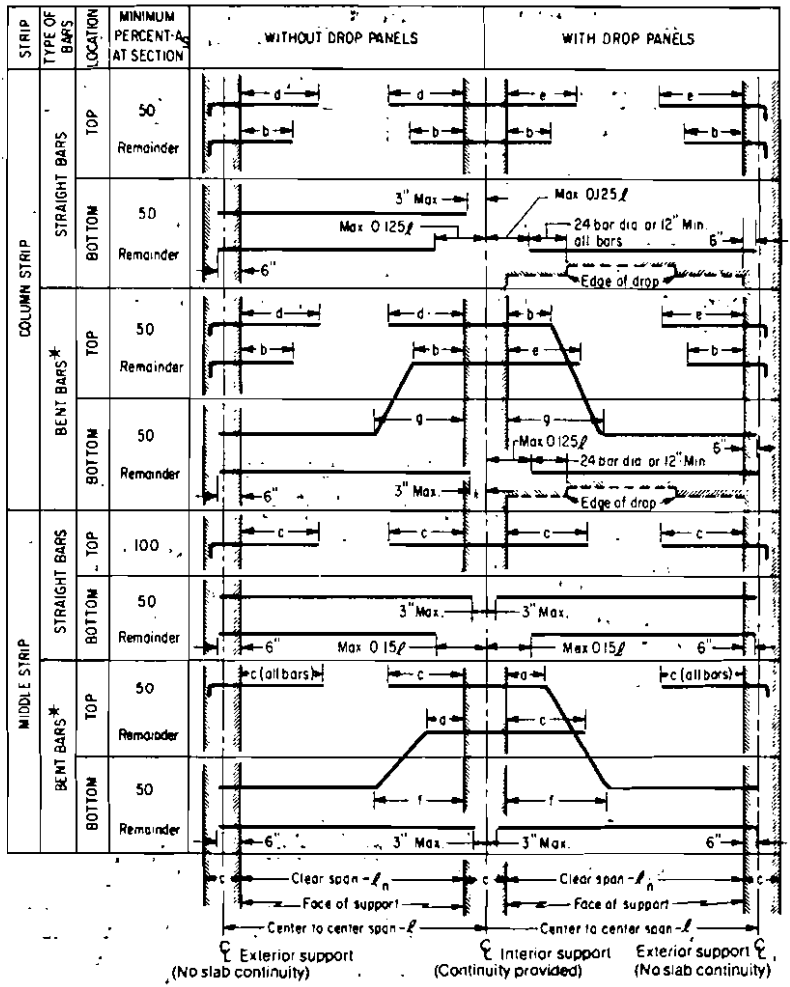


* Bent bars at exterior supports may be used if a general analysis is made

| | BAR LENGTH FROM FACE OF SUPPORT | | | | | | |
|---|---|---|---|---|---|---|---|
| | MINIMUM LENGTH | | | | | MAXIMUM LENGTH | |
| MARK | a | b | c' | d | e | f | g |
| LENGTH | $0.14\ell_n$ | $0.20\ell_n$ | $0.22\ell_n$ | $0.30\ell_n$ | $0.33\ell_n$ | $0.20\ell_n$ | $0.24\ell_n$ |

**FIGURE NO. 26-1—MINIMUM BEND POINT LOCATIONS AND EXTENSIONS FOR REINFORCEMENT IN SLABS WITHOUT BEAMS**
**[See Section 2612 (l) 1 for reinforcement extension into supports.]**



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## TABLE NO. 26-A-1—MODIFICATION FACTOR FOR STANDARD DEVIATION WHEN LESS THAN 30 TESTS ARE AVAILABLE

| NUMBER OF TESTS[1] | MODIFICATION FACTOR FOR STANDARD DEVIATION[2] |
|---|---|
| less than 15 | Use Table No. 26-A-2 |
| 15 | 1.16 |
| 20 | 1.08 |
| 25 | 1.03 |
| 30 or more | 1.00 |

[1] Interpolate for intermediate numbers of tests.

[2] Modified standard deviation to be used to determine required average strength $f'_{cr}$ from Section 2604 (d) 2, first paragraph.

## TABLE NO. 26-A-2—REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A STANDARD DEVIATION

| SPECIFIED COMPRESSIVE STRENGTH $f'_c$ PSI | REQUIRED AVERAGE COMPRESSIVE STRENGTH $f'_{cr}$ PSI |
|---|---|
| Less than 3000 psi | $f'_c + 1000$ |
| 3000 to 5000 | $f'_c + 1200$ |
| Over 5000 | $f'_c + 1400$ |

## TABLE NO. 26-A-3—MAXIMUM PERMISSIBLE WATER-CEMENT RATIOS FOR CONCRETE WHEN STRENGTH DATA FROM FIELD EXPERIENCE OR TRIAL MIXTURES ARE NOT AVAILABLE

| SPECIFIED COMPRESSIVE STRENGTH $f'_c$ PSI[1] | ABSOLUTE WATER-CEMENT RATIO BY WEIGHT | |
|---|---|---|
| | Nonair-entrained Concrete | Air-entrained Concrete |
| 2500 | 0.67 | 0.54 |
| 3000 | 0.58 | 0.46 |
| 3500 | 0.51 | 0.40 |
| 4000 | 0.44 | 0.35 |
| 4500 | 0.38 | [2] |
| 5000 | [2] | [2] |

[1] Twenty-eight day strength. With most materials, water-cement ratios shown will provide average strengths greater than indicated in Section 2604 (d) 2 as being required.

[2] For strengths above 4500 psi (nonair-entrained concrete) and 4000 psi (air-entrained concrete), concrete proportions shall be established by methods of Section 2604 (d).



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## TABLE NO. 26-A-4—TOTAL AIR CONTENT FOR FROST-RESISTANT CONCRETE

| NOMINAL MAXIMUM AGGREGATE SIZE, IN.[1] | AIR CONTENT, PERCENT | |
|---|---|---|
| | Severe Exposure | Moderate Exposure |
| 3/8 | 7 1/2 | 6 |
| 1/2 | 7 | 5 1/2 |
| 3/4 | 6 | 5 |
| 1 | 6 | 4 1/2 |
| 1 1/2 | 5 1/2 | 4 1/4 |
| 2[2] | 5 | 4 |
| 3[2] | 4 1/2 | 3 1/2 |

[1] See U.B.C. Standard No. 26-2 for tolerances on oversize for various nominal maximum size designations.

[2] These air contents apply to total mix, as for the preceding aggregate sizes. When testing this concrete, however, aggregate larger than 1 1/2 inch is removed by hand picking or sieving, and air content is determined on the minus 1 1/2-inch fraction.

## TABLE NO. 26-A-5—REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS

| EXPOSURE CONDITION | MAXIMUM WATER-CEMENT RATIO, NORMAL-WEIGHT AGGREGATE CONCRETE | MINIMUM $f'_c$ LIGHTWEIGHT AGGREGATE CONCRETE |
|---|---|---|
| Concrete intended to be watertight: | | |
| a. Concrete exposed to fresh water | 0.50 | 3750 |
| b. Concrete exposed to brackish or seawater | 0.45 | 4250 |
| Concrete exposed to freezing and thawing in a moist condition | | |
| a. Curbs, gutters, guardrails or thin sections | 0.45 | 4250 |
| b. Other elements | 0.50 | 3750 |
| c. In presence of de-icing chemicals | 0.45 | 4250 |
| For corrosion protection for reinforced concrete exposed to de-icing salts, brackish water, seawater or spray from these sources | 0.40[1] | 4750[1] |

[1] If minimum concrete cover required by Section 2607 (h) is increased by 0.5 inch, water-cement ratio may be increased to 0.45 for normal-weight concrete, or $f'_c$ reduced to 4250 psi for lightweight concrete.



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## TABLE NO. 26-A-6—REQUIREMENTS FOR CONCRETE EXPOSED TO SULFATE-CONTAINING SOLUTIONS

| SULFATE EXPOSURE | WATER SOLUBLE SULFATE ($SO_4$) IN SOIL, PERCENT BY WEIGHT | SULFATE ($SO_4$) IN WATER, PPM | CEMENT TYPE | NORMAL-WEIGHT AGGREGATE | LIGHTWEIGHT-AGGREGATE CONCRETE |
|---|---|---|---|---|---|
| | | | | Maximum Water-Cement Ratio, by Weight[1] | Minimum Compressive Strength, $f'_c$ psi[1] |
| Negligible | 0.00-0.10 | 0-150 | — | — | — |
| Moderate[2] | 0.10-0.20 | 150-1500 | II, IP(MS), IS(MS) | 0.50 | 3750 |
| Severe | 0.20-2.00 | 1500-10,000 | V | 0.45 | 4250 |
| Very Severe | Over 2.00 | Over 10,000 | V plus pozzolan[3] | 0.45 | 4250 |

[1] A lower water-cement ratio or higher strength may be required for watertightness or for protection against corrosion of embedded items or freezing and thawing (Table No. 26-A-5).

[2] Seawater.

[3] Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.

## TABLE NO. 26-A-7—MAXIMUM CHLORIDE ION CONTENT FOR CORROSION PROTECTION

| TYPE OF MEMBER | MAXIMUM WATER SOLUBLE CHLORIDE ION (CL) IN CONCRETE, PERCENT BY WEIGHT OF CEMENT |
|---|---|
| Prestressed concrete | 0.06 |
| Reinforced concrete exposed to chloride in service | 0.15 |
| Reinforced concrete that will be dry or protected from moisture in service | 1.00 |
| Other reinforced concrete construction | 0.30 |



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### TABLE NO. 26-B—CONCRETE AIR CONTENT FOR VARIOUS SIZES OF COARSE AGGREGATE

| NOMINAL MAXIMUM SIZE OF COARSE AGGREGATE, (Inches) | TOTAL AIR CONTENT, PERCENT BY VOLUME |
|---|---|
| 3/8 | 6 to 10 |
| 1/2 | 5 to 9 |
| 3/4 | 4 to 8 |
| 1 | 3.5 to 6.5 |
| 1 1/2 | 3 to 6 |
| 2 | 2.5 to 5.5 |
| 3 | 1.5 to 4.5 |

### TABLE NO. 26-C—MINIMUM DIAMETERS OF BEND

| BAR SIZE | MINIMUM DIAMETER |
|---|---|
| Nos. 3 through 8 | $6d_b$ |
| Nos. 9, 10 and 11 | $8d_b$ |
| Nos. 14 and 18 | $10d_b$ |

### TABLE NO. 26-D—MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE COMPUTED[1]

| MEMBER | MINIMUM THICKNESS, $h$ | | | |
|---|---|---|---|---|
| | SIMPLY SUPPORTED | ONE END CONTINUOUS | BOTH ENDS CONTINUOUS | CANTILEVER |
| | Members not supporting or attached to partitions or other construction likely to be damaged by large deflections | | | |
| Solid one-way slabs | $l$/20 | $l$/24 | $l$/28 | $l$/10 |
| Beams or ribbed one-way slabs | $l$/16 | $l$/18.5 | $l$/21 | $l$/8 |

[1]Span length $l$ is in inches.

Values given shall be used directly for members with normal-weight concrete ($w_c = 145$ pcf) and Grade 60 reinforcement. For other conditions, the values shall be modified as follows:

(a) For structural lightweight concrete having unit weights in the range 90-120 pounds per cubic foot, the value shall be multiplied by $(1.65 - 0.005w_c)$ but not less than 1.09, where $w_c$ is the unit weight in pounds per cubic foot.

(b) For $f_y$ other than 60,000 psi, the values shall be multiplied by $(0.4 + f_y/100{,}000)$.



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TABLE NO. 26-E—VALUES OF $\alpha_{min}$

| $\beta_a$ | ASPECT RATIO $l_2/l_1$ | RELATIVE BEAM STIFFNESS, $\alpha$ | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 0.5 | 1.0 | 2.0 | 4.0 |
| 2.0 | 0.5-2.0 | 0 | 0 | 0 | 0 | 0 |
| 1.0 | 0.5 | 0.6 | 0 | 0 | 0 | 0 |
| | 0.8 | 0.7 | 0 | 0 | 0 | 0 |
| | 1.0 | 0.7 | 0.1 | 0 | 0 | 0 |
| | 1.25 | 0.8 | 0.4 | 0 | 0 | 0 |
| | 2.0 | 1.2 | 0.5 | 0.2 | 0 | 0 |
| 0.5 | 0.5 | 1.3 | 0.3 | 0 | 0 | 0 |
| | 0.8 | 1.5 | 0.5 | 0.2 | 0 | 0 |
| | 1.0 | 1.6 | 0.6 | 0.2 | 0 | 0 |
| | 1.25 | 1.9 | 1.0 | 0.5 | 0 | 0 |
| | 2.0 | 4.9 | 1.6 | 0.8 | 0.3 | 0 |
| 0.33 | 0.5 | 1.8 | 0.5 | 0.1 | 0 | 0 |
| | 0.8 | 2.0 | 0.9 | 0.3 | 0 | 0 |
| | 1.0 | 2.3 | 0.9 | 0.4 | 0 | 0 |
| | 1.25 | 2.8 | 1.5 | 0.8 | 0.2 | 0 |
| | 2.0 | 13.0 | 2.6 | 1.2 | 0.5 | 0.3 |



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## TABLE NO. 26-F—ALLOWABLE SERVICE LOAD ON EMBEDDED BOLTS (In Pounds)[1,2]

| DIAMETER (In Inches) | MINIMUM[3] EMBEDMENT (In Inches) | MINIMUM CONCRETE STRENGTH (In psi) | | |
|---|---|---|---|---|
| | | SHEAR[4] | | TENSION[5] |
| | | 2000 | 3000 | 2000 to 5000 |
| 1/4 | 2 1/2 | 500 | 500 | 200 |
| 3/8 | 3 | 1100 | 1100 | 500 |
| 1/2 | 4 | 2000 | 2000 | 950 |
| 5/8 | 4 | 2750 | 3000 | 1500 |
| 3/4 | 5 | 2940 | 3560 | 2250 |
| 7/8 | 6 | 3580 | 4150 | 3200 |
| 1 | 7 | 3580 | 4150 | 3200 |
| 1 1/8 | 8 | 3580 | 4500 | 3200 |
| 1 1/4 | 9 | 3580 | 5300 | 3200 |

[1]Values are for natural stone aggregate concrete and bolts of at least A307 quality. Bolts shall have a standard bolt head or an equal deformity in the embedded portion.

[2]Values are based upon a bolt spacing of 12 diameters with a minimum edge distance of 6 diameters. Such spacing and edge distance may be reduced 50 percent with an equal reduction in value. Use linear interpolation for intermediate spacings and edge margins.

[3]An additional 2 inches of embedment shall be provided for anchor bolts located in the top of columns for buildings located in Seismic Zones Nos. 2, 3 and 4.

[4]Values shown are for work with or without special inspection.

[5]Values shown are for work without special inspection. Where special inspection is provided values may be increased 100 percent.

## TABLE NO. 26-G—TENSION LAP SPLICES

| $A_s$ PROVIDED[1] / $A_s$ REQUIRED | MAXIMUM PERCENT OF $A_s$ SPLICED WITHIN REQUIRED LAP LENGTH | | |
|---|---|---|---|
| | 50 | 75 | 100 |
| Equal to or greater than 2 | Class A | Class A | Class B |
| Less than 2 | Class B | Class C | Class C |

[1]Ratio of area of reinforcement provided to area of reinforcement required by analysis at splice location.



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### TABLE NO. 26-H—MINIMUM ULTIMATE COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY AND OF RIGIDITY OF REINFORCED GYPSUM CONCRETE

| CLASS | COMPRESSIVE STRENGTH PSI ($f_g$) | MODULUS OF ELASTICITY PSI ($E$) | $E_s/E_g$ ($n$) | MODULUS OF RIGIDITY ($G$) |
|---|---|---|---|---|
| A | 500 | 200,000 | .150 | .36E |
| B | 1000 | 600,000 | 50 | .40E |

### TABLE NO. 26-I—ALLOWABLE UNIT WORKING STRESS REINFORCED GYPSUM CONCRETE

| TYPE OF STRESS | FACTOR | CLASS A (Pounds per Square Inch) | CLASS B (Pounds per Square Inch) |
|---|---|---|---|
| Flexural Compression | $.25f_g$ | 125 | 250 |
| Axial Compression or Bearing | $.20f_g$ | 100 | 200 |
| Bond for Plain Bars and Shear[1] | $.02f_g$ | 10 | 20 |
| Bond for Deformed Bars and Electrically Welded Wire Mesh[1] | $.03f_g$ | 15 | 30 |

[1]Electrically welded wire mesh reinforcement shall be considered as meeting the bond and shear requirements of this section. In no case shall the area of principal reinforcement be less than 0.26 square inch per foot of slab width.

### TABLE NO. 26-J—SHEAR ON ANCHOR BOLTS AND DOWELS—REINFORCED GYPSUM CONCRETE[1]

| BOLT OR DOWEL SIZE (Inches) | EMBEDMENT (Inches) | SHEAR[2] (Pounds) |
|---|---|---|
| 3/8 Bolt | 4 | 325 |
| 1/2 Bolt | 5 | 450 |
| 5/8 Bolt | 5 | 650 |
| 3/8 Deformed Dowel | 6 | 325 |
| 1/2 Deformed Dowel | 6 | 450 |

[1]The bolts or dowels shall be spaced not closer than 6 inches on center.

[2]The tabulated values may be increased one third for bolts or dowels resisting wind or seismic forces.



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# Chapter 27
# STEEL

## Material Standards and Symbols

**Sec. 2701.** (a) **General.** The quality, testing and design of steel used structurally in buildings or structures shall conform to the requirements specified in this chapter and to the applicable standards listed in Chapter 60.

(b) **Identification.** Steel furnished for structural load-carrying purposes shall be properly identified for conformity to the ordered grade as follows:

Structural steels shall be identified in accordance with U.B.C. Standard No. 27-2. Where structural steel is furnished to a specified minimum yield point greater than 36,000 pounds per square inch, the ASTM or other specification designation shall be marked thereon in accordance with the requirements of U.B.C. Standard No. 27-2.

Cold-formed carbon and low-alloy steel shall be identified by the fabricator in accordance with U.B.C. Standard No. 27-9. Where cold-formed steel structural members are furnished to a specified minimum yield point greater than 33,000 pounds per square inch, the grade and the ASTM specification number or other specification designation shall be indicated by painting, decal, tagging or other suitable means on each lift or bundle of fabricated elements. In the case of members having a yield point of, or in excess of, 33,000 pounds per square inch obtained through additional treatment, the resulting minimum yield point shall be indicated in addition to the specification designation.

Cold-formed stainless steel structural elements designed in accordance with U.B.C. Standard No. 27-10 shall be identified as to grade through mill test reports, and certification shall be furnished that the yield point of the material supplied equals or exceeds that considered in the design. Identification shall be by painting, decal, tagging or other suitable means on each lift or bundle of fabricated elements.

Each lift or bundle of open web steel joists and similar fabricated light structural load-carrying members shall be identified in accordance with U.B.C. Standard No. 27-4 as to type, size and manufacturer by tagging or other suitable means at the time of manufacture or fabrication, and such identification shall be maintained continuously to the point of their installation in a structure.

The fabricator, in processing steel through his works, shall maintain identity of the material and shall maintain suitable procedures and records attesting that the specified grade has been furnished in conformity with the applicable U.B.C. standard. Where structural steel is furnished to a specified minimum yield point greater than 36,000 pounds per square inch, the ASTM or other specification designation shall be included near the erection mark on each shipping assembly or important construction component over any shop coat of paint prior to shipment from the fabricator's plant. The fabricator's identification mark system shall be established and on record prior to fabrication.

Steel which is not readily identifiable as to grade from marking and test records



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shall be tested to determine conformity to such standard. The fabricator shall, when requested, furnish an affidavit of compliance with such standard.

(c) **Symbols and Notations.** The symbols and notations used in these regulations are defined as follows:

$A_b$ = Normal body area of a fastener; the area of a rivet before driving or the area of a bolt or threaded part based upon its major diameter.

$A_{bc}$ = Planar area of web at beam-to-column connection.

$A_c$ = Actual area of effective concrete flange in composite design as defined in Section 2708 (a).

$A_e$ = Effective net area of an axially loaded tension member.

$A_f$ = Area of compression flange.

$A_n$ = Net area of an axially loaded tension member.

$A_s$ = Area of steel beam in composite design.

$A_{sr}$ = Area of reinforcing steel providing composite action at point of negative reinforcement within the boundaries specified in Section 2708 (a).

$A_{st}$ = Cross-sectional area of stiffener or pair of stiffeners.

$A_w$ = Area of girder web.

$A_1$ = Bearing area of base plate.

$A_2$ = Area of concrete.

$C$ = Ratio of bolt tensile strength to tensile strength of connected part.

$C_b$ = Bending coefficient dependent upon moment gradient; equal to

$$1.75 + 1.05\left(\frac{M_1}{M_2}\right) + 0.3\left(\frac{M_1}{M_2}\right)^2$$

$C_c$ = Column slenderness ratio separating elastic and inelastic buckling; equal to

$$\sqrt{\frac{2\pi^2 E}{F_y}}$$

$C_m$ = Coefficient for prismatic members applied to bending term in interaction formula and dependent upon column curvature caused by applied moments.

$C'_m$ = Coefficient applied to bending term in interaction formula for tapered members and dependent upon axial stress at the small end of the member.

$C_p$ = Stiffness factor for primary member in a flat roof.

$C_s$ = Stiffness factor for secondary member in a flat roof.

$C_v$ = Ratio of "critical" web stress, according to the linear buckling theory, to the shear yield stress of web material.

$D$ = Factor depending upon type of transverse stiffeners.

$E$ = Modulus of elasticity of steel (29,000 kips per square inch).

$E_c$ = Modulus of elasticity of concrete.



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$F$ = Load factor in plastic design.

$F_a$ = Axial compressive stress permitted in the absence of bending moment.

$F_{as}$ = Axial compressive stress permitted in the absence of bending moment for bracing and other secondary members.

$F_b$ = Bending stress permitted in the absence of axial force.

$F'_b$ = Allowable bending stress in compression flange of plate girders as reduced for hybrid girders or because of large web depth-to-thickness ratio.

$F'_e$ = Euler stress divided by factor of safety; equal to

$$\frac{12\pi^2 E}{23(Kl_b/r_b)^2}$$

$F_p$ = Allowable bearing stress.

$F_t$ = Allowable axial tensile stress.

$F_u$ = Specified minimum tensile strength of the type of steel or fasteners being used (kips per square inch).

$F_v$ = Allowable shear stress.

$F_y$ = Specified minimum yield stress of the type of steel being used (kips per square inch). As used in the specification, "yield stress" denotes either the specified minimum yield point (for those steels that have a yield point) or specified minimum yield strength (for those steels that do not have a yield point).

$F_{yc}$ = Column yield stress (ksi).

$F_{yr}$ = Yield stress of reinforcing steel providing composite action at point of negative moment.

$F_{yst}$ = Stiffener yield stress (ksi).

$H_s$ = Length of a stud shear connector.

$I_d$ = Moment of inertia of steel deck on a flat roof.

$I_{eff}$ = Effective moment of inertia of composite sections for deflection computations.

$I_p$ = Moment of inertia of primary member.

$I_s$ = Moment of inertia of secondary member in flat roof framing; moment of inertia of steel beam in composite construction.

$I_{tr}$ = Moment of inertia of transformed composite section.

$K$ = Effective length factor.

$L$ = Span length, in feet.

$L_p$ = Length of primary member in a flat roof (feet).

$L_s$ = Length of secondary member in a flat roof (feet).

$M$ = Moment.

$M_1$ = Smaller moment at end of unbraced length of beam-column.

$M_2$ = Larger moment at end of unbraced length of beam-column.



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$M_D$ = Moment produced by dead load.

$M_L$ = Moment produced by live load.

$M_m$ = Critical moment that can be resisted by a plastically designed member in absence of axial load.

$M_p$ = Plastic moment.

$M_s$ = Flexural strength of member.

$N$ = Length of bearing of applied load.

$N_1$ = Number of shear connectors equal to $V_{h/q}$.

$N_2$ = Number of shear connectors required where closer spacing is needed adjacent to point of zero moment.

$P$ = Applied load.

$P_{bf}$ = Factored beam flange or connection plate force in a restrained connection (kips).

$P_{cr}$ = $1.70AF_a$.

$P_{DL}$ = Axial dead load on member.

$P_E$ = Axial load on member due to earthquake.

$P_e = \dfrac{\pi^2 EI}{l^2}$ (kips)

$P_{LL}$ = Axial live load on member.

$P_{sc}$ = Compressive axial strength of member.

$P_{st}$ = Tensile axial strength of member.

$P_y$ = Plastic axial load; equal to profile area times specified minimum yield stress (kips).

$Q_a$ = Ratio of effective profile area of an axially loaded member to its total profile area.

$Q_s$ = Axial stress reduction factor where width-thickness ratio of unstiffened elements exceeds limiting value given in section.

$R$ = Reaction or concentrated transverse load applied to beam or girder, (kips).

$S$ = Spacing of secondary members in a flat roof (feet).

$S_s$ = Section modulus of steel beam used in composite design, referred to the bottom flange.

$S_{tr}$ = Section modulus of transformed composite cross section, referred to the bottom flange, based upon maximum permitted effective width of concrete flange, Section 2708 (a).

$T_b$ = Specified pretension of a high-strength bolt, in kips.

$V$ = Statical shear on beam.

$V_h$ = Total horizontal shear to be resisted by connectors under full composite action.



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$V'_h$ = Total horizontal shear to be resisted by connectors in providing partial composite action (kips). See Section 2708 (d).

$V_s$ = Shear strength of member.

$V_u$ = Statical shear produced by "ultimate" load in plastic design.

$Y$ = Ratio of yield point of web steel to yield point of stiffener steel.

$Z$ = Plastic section modulus.

$a$ = Clear distance between transverse stiffeners.

$a'$ = Distance required at ends of welded partial length cover plate to develop stress.

$b$ = Effective width of concrete slab; actual width of stiffened compression element.

$b_e$ = Effective width of stiffened compression element.

$b_f$ = Flange width of rolled beam or plate girder.

$c$ = Distance from neutral axis to extreme fiber of beam.

$d$ = Depth of beam or girder. Also diameter of roller or rocker bearings, or major diameter of fastener.

$d_c$ = Column web depth clear of fillets.

$e$ = Horizontal displacement, in the direction of the span, between top and bottom of simply supported beam at its ends.

$f$ = Axial compression load on member divided by effective area (kips per square inch).

$f_a$ = Computed axial stress.

$f_b$ = Computed bending stress.

$f'_c$ = Specified compression strength of concrete.

$f_p$ = Computed bearing stress.

$f_t$ = Computed tensile stress.

$f_v$ = Computed shear stress.

$f_{vs}$ = Shear between girder web and transverse stiffeners, in kips per linear inch of single stiffener or pair of stiffeners.

$g$ = Transverse spacing between fastener gauge lines.

$h$ = Clear distance between flanges of a beam or girder.

$k$ = Coefficient relating linear buckling strength of a plate to its dimensions and condition of edge support. Also, distance from outer face of flange to web toe of fillet.

$l$ = Actual unbraced length, in inches.

$l_b$ = Actual unbraced length in plane of bending, in inches.

$l_{cr}$ = Critical unbraced length adjacent to plastic hinge, in inches.

$n$ = Modular ratio; equal to $E/E_c$.

$n_r$ = Number of studs in one rib not to exceed three in calculations.

$q$ = Allowable horizontal shear to be resisted by a shear connector.



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$r$ = Governing radius of gyration.
$r_b$ = Radius of gyration about axis of concurrent bending.
$r_y$ = Lesser radius of gyration.
$s$ = Spacing (pitch) between successive holes in line of stress.
$t$ = Girder, beam or column web thickness.
$t_b$ = Beam flange thickness at rigid beam-to-column connection.
$t_f$ = Flange thickness.
$t_t$ = Thickness of thinner part joined by partial penetration groove weld.
$v$ = Poisson's ratio, may be taken as 0.3 for steel.
$w$ = Length of channel shear connectors.
$x$ = Subscript relating symbol to strong axis bending.
$y$ = Subscript relating symbol to weak axis bending.
$\alpha$ = Ratio of hybrid girder web yield stress to flange yield stress.
$\Delta$ = Displacement of the neutral axis of a loaded member from its position when the member is not loaded.
$\beta$ = Ratio $S_{tr}/S_s$ or $S_{eff}/S_s$.

## Allowable Unit Stresses

**Sec. 2702.** (a) **General.** Except as provided in Sections 2703, 2704, 2707, 2708 and 2721, all components of the structure shall be so proportioned that the stress in kips per square inch shall not exceed the values specified in this section. Allowable stresses for web-tapered members may be governed by these provisions or by other approved methods.

(b) **Structural Steel.** 1. **Tension.** Except for pin-connected members, $F_t$ shall not exceed $0.6F_y$ on the gross area nor $0.5F_u$ on the effective net area.

For pin-connected members, $F_t = 0.45F_y$ on the net area.

For tension on threaded parts, see Table No. 27-A.

2. **Shear.** On the gross section (for shear calculation, the gross section of rolled and fabricated shapes may be taken as the product of the overall depth and the thickness of the web).

$$F_v = 0.40F_y$$

At beam end connections where the top flange is coped, and similar situations where failure might occur by shear along a plane through the fasteners or by a combination of shear along a plane through the fasteners plus tension along a perpendicular plane, on the area effective in resisting tearing failure:

$$F_v = 0.30F_u$$

**WHERE:**

The effective area is the minimum net surface, bounded by the bolt holes.

See Section 2707 for reduction required for thin webs.

3. **Compression.** On the gross section of axially loaded compression members whose cross sections meet the provisions of Section 2706 when $Kl/r$, the largest



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effective slenderness ratio of any unbraced segment as defined in Section 2705, is less than $C_c$.

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right]F_y}{\text{F.S.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2\text{-}1)$$

**WHERE:**

$$\text{F.S.} = \text{factor of safety} = \frac{5}{3} + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}$$

**AND**

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

On the gross section of axially loaded compression members when $Kl/r$ exceeds $C_c$.

$$F_a = \frac{12\pi^2 E}{23(Kl/r)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2\text{-}2)$$

On the gross section of axially loaded bracing and secondary members, when $l/r$ exceeds 120 (for this case $K$ is taken as unity).

$$F_{as} = \frac{F_a \text{[by Formula (2-1) or (2-2)]}}{1.6 - \frac{l}{200r}} \quad \ldots\ldots\ldots\ldots (2\text{-}3)$$

On the gross area of plate girder stiffeners

$$F_a = 0.60F_y$$

On the web of rolled shapes at the toe of the fillet for crippling

$$F_a = 0.75F_y$$

Web stiffeners shall be provided as specified in Section 2707 (j) when the compressive stress of the web toe exceeds the allowable stress specified in the preceding paragraph.

4. **Bending.** Except for hybrid girders and members of A514 steel, tension and compression on extreme fibers of compact hot-rolled or built-up members symmetrical about, and loaded in, the plane of their minor axis and meeting the requirements of this section shall not exceed:

$$F_b = 0.66F_y$$

**PROVIDED:**

(i) The flange is continuously connected to the web or webs.

(ii) The width-thickness ratio of unstiffened projecting elements of the compression flange as defined in Section 2706 does not exceed:

$$\frac{65}{\sqrt{F_y}}$$



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(iii) The width-thickness ratio of stiffened elements of the compression flange as defined in Section 2706 does not exceed:

$$\frac{190}{\sqrt{F_y}}$$

(iv) The depth-thickness ratio of the web or webs does not exceed:

$$\frac{640\,(1-3.74\,\frac{f_a}{F_y})}{\sqrt{F_y}} \text{ when } \frac{f_a}{F_y} \leq 0.16 \qquad \text{(2-4)}$$

nor:

$$\frac{257}{\sqrt{F_y}} \text{ when } \frac{f_a}{F_y} > 0.16$$

(v) The laterally unsupported length of the compression flange of members other than circular or box members shall not exceed the value $76.0b_f/\sqrt{F_y}$ nor

$$\frac{20{,}000}{(d/A_f)F_y}$$

(vi) The laterally unsupported length of the compression flange of a box-shaped member of rectangular cross section whose depth is not more than six times the width and whose flange thickness is not more than two times the web thickness shall not exceed the value

$$\left(1950 + 1200\,\frac{M_1}{M_2}\right)\frac{b}{F_y}$$

except that it need not be less than $1200\,(b/F_y)$.

(vii) The diameter-thickness ratio of circular sections shall not exceed $3300/F_y$.

Except as specified in this paragraph, beams and girders, including members designed for composite action, qualifying for $F_b = 0.66F_y$ and which are continuous over supports or are rigidly framed to columns by means of rivets, high-strength bolts or welds, may be proportioned for nine tenths of the negative moments produced by gravity loading which are maximum at points of support, provided that, for such members, the maximum positive moment shall be increased by one tenth of the average negative moments. This reduction shall not apply to tapered girders or moments produced by loading on cantilevers or when including the one-third allowable stress increase for wind or earthquake forces. If the negative moment is resisted by a column rigidly framed to the beam or girder, the one-tenth reduction may be used in proportioning the column for the combined axial and bending loading, provided that the unit stress $f_a$ due to any concurrent axial load on the member does not exceed $0.15\,F_a$.



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Members qualifying for $F_b = 0.66F_y$, except that $b_f/2t_f$ exceeds $65/\sqrt{F_y}$ but is less than $95.0/\sqrt{F_y}$ may have an allowable bending stress of:

$$F_b = F_y \left[ .79 - .002 \left(\frac{b_f}{2t_f}\right) (\sqrt{F_y}) \right] \quad \ldots\ldots\ldots (2\text{-}5)$$

Tension and compression on extreme fibers of doubly symmetrical I- and H-shape members with flanges continuously connected to web or webs, unstiffened projecting elements of the compression flange not exceeding $65/\sqrt{F_y}$ and bent about their minor axis; solid round and square bars; and solid rectangular bars bent about their weaker axis shall not exceed

$$F_b = 0.75F_y$$

This does not include I and H shapes of A514 steel.

Doubly symmetrical I- and H-shape members bent about their minor axis (except hybrid girders and members of A514 steel) with the flanges continuously connected to the web or webs, except where $b_f/2t_f$ exceeds $65/\sqrt{F_y}$ but is less than $95.0/\sqrt{F_y}$, may be designed on the basis of an allowable bending stress of

$$F_b = F_y \left[ 1.075 - 0.005 \left(\frac{b_f}{2t_f}\right) \sqrt{F_y} \right]$$

Rectangular tubular sections bent about their minor axis and meeting the requirements of subparagraphs (i), (iii) and (iv) above may be designed on the basis of an allowable bending stress of

$$F_b = 0.66F_y$$

Lateral torsional buckling need not be investigated for a box section whose depth is less than six times its width. Lateral support requirements for box sections of larger depth-to-width ratios must be determined by special analysis.

Tension on extreme fibers of flexural members not previously covered in this subsection on bending shall not exceed $F_b = 0.60F_y$.

Compression on extreme fibers of flexural members included under the preceding paragraph and meeting the requirements of Subsection 2706 (a), having an axis of symmetry in and loaded in the plane of their web, and compression on extreme fibers of channels bent about their major axis shall not exceed the larger of Formulas (2-6a) or (2-6b) and (2-7), when applicable, but not more than $0.60F_y$.

Only Formula (2-7) is applicable to channels. See Section 2707 for further limitations to plate girder flange stress.



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**WHEN:**

$$\sqrt{\frac{102\ (10^3)\ C_b}{F_y}} \leqq l/r_t \leqq \sqrt{\frac{510\ (10^3)\ C_b}{F_y}}$$

$$F_b = \left[\frac{2}{3} - \frac{F_y\ (l/r_t)^2}{1530\ (10^3)\ C_b}\right] F_y \quad \text{.....(2-6a)}$$

**WHEN:**

$$l/r_t \geqq \sqrt{\frac{510\ (10^3)\ C_b}{F_y}}$$

$$F_b = \frac{170\ (10^3)\ C_b}{(l/r_t)^2} \quad \text{.....(2-6b)}$$

Or when the compression flange is solid and approximately rectangular in cross section and the area is not less than the tension flange:

$$F_b = \frac{12\ (10^3)\ C_b}{ld/A_f} \quad \text{.....(2-7)}$$

**WHERE:**

$l$ = distance between cross sections braced against twist or lateral displacement of the compression flange. For cantilevers braced against twist at the support only, "$l$" may conservatively be taken as the actual length.

$r_t$ = Radius of gyrations of a section comprising the compression flange plus one third of the compression web area, taken about an axis in the plane of the web.

$$C_b = 1.75 + 1.05\left(\frac{M_1}{M_2}\right) + 0.3\left(\frac{M_1}{M_2}\right)^2 \quad \text{.....(2-8)}$$

but not more than 2.3 ($C_b$ may be conservatively taken as unity) where $M_1$ is the smaller and $M_2$ the larger bending moment at the ends of the unbraced length, taken about the strong axis of the member, and where $M_1/M_2$, the ratio of end moments, is positive when there is reverse curvature bending and negative when there is single curvature bending. When the bending moment at any point within an unbraced length is larger than that at both ends of this length, $C_b$ shall be unity. When computing $F_{bx}$ and $F_{by}$ to be used in Formula (3-1a), $C_b$ may be computed by the formula given above for frames subject to joint translation, and it shall be taken as unity for frames braced against joint translation. $C_b$ may be conservatively taken as 1.0 for cantilever beams.



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For hybrid plate girders, $F_y$ in Formulas (2-6a) and (2-6b) is the yield stress of the compression flange. Formula (2-7) shall not apply to hybrid girders.

Compression on extreme fibers of flexural members not previously covered in this subsection on bending and meeting the requirements of Section 2706 (a), which do not qualify for Formulas (2-6a), (2-6b) and (2-7), and provided that sections bent about their major axis are braced laterally in the region of compression stress at intervals not exceeding $76.0b_f/\sqrt{F_y}$ shall not exceed

$$F_b = 0.60F_y$$

5. **Bearing (on contact area).** Milled surfaces, pins in reamed, drilled or bored holes and ends of fitted bearing stiffeners:

$$F_p = 0.90F_y^*$$

Expansion rollers and rockers, kips per linear inch

$$F_p = \left(\frac{F_y - 13}{20}\right) 0.66d$$

where $d$ is the diameter of roller or rocker in inches.

*When parts in contact have different yield points, $F_y$ shall be the smaller value.

6. **Bearing (on concrete).**

On the full area of concrete support . . . . . $F_p = 0.35f'_c$

On less than the full area of a concrete support . . . . . $F_p = 0.35f'_c\sqrt{A_2/A_1} \leq 0.7f'_c$

(c) **Rivets, Bolts and Threaded Parts.** 1. Allowable tension and shear stress on rivets, bolts and threaded parts (kips per square inch of area of rivets before driving or the area of threaded portion of bolts and threaded parts based on their major diameter) shall not exceed the values set forth in Table No. 27-A.

2. High-strength bolts required to support applied loads by direct tension shall have an average tensile stress, independent of any initial tightening force, not exceeding the appropriate stress in Table No. 27-A. The applied load shall be the sum of the external load and any tension resulting from prying action produced by deformation of the connected parts.

3. The design for rivets, bolts and threaded parts subject to fatigue loading shall be in accordance with U.B.C. Standard No. 27-3.

4. Maximum allowable bearing stress on the connected parts produced by fasteners in shear:

$$F_p = 1.5F_u$$

where $F_u$ is the minimum tensile strength of the connected parts. Also see Section 2713 (d) and (e).

(d) **Welds.** Except as modified by Section 2704, weld stresses shall comply with Table No. 27-B.



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(e) **Effective Areas of Weld Metal.** The effeetive area of groove and fillet welds shall be eonsidered as the effective length of the weld times the effeetive throat thiekness.

The effeetive shearing area of plug and slot welds shall be considered as the nominal cross-sectional area of the hole or slot in the plane of the faying surface.

The effective area of fillet welds in holes and slots shall be computed as specified above for fillet welds, using for effective length the length of center line of the weld through the center of the plane through the throat. However, in the case of overlapping fillets, the effective area shall not exceed the nominal cross-sectional area of the hole or slot in the plane of the faying surfaee.

The effective length of a fillet weld shall be the overall length of full-size fillet including returns.

The effective length of a groove weld shall be the width of the part joined.

The effective throat thickness of a fillet weld shall be the shortest distance from the root to the face of the diagrammatic weld. However, for fillet welds made by the submerged arc process, the effective throat thickness shall be the leg size for 3/8 inch and smaller fillet welds and equal to the theoretical throat plus 0.11 inch for fillet welds over 3/8 inch.

The effective throat thickness of a complete penetration groove weld (i.e., a groove weld conforming to the requirements of U.B.C. Standard No. 27-6) shall be the thickness of the thinner part joined.

The effective throat of a partial joint penetration groove weld shall be the depth of chamfer, less 1/8 inch for grooves having an ineluded angle less than 60 degrees, but not less than 45 degrees at the root of the groove, when deposited by shielded metal arc or submerged arc welding, or when deposited in vertical or overhead positions by gas metal arc or flux-cored welding.

The effeetive throat of a partial joint penetration groove weld shall be the dcpth of chamfer for grooves:

(i) having an included angle of 60 degrees or greater at the root of the groove when deposited by any of the following welding processes: shielded metal arc, submerged arc, gas mctal arc, flux-cored are or elcctrogas welding; or

(ii) having an included angle not less than 45 degrees at the root of the groove when deposited in flat or horizontal positions by gas metal arc or flux-cored are welding.

The effective throat thiekness for flare groove welds when flush to the surface of the solid section of the bar shall be as shown in Table No. 27-F.

1. Random sections of production welds for each welding procedure, or such test seetions as may be required, shall be used to verify that the effective throat is consistently obtained.

2. Where for a given set of procedural conditions it can be established that eonsistently larger effeetive throats than those shown in Table No. 27-F can be provided, such larger effective throats may be established by qualification.

3. Qualification required by Item No. 2 shall consist of sectioning the radiused member, normal to its axis, at midlength and terminal ends of the weld. Such sectioning shall be made on a number of combinations of material sizes representative of the range used in eonstruction.



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(f) **Cast Steel and Steel Forgings.** The allowable stress for cast steel and steel forgings shall not exceed the values specified in Section 2702 (b), where applicable.

## Combined Stresses

**Sec. 2703.** (a) **Axial Compression and Bending.** Members subject to both axial compression and bending stresses shall be proportioned to satisfy the following requirements:

$$\frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F'_{ex}}\right) F_{bx}} + \frac{C_{my} f_{by}}{\left(1 - \frac{f_a}{F'_{ey}}\right) F_{by}} \leq 1.0 \quad \text{.....(3-1a)}$$

$$\frac{f_a}{0.60F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \quad \text{.....(3-1b)}$$

**WHEN:**

$f_a/F_a \leq 0.15$, Formula (3-2) may be used in lieu of Formulas (3-1a) and (3-1b):

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \quad \text{.....(3-2)}$$

$C_m$ = A coefficient whose value shall be taken as follows:

1. For compression members in frames subject to joint translation (sidesway) $C_m = 0.85$.
2. For restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending, $C_m = 0.6 - 0.4\,M_1/M_2$, but not less than 0.4, where $M_1/M_2$ is the ratio of the smaller to the larger moments at the ends of that portion of the member, unbraced in the plane of bending, under consideration. $M_1/M_2$ is positive when the member is bent in reverse curvature and negative when bent in single curvature.
3. For compression members in frames braced against joint translation in the plane of loading and subjected to transverse loading between their supports, the value of $C_m$ may be determined by rational analysis. However, in lieu of such analysis, the following values may be used: (i) for members whose ends are restrained, $C_m = 0.85$; (ii) for members whose ends are unrestrained, $C_m = 1$.

(b) **Axial Tension and Bending.** Members subject to both axial tension and bending stresses shall be proportioned at all points along their length to satisfy the requirements of Formula (3-1b) where $f_b$ is the computed bending tensile stress. However, the computed compressive stress, taken alone, shall not exceed the applicable value permitted by Section 2702 (b) 4.



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(c) **Shear and Tension.** Rivets and bolts subject to combined shear and tension shall be so proportioned that the tension stress, in kips per square inch, on the nominal area $A_b$ produced by forces applied to the connected parts shall not exceed the following:

| | |
|---|---|
| For A502 Grade 1 rivets | $F_t = 30 - 1.3f_v \leq 23$ |
| For A502 Grade 2 rivets | $F_t = 38 - 1.3f_v \leq 29$ |
| For A307 bolts | $F_t = 26 - 1.8f_v \leq 20$ |
| For A449 bolts over 1½-inch diameter and threaded parts, threads not excluded | $F_t = .43f_u - 1.8f_v \leq .33F_u$ |
| For A449 bolts over 1½-inch diameter and threaded parts, threads excluded | $F_t = .43f_u - 1.4f_v \leq .33F_u$ |
| For A325 bearing bolts, threads not excluded | $F_t = 55 - 1.8f_v \leq 44$ |
| For A325 bearing bolts, threads excluded | $F_t = 55 - 1.4f_v \leq 44$ |
| For A490 bearing bolts, threads not excluded | $F_t = 68 - 1.8f_v \leq 54$ |
| For A490 bearing bolts, threads excluded | $F_t = 68 - 1.4f_v \leq 54$ |

The shear stress $f_v$ produced by the same forces shall not exceed the allowable value for shear specified in Section 2702 (c). When allowable stresses are increased for wind or seismic loads in accordance with Section 2303 (d), the constants in the above formulas may be increased one third, but the factor coefficient applied to $f_v$ shall not be increased.

For bolts in friction-type joints, the shear stress allowed in Section 2702 (c) shall be reduced so that:

| | |
|---|---|
| For A325 bolts in standard holes | $F_v \leq 17.5\,(1 - f_t A_b/T_b)$ |
| For A325 bolts in oversize and short-slotted holes | $F_v \leq 15.0\,(1 - f_t A_b/T_b)$ |
| For A325 bolts in long-slotted holes | $F_v \leq 12.5\,(1 - f_t A_b/T_b)$ |
| For A490 bolts in standard holes | $F_v \leq 22.0\,(1 - f_t A_b/T_b)$ |
| For A490 bolts in oversize and short-slotted holes | $F_v \leq 19.0\,(1 - f_t A_b/T_b)$ |
| For A490 bolts in long-slotted holes | $F_v \leq 16.0\,(1 - f_t A_b/T_b)$ |

**WHERE:**

$f_t$ is the average tensile stress due to a direct load applied to all of the bolts in a connection, and $T_b$ is the specified pretension load of the bolt. When allowable stresses are increased for wind or seismic loads in accordance with Section 2303 (d), the allowable shear stress $f_v$ may be increased one-third.



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## Stress Reversal

**Sec. 2704.** Members or connections which are subjected to a variation or reversal of stress shall be designed as set forth in U.B.C. Standard No. 27-3.

## Stability and Slenderness Ratios

**Sec. 2705.** (a) **General.** General stability shall be provided for the structure as a whole and for each compression element. In determining the slenderness ratio of an axially loaded compression member, except as provided by Formula (2-3) the length $l$ shall be taken as its effective length $Kl$ and $r$ the corresponding radius of gyration.

(b) **Sidesway Prevented.** In frames where lateral stability is provided and in trusses, the effective length factor $K$ for the compression members shall be taken as unity.

**EXCEPTION:** A $K$ value of less than one may be used where substantiating data justify such a reduction.

(c) **Sidesway Not Prevented.** In frames where lateral stability is dependent on the bending stiffness of rigidly connected beams and columns, the effective length $Kl$ of compression members shall be determined by a rational method and shall be not less than the actual unbraced length.

(d) **Maximum Ratios.** The slenderness ratio, $Kl/r$, of compression members shall not exceed 200.

The slenderness ratio, $l/r$, of tension members, other than rods, should not exceed:

For main members ..... 240

For lateral bracing members and other secondary members ..... 300

## Width-Thickness Ratios

**Sec. 2706.** (a) **Unstiffened Elements Under Compression.** Unstiffened (projecting) compression elements are those having one free edge parallel to the direction of compression stress. The width of unstiffened plates shall be taken from the free edge to the first row of fasteners or welds; the width of angle legs, channel and zee flanges and stems of tees shall be taken as the full nominal dimension; the flanges of I-shaped members and tees shall be taken as one half the full nominal width. The thickness of a sloping flange shall be measured halfway between a free edge and the corresponding face of the web.

Unstiffened elements subject to axial compression or compression due to bending shall be considered as fully effective when the ratio of width to thickness is not greater than the following:

Single-angle struts; double-angle struts with separators ..... $76/\sqrt{F_y}$

Struts comprising double angles in contact; angles or plates projecting from girders, columns or other compression members; compression flanges of beams; stiffeners on plate girders ..... $95/\sqrt{F_y}$

Stems of tees ..... $127/\sqrt{F_y}$

When the actual width-to-thickness ratio exceeds these values, the design shall be governed by other approved methods.



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(b) **Stiffened Elements Under Compression.** Stiffened compression elements are those having lateral support along both edges which are parallel to the direction of the compression stress. The width of such elements shall be the distance between nearest lines of fasteners or welds, or between the roots of flanges of rolled sections.

Stiffened elements subject to axial compression or to uniform compression due to bending, such as the flange of a flexural member see Section 2707 (b) and (f), shall be considered fully effective when the ratio of width to thickness does not exceed the following:

Flanges of square and rectangular box sections of uniform thickness . . . . . $238/\sqrt{F_y}$

Unsupported width of cover plates perforated with a succession of access holes . . . . . $317/\sqrt{F_y}$
(Assumes net area of plate at widest hole in computing compression stress.)

All other uniformly compressed stiffened elements . . . . . $253/\sqrt{F_y}$

Except in the case of perforated cover plates, when the actual width-to-thickness ratio exceeds these values the design shall be governed by other approved methods.

(c) **Circular Tubular Elements.** Circular tubular elements subject to axial compression shall be considered as fully effective when the ratio of diameter to thickness is not greater than $3300/F_y$.

## Plate Girders and Rolled Beams

**Sec. 2707.** (a) **Proportions.** Riveted and welded plate girders, cover-plated beams and rolled or welded beams shall be proportioned by the moment of inertia of the gross section. No deduction shall be made for shop or field rivet or bolt holes in either flange, except that in cases where the reduction of the area of either flange by such holes, calculated in accordance with the provisions of Section 2711 (b), exceeds 15 percent of the gross flange area, the excess shall be deducted.

Hybrid girders may be proportioned by the moment of inertia of their gross section (web stresses produced by the bending moment are unlimited except as regulated in Section 2704 and U.B.C. Standard No. 27-3), subject to the other provisions of this section, provided they do not resist an axial force exceeding $0.15F_y$ times the gross section where $F_y$ is the yield stress of the flange material. Hybrid girders must have flanges of equal areas at any section and have the same grade of steel.

(b) **Web.** The clear distance between flanges in inches shall not exceed

$$\frac{14{,}000\ (t)}{\sqrt{F_y\ (F_y + 16.5)}}$$



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**WHERE:**

$F_y$ = Yield stress of the compression flanges. A limiting value of 2000 $(t)/\sqrt{F_y}$ may be used, provided there are transverse stiffeners spaced not more than 1.5 times the girder depth.

(c) **Flanges.** The thickness of outstanding parts of flanges shall conform to the requirements of Section 2706 (a).

The total cross-sectional area of cover plates of riveted girders shall not exceed 70 percent of the total flange area. Provision shall be made for stresses resulting from abrupt changes in flange direction and other conditions that introduce stress concentration.

(d) **Flange Development.** Rivets, high-strength bolts or welds connecting flange to web, or cover plate to flange, shall be proportioned to resist the total horizontal shear resulting from the bending forces on the girder. The longitudinal distribution of these rivets, bolts or of intermittent welds shall be in proportion to the intensity of the shear. But the longitudinal spacing shall not exceed the maximum permitted, respectively, for compression or tension members in Section 2715 (e) or (d). In addition, rivets or welds connecting flange to web shall be proportioned to transmit to the web loads applied directly to the flange except where provision is made to transmit such loads by direct bearing.

Partial length cover plates shall be extended beyond the theoretical cutoff point and the extended portion shall be attached to the beam or girder by rivets, high-strength bolts or fillet welds adequate to develop the cover plate's portion of the flexural stresses in the beam or girder at the theoretical cutoff point. In addition, for welded cover plates, the welds connecting the cover plate termination to the beam or girder in the length $a'$, defined below, shall be adequate to develop the cover plate's portion of the flexural stresses in the beam or girder at the distance $a'$ from the end of the cover plate. The length $a'$, measured from the end of the cover plate, shall be:

1. A distance equal to the width of the cover plate when there is a continuous weld equal to or larger than three fourths of the plate thickness across the end of the plate and continued welds along both edges of the cover plate in the length $a'$.
2. A distance equal to one and one-half times the width of the cover plate when there is a continuous weld smaller than three fourths of the plate thickness across the end of the plate and continued welds along both edges of the cover plate in the length $a'$.
3. A distance equal to two times the width of the cover plate when there is no weld across the end of the plate but continuous welds along both edges of the cover plate in the length $a'$.

(e) **Stiffeners.** Bearing stiffeners shall be placed in pairs at unframed ends on the webs of plate girders and, where required [see Section 2707 (j) for welded plate girders], at points of concentrated loads. Such stiffeners shall have a close bearing against the flange, or flanges, through which they receive their loads or reactions and shall extend approximately to the edge of the flange plates or flange angles. They shall be designed as columns subject to the provisions of Section



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2702 (b) 3, assuming the column section to comprise the pair of stiffeners and a centrally located strip of the web, whose width is equal to not more than 25 times its thickness at interior stiffeners, or a width equal to not more than 12 times its thickness when the stiffeners are located at the end of the web. The effective length shall be taken as not less than three fourths of the length of the stiffeners in computing the ratio $l/r$. Only that portion of the stiffener outside of the flange angle fillet or the flange-to-web welds shall be considered effective in bearing.

Except as provided in this section the average web shear $f_v$ in kips per square inch, shall not exceed:

$$F_v = \frac{F_y\,(C_v)}{2.89} \leqq 0.4F_y \qquad (7\text{-}1)$$

**WHERE:**

$$C_v = \frac{45{,}000k}{F_y(h/t)^2} \text{ when } C_v \text{ is less than } 0.8.$$

$$C_v = \frac{190}{h/t}\sqrt{\frac{k}{F_y}} \text{ when } C_v \text{ is more than } 0.8.$$

$$k = 4.00 + \frac{5.34}{(a/h)^2} \text{ when } a/h \text{ is less than } 1.0.$$

$$k = 5.34 + \frac{4.00}{(a/h)^2} \text{ when } a/h \text{ is more than } 1.0.$$

Where intermediate stiffeners are provided at spacings complying with this section and if $C_v \leqq 1.00$, girders other than hybrid types may have an allowable shear of:

$$F_v = \frac{F_y}{2.89}\left[C_v + \frac{1 - C_v}{1.15\sqrt{1 + (a/h)^2}}\right] \leqq 0.4F_y \qquad (7\text{-}2)$$

(Recognizes the contribution of tension field action.)

Subject to the limitations of Section 2707 (b), intermediate stiffeners are not required when the ratio $h/t$ is less than 260 and the maximum web shear stress $f_v$ is less than that permitted by Formula (7-1).

The spacing of intermediate stiffeners, when stiffeners are required, shall be such that the web shear stress will not exceed the value for $F_v$ given by Formula (7-1) or (7-2), as applicable and the ratio $a/h$ shall not exceed:

$$\left(\frac{260}{h/t}\right)^2 \text{ nor } 3.0.$$



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For girders designed for tension field action, the spacing between stiffeners at end panels and panels containing large holes and panels adjacent thereto shall be such that $f_v$ does not exceed the value given by Formula (7-1).

The moment of inertia of a pair of intermediate stiffeners or a single intermediate stiffener about an axis in the web plane shall be not less than $(h/50)4$.

The gross area, in square inches, of intermediate stiffeners spaced in accordance with Formula (7-2) shall be not less than that computed by Formula (7-3).

$$A_{st} = \frac{1 - C_v}{2}\left[\frac{a}{h} - \frac{(a/h)^2}{\sqrt{1 + (a/h)^2}}\right] YDht \quad \text{.....(7-3)}$$

(Total area when stiffeners are furnished in pairs.)

**WHERE:**

$C_v$ is as defined in Section 2707 (e).

$Y$ = yield stress of web steel/yield stress of stiffener steel.

$D$ = 1.0 for stiffeners furnished in pairs.

= 1.8 for single angle stiffeners.

= 2.4 for single plate stiffeners.

When the greatest shear stress $f_v$ in a panel is less than that permitted by Formula (7-2), this gross area requirement may be reduced in like proportion.

Intermediate stiffeners required by the provisions of Formula (7-2) shall be connected for a shear transfer in kips per linear inch of single or pairs of stiffeners not less than

$$f_{vs} = h\sqrt{\left(\frac{F_y}{340}\right)^3} \quad \text{.....(7-4)}$$

**WHERE:**

$F_y$ = yield stress of web steel.

This shear transfer may be reduced in the same proportion that the largest computed shear stress $f_v$ in the adjacent panels is less than that permitted by Formula (7-2). However, rivets and welds in intermediate stiffeners which are required to transmit to the web an applied concentrated load or reaction shall be proportioned for not less than the applied load or reaction.

Intermediate stiffeners may be stopped short of the tension flange, provided bearing is not needed to transmit a concentrated load or reaction. The weld by which intermediate stiffeners are attached to the web shall be terminated not closer than four nor more than six times the web thickness from the toe of the web to flange weld. When single stiffeners are used they shall be attached to the compression flange, if it consists of a rectangular plate, to resist any uplift tendency due to torsion in the plate. When lateral bracing is attached to a stiffener or a pair of stiffeners these, in turn, shall be connected to the compression flange to transmit 1 percent of the total flange stress, unless the flange is composed only of angles.



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Rivets connecting stiffeners to the girder web shall be spaced not more than 12 inches on center. If intermittent fillet welds are used, the clear distance between welds shall be not more than 16 times the web thickness nor more than 10 inches.

(f) **Reduction in Flange Stress.** When the web depth-to-thickness ratio exceeds $760/\sqrt{F_b}$, the maximum stress in the compression flange shall not exceed:

$$F'_b \leqq F_b \left[1.0 - 0.0005 \frac{A_w}{A_f}\left(\frac{h}{t} - \frac{760}{\sqrt{F_b}}\right)\right] \quad \text{.....(7-5)}$$

The maximum stress in either flange of a hybrid girder shall not exceed $F'_b$ in Formula (7-5) nor

$$F'_b \leqq F_b \left[\frac{12 + \left(\frac{A_w}{A_f}\right)(3\alpha - \alpha^3)}{12 + 2\,(A_w/A_f)}\right] \quad \text{.....(7-6)}$$

**WHERE:**

$\alpha$ = ratio of web yield stress to flange yield stress.

(g) **Combined Shear and Tension Stress.** Plate girder webs shall be so proportioned that the bending tensile stress due to moment in the plane of the girder web shall not exceed:

$$0.6F_u \text{ nor } \left(0.825 - 0.375 \frac{f_v}{F_v}\right) F_u \quad \text{.....(7-7)}$$

The allowable shear stress in webs of girders having A514 flanges and webs shall not exceed that determined by Formula (7-1) if the flexural stress in the flange exceeds $0.75F_b$.

(h) **Splices.** Groove welded splices in plate girders and beams shall develop the full strength of the smaller spliced section. Other types of splices in cross sections of plate girders and in beams shall develop the strength required by the stresses at the point of splice.

(i) **Horizontal Forces.** The flanges of plate girders supporting cranes or other moving loads shall be proportioned to resist the horizontal forces produced by such loads.

The lateral force on crane runways shall be 20 percent of the sum of the weights of the lifted load and of the crane trolley, applied at the top of rail, one half on each side of the runway; and shall be considered as acting in either direction normal to the runway rail.

The longitudinal force shall be 10 percent of the maximum wheel loads of the crane applied at the top of rail.

(j) **Web Crippling.** Webs of beams and welded plate girders shall be so



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proportioned that the compressive stress at the web toe of the fillets, resulting from concentrated loads not supported by bearing stiffeners, does not exceed $0.75F_y$.

The compressive stress at the web top of the fillets shall be computed using the following formulas:

For interior loads:

$$\frac{R}{t(N+2k)} \leqq 0.75F_y \quad \text{.....(7-8)}$$

For end reactions:

$$\frac{R}{t(N+k)} \leqq 0.75F_y \quad \text{.....(7-9)}$$

**WHERE:**

$N$ = length of bearing in inches (not less than $k$ for end reactions).

Bearing stiffeners shall be provided where the compressive stress exceeds that determined by Formulas (7-8) and (7-9).

Webs of welded plate girders also shall be so proportioned or stiffened that the sum of the compression stresses resulting from concentrated and distributed loads bearing directly on or through a flange plate, upon the compression edge of the web plate and not supported directly by bearing stiffeners does not exceed the following:

When the flange is restrained against rotation,

$$\left[5.5 + \frac{4}{(a/h)^2}\right] \frac{10{,}000}{(h/t)^2} \quad \text{.....(7-10)}$$

When the flange is not restrained against rotation,

$$\left[2 + \frac{4}{(a/h)^2}\right] \frac{10{,}000}{(h/t)^2} \quad \text{.....(7-11)}$$

These stresses shall be computed as follows: concentrated loads shall be divided by the product of the web thickness and the girder depth or the length of panel in which the load is placed, whichever is the lesser panel dimension.

Distributed loads in kips per lineal inch of length shall be divided by the web thickness.

(k) **Rotational Restraint at Points of Support.** Beams, girders and trusses shall be restrained against rotation about their longitudinal axis at points of support.

## Composite Construction

**Sec. 2708.** (a) **Definition.** Composite construction shall consist of steel beams or girders supporting a reinforced concrete slab, so interconnected that the beam and slab act together to resist bending. When the slab extends on both sides of the beam, the effective width of the concrete flange shall be taken as no more than one fourth of the span of the beam, and its effective projection beyond the edge of the beam shall not be taken as more than one half the clear distance to the adjacent



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beam nor more than eight times the slab thickness. When the slab is present on only one side of the beam, the effective projection of the concrete flange shall be taken as not more than one twelfth of the beam span nor six times its thickness nor one half the clear distance to the adjacent beam. Composite construction may also be permitted using a metal deck with a structural concrete fill and designed by an approved method of analysis.

Beams totally encased 2 inches or more on their sides and soffit in concrete cast integrally with the slab may be assumed to be interconnected to the concrete by natural bond, without additional anchorage, provided the top of the beam is not less than 1½ inches below the top and 2 inches above the bottom of the slab, and provided that the encasement has adequate mesh or other reinforcing steel throughout the depth and across the soffit of the beam. When shear connectors are provided in accordance with Section 2708 (d), encasement of the beam to achieve composite action is not required.

(b) **Design Assumptions.** Encased beams shall be proportioned to support unassisted all dead loads applied prior to the hardening of the concrete except where these loads are supported temporarily on shoring. The beams acting in conjunction with the slab shall support all dead and live loads applied after hardening of the concrete, without exceeding a computed bending stress of $0.66F_y$, where $F_y$ is the yield stress of the steel beam. The bending stress produced by loads after the concrete has hardened shall be computed on the basis of the section properties of the composite section. Concrete tension stress shall be neglected. Alternatively, the steel beam may be proportioned to resist unassisted the positive moment produced by all loads, live and dead, using a bending stress equal to $0.76F_y$, in which case temporary shoring is not required.

When shear connectors are used in accordance with Section 2708 (d) the composite section shall be proportioned to support all of the loads without exceeding the allowable stress prescribed in Section 2702 (b) 4. This includes composite sections where the structural steel is not shored during construction. When using shear transfer devices on a noncompositely designed beam, those devices must be able to resist the combined effects produced by composite action plus shear transfer loads. In calculations involving composite sections in positive moment areas, the steel cross section is exempt from compactness requirements of subparagraphs (ii), (iii) and (v) of Section 2702 (b) 4.

Reinforcement parallel to the beam within the effective width of the slab, when anchored in conformance with Chapter 26, may be included in the properties of composite sections, provided shear connectors comply with Section 2708 (d). The section properties of the composite section shall be computed in accordance with the elastic theory. Concrete tension stresses shall be neglected. For stress computations the compression area of lightweight or normal-weight concrete shall be treated as an equivalent area of steel by dividing it by the modular ratio, $n$, for normal-weight concrete of the strength specified when determining the section properties. For deflection calculations only, the transformed section properties shall be based on the appropriate modular ratio, $n$, for the strength and weight concrete specified.



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Where shear connectors in conformance with Section 2708 (d) are not provided, the effective section modulus used in stress calculations shall not exceed:

$$S_{eff} = S_s + \sqrt{\frac{V'_h}{V_h}}\,(S_{tr} - S_s) \quad \text{.....(8-1)}$$

For construction without temporary shoring, stress in the steel section may be computed from the total dead plus live load moment and the actual transformed section modulus $S_{tr}$ except that the numerical value of $S_{tr}$ so used shall not exceed that of Formula (8-2). These stresses shall not exceed the appropriate value of Section 2702. Section 2303 (d) shall not apply to stresses in the negative moment area computed under the provisions of this paragraph.

$$S_{tr} = \left(1.35 + 0.35\,\frac{M_L}{M_D}\right) S_s \quad \text{.....(8-2)}$$

**WHERE:**

$M_L$ = moment caused by loads applied after concrete has attained 75 percent of its required strength.

$M_D$ = moment caused by loads applied prior to this time.

At sections subject to positive bending moment, the stress shall be computed for the steel tension flange. At sections subject to negative bending moment, the stress shall be computed for the steel tension and compression flanges. These stresses shall not exceed the appropriate value of Section 2702.

The steel beam alone, supporting the loads before the concrete has hardened, shall not be stressed to more than the applicable bending stress given in Section 2702 (b).

Provisions shall be made to prevent cracking of the slab spanning perpendicular to the beam.

The actual section modulus of the transformed composite section shall be used in calculating the concrete flexural compression stress and, for construction without temporary shores, this stress shall be based upon loading applied after the concrete has reached 75 percent of its required strength. The stress in the concrete shall not exceed $0.45f'_c$.

(e) **End Shear.** The web and the end connections of the steel beam shall be designed to carry the total reaction.

(d) **Shear Connectors.** The horizontal shear between the steel beam and concrete slab shall be transferred by shear connectors welded to the beam and embedded in the concrete except as specified in Section 2708 (a). For full composite action with concrete subject to flexural compression, the total horizon-



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tal shear between the point of maximum positive moment and points of zero moment shall be the smaller of the following:

$$V_h = \frac{0.85 f'_c A_c}{2} \quad \text{(8-3)}$$

**AND**

$$V_h = \frac{A_s F_y}{2} \quad \text{(8-4)}$$

$A'_s F_{yr}/2$ shall be added to the right hand side of Formula (8-3) if longitudinal reinforcing steel with area $A'_s$ located within the effective width of the concrete flange is included in the properties of the composite section.

In continuous composite beams where longitudinal reinforcing steel is considered to act compositely with the steel beam in the negative moment regions, the total horizontal shear resisted by shear connectors between an interior support and each adjacent point of contraflexure shall be:

$$V_h = \frac{A_{sr} F_{yr}}{2} \quad \text{(8-5)}$$

For full composite action, the number of connectors resisting the horizontal shear obtained from Formula (8-3) or (8-4) shall be not less than that determined by the following formula:

$$N_1 = \frac{V_h}{q} \quad \text{(8-6)}$$

Working values for flat soffit concrete slabs with aggregates not conforming with U.B.C. Standards No. 26-2 and No. 26-3, and for connectors other than shown in Table No. 27-C, must be established by an approved test program.

For partial composite action with concrete subject to flexural compression, $V'_h$ in Formula (8-1) shall be $q$ multiplied by the number of connectors furnished between the point of maximum moment and the nearest point of zero moment. The value of $V'_h$ shall be not less than one fourth the smaller value of Formula (8-3), using the maximum permitted effective width of the concrete flange, and Formula (8-4). The effective moment of inertia for deflection computations shall be determined by:

$$I_{eff} = I_s + \sqrt{\frac{V'_h}{V_h}} (I_{tr} - I_s) \quad \text{(8-7)}$$

**WHERE:**

$I_s$ = moment of inertia of the steel beam (inches$^4$)

$I_{tr}$ = moment of inertia of the transformed composite section (inches$^4$)



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The connectors required on each side of the point of maximum moment in an area of positive bending may be uniformly distributed between that joint and adjacent points of zero moment except that $N_2$, the number of shear connectors required between any concentrated load in that area and the nearest point of zero moment, shall be determined by the following formula:

$$N_2 = \frac{N_1\left[\frac{M\beta}{M\ (max)} - 1\right]}{\beta - 1} \quad \text{.....(8-8)}$$

**WHERE:**

$M$ = The moment (less than the maximum moment) at a concentrated load point.

$N_1$ = Number of connectors required between point of maximum moment and point of zero moment determined by the relationship $V_h/q$ or $V'_h/q$, as applicable.

$$\beta = \frac{S_{tr}}{S_s} \text{ or } \frac{S_{eff}}{S_s}, \text{ as applicable.}$$

Connectors required in the region of negative bending on a continuous beam may be uniformly distributed between the point of maximum moment and each point of zero moment.

Except for connectors installed in the ribs of formed steel decks, shear connectors shall have at least 1 inch of concrete cover in all directions. Unless located directly over the web, the diameter of studs shall be not greater than 2.5 times the thickness of the flange to which they are welded. The minimum center-to-center spacing of stud connectors shall be six diameters along the longitudinal axis of the supporting composite beam and four diameters transverse to the longitudinal axis of the supporting composite beam. The maximum center-to-center spacing of stud connectors shall not exceed eight times the total slab thickness.

(e) **Composite Beams or Girders with Formed Steel Deck.** Composite construction of concrete slabs on formed steel deck connected to steel beams or girders shall be designed by the applicable portions of Section 2708 (a) through (d) with the following modifications:

1. Subsections (e), (f) and (g) are applicable to decks with nominal rib height not more than 3 inches.
2. The average width of concrete rib, $w_r$, shall be at least 2 inches, but $w_r$ shall not be taken in calculations as more than the minimum clear width near the top of the steel deck.
3. Concrete shall be connected to the steel member with welded stud shear connectors ¾ inch or less in diameter. Studs may be welded through the deck or directly to the steel member.
4. Shear connections as installed shall extend not less than 1½ inches above the top of the steel deck.



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5. Total slab thickness including ribs shall be used in determining the effective width of concrete flange.

6. The slab thickness above the steel deck shall be at least 2 inches.

(f) **Deck Ribs Oriented Perpendicular to Steel Beam or Girder.**

1. Concrete below the top of the steel deck shall be neglected when determining section properties and in calculating $A_c$ for Formula (8-3).

2. The allowable shear load per stud connector determined from Table No. 27-C shall be multiplied by the reduction factor

$$\left(\frac{0.85}{\sqrt{n_r}}\right)\left(\frac{w_r}{h_r}\right)\left(\frac{H_s}{h_r} - 1.0\right) \leq 1.0$$

in which $H_s$ equals length of stud connector after welding (inches) and $n_r$ equals the number of studs in one rib not to exceed three. While more than three studs may be installed in a rib, no more than three studs per rib shall be considered in computing the shear capacity of the rib. For reduction factor calculations, $H_s$ shall be taken no more than $h_r$ plus 3 inches. The value of $h_r$ shall be taken as the nominal rib height (inches).

3. The slab shall be anchored to the steel beam or girder to resist uplift by welded studs or a combination of welded studs and arc spot (puddle) welds or other devices specified by the engineer. Such anchor spacing shall not exceed 16 inches. The stud spacing shall not exceed 32 inches.

(g) **Deck Ribs Oriented Parallel to Steel Beam or Girder.**

1. Concrete below the top of the steel deck may be included when determining section properties and shall be included in calculating $A_c$ for Formula (8-3).

2. The steel deck may be split over the supporting member to form a haunch. When deck is a nominal 1.5 inch or deeper, the average width, $w_r$, of haunch or rib over the supporting member shall be at least 2 inches for the first stud in the transverse row plus four stud diameters for each additional stud.

3. The allowable shear load per stud connector shall be determined from Table No. 27-C. When $w_r/h_r$ is less than 1.5, the allowable load shall be multiplied by the reduction factor

$$0.6\left(\frac{w_r}{h_r}\right)\left(\frac{H_s}{h_r} - 1.0\right) \leq 1.0$$

## Simple and Continuous Spans

**Sec. 2709.** (a) **Simple Spans.** Beams, girders and trusses shall be designed on the basis of simple spans whose effective length is equal to the distance between the centers of gravity of the members to which they deliver their end reactions.

(b) **Continuous Spans.** Beams, girders and trusses designed on the assumption of full or partial end restraint shall be designed to carry the shears and



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moments caused by continuity without exceeding the unit stresses prescribed in Section 2702 (b), except that some nonelastic but self-limiting deformation of a part of the connection may be permitted when this is essential to the avoidance of overstressing of fasteners.

## Deflections, Vibrations and Ponding

**Sec. 2710.** (a) **General.** Horizontal framing members shall be designed for the deflection criteria and ponding requirements specified in Sections 2307 and 2305 (f).

Beams and girders supporting large open floor areas free of partitions or other sources of damping, where transient vibration due to pedestrian traffic might not be acceptable, shall be designed with due regard for vibration.

(b) **Ponding.** Unless a roof surface is provided with sufficient slope toward points of free drainage or adequate individual drains to prevent the accumulation of water, the roof system shall be investigated by a rational analysis to assure stability under ponding conditions. The roof system shall be considered stable and no further investigation needed, provided the following formulas are satisfied:

$$C_p + 0.9C_s \leqq 0.25$$

**AND**

$$I_d \geqq \frac{25S^4}{10^6}$$

**WHERE:**

$$C_p = \frac{32L_s L_p^4}{10^7 I_p}$$

$$C_s = \frac{32SL_s^4}{10^7 I_s}$$

For trusses and joists $I_s$ shall be decreased by 15 percent when used in the above formulas. A steel deck shall be considered a secondary member when it is directly supported by the primary members.

Total bending stress due to dead loads, live loads and ponding shall not exceed $0.8F_y$ for primary and secondary members. Stresses due to wind or seismic forces need not be included in the ponding analysis.

## Gross and Net Areas

**Sec. 2711.** (a) **General.** The gross area of a member at any point shall be determined by summing the products of the thickness and the gross width of each element as measured normal to the axis of the member. The net area shall be determined by substituting for the gross width the net width computed in accordance with Subsections (b) through (e).

(b) **Net Area and Effective Net Area.** 1. In the case of a chain of holes extending across a part in any diagonal or zigzag line, the net width of the part shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain, and adding, for each gauge space in the chain, the quantity



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$$\frac{s^2}{4g}$$

**WHERE:**

$s$ = longitudinal spacing (pitch, in inches) of any two consecutive holes.

$g$ = transverse spacing (gauge, in inches) of the same two holes.

The critical net area $A_n$ of the part is obtained from that chain which gives the least net width.

In determining the net area across plug or slot welds, the weld metal shall not be considered as adding to the net area.

2. The effective net area, $A_e$, of axially loaded tension members, where the load is transmitted by bolts or rivets through some but not all of the cross-sectional elements of the member, shall be computed from the formula $A_e = C_t A_n$.

**WHERE:**

$A_n$ = net area of the member.

$C_t$ = a reduction coefficient.

Unless a larger coefficient can be justified by tests or other recognized criteria, the following values of $C_t$ shall be used in computations:

A. W, M or S shapes with flange widths not less than two-thirds the depth, and structural tees cut from these shapes, provided the connection is to the flanges and has no fewer than three fasteners per line in the direction of stress $C_t = 0.90$.

B. W, M or S shapes not meeting the conditions of subparagraph 1, structural tees cut from these shapes, and all other shapes, including built-up cross sections, provided the connection has not less than three fasteners per line in the direction of stress $C_t = 0.85$.

C. All members whose connections have only two fasteners per line in the direction of stress $C_t = 0.75$.

3. Riveted and bolted splice and gusset plates and other connection fittings subject to tensile force shall be designed in accordance with the provisions of Section 2702 (b) 1, where the effective net area shall be taken as the actual net area except that, for the purpose of design calculations, it shall be taken as not greater than 85 percent of the gross area.

(c) **Angles.** The gross width of angles shall be the sum of the widths of the legs less the thickness. The gauge for holes in opposite legs shall be the sum of the gauges from back of angles less the thickness.

(d) **Size of Holes.** In computing net area the width of a rivet or bolt hole shall be taken as 1/16 inch greater than the nominal dimension of the hole normal to the direction of applied stress.

(e) **Pin-connected Members.** Eyebars shall be of uniform thickness without reinforcement at the pinholes. They shall have "circular" heads in which the periphery of the head beyond the pinhole is concentric with the pinhole. The radius of transition between the circular head and the body of the eyebar shall be equal to or greater than the diameter of the head.

The width of the body of the eyebar shall not exceed eight times its thickness, and the thickness shall be not less than 1/2 inch. The net area of the head through



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the pinhole, transverse to the axis of the eyebar, shall be not less than 1.33 nor more than 1.50 times the cross-sectional area of the body of the eyebar. The diameter of the pin shall be not less than seven eighths the width of the body of the eyebar. The diameter of the pinhole shall be not more than 1/32 inch greater than the diameter of the pin. For steels having a yield stress greater than 70 ksi, the diameter of the pinhole shall not exceed five times the plate thickness.

In pin-connected plates other than eyebars, the tensile stress on the net area, transverse to the axis of the member, shall not exceed the stress allowed in Section 2702 (b) 5, and the bearing stress on the projected area of the pin shall not exceed the stress allowed in Section 2702 (b) 5. The net area beyond the pinhole, parallel to the axis of the member, shall be not less than two thirds of the net area across the pinhole.

The corners beyond the pinhole may be cut at 45 degrees to the axis of the member, provided the net section beyond the pinhole on a plane perpendicular to the cut is not less than that required beyond the pinhole parallel to the axis of the member.

The distance transverse to the axis of a pin-connected plate or any individual element of a built-up member, from the edge of the pinhole to the edge of the member or element, shall not exceed four times the thickness at the pinhole. The diameter of the pinhole shall be not less than 1.25 times the smaller of the distances from the edge of the pin hole to the edge of a pin-connected plate or separated element of a built-up member at the pinhole. For pin-connected members in which the pin is expected to provide for relative movement between connected parts while under full load, the diameter of the pinhole shall be not more than 1/32 inch greater than the diameter of the pin.

The corners beyond the pinhole may be cut at 45 degrees to the axis of the member, provided the net area beyond the pinhole on a plane perpendicular to the cut is not less than that required beyond the pinhole parallel to the axis of the member.

Thickness limitations on both eyebars and pin-connected plates may be waived whenever external nuts are provided so as to tighten pin plates and filler plates into snug contaet. When the plates are thus contained, the allowable stress in bearing shall be no greater than as specified in Section 2702 (b) 5.

## Connections

**Sec. 2712.** (a) **Minimum Connections.** Connections shall be designed for all tributary forces and shall be capable of supporting not less than six kips.

**EXCEPTION:** Lacing, sag bars and girts may be designed only for tributary forces.

(b) **Eccentric Connections.** Members and their conneetions shall be designed for eccentricity where the gravity axes of the eonnected members do not meet at a point.

(c) **Placement of Rivets, Bolts and Welds.** Except as hereinafter provided, groups of rivets, bolts or welds at the ends of any member transmitting axial stress into that member shall have their centers of gravity on the gravity axis of the member unless provision is made for the effect of the resulting eccentricity.



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Except in members subject to repeated variation in stress as defined in U.B.C. Standard No. 27-3, disposition of fillet welds to balance the forces about the neutral axis or axes for end connections of single angle, double angle and similar-type members is not required. Eccentricity between the gravity axes of such members and the gauge lines for their riveted or bolted end connections may be neglected in statically loaded members and shall be considered in members subject to fatigue loading.

(d) **Unrestrained Members.** Beam, girder or truss connections may be proportioned for the reaction shears only where the connections are flexible.

Flexible beam connections shall accommodate end rotations of unrestrained (simple) beams. To accomplish this, inelastic action in the connection is permitted.

(e) **Restrained Members.** Fasteners or welds for end connections of beams, girders and trusses shall be designed for the combined effect of forces resulting from moment and shear induced by the rigidity of the connections.

When flanges or moment connection plates for end connections of beams and girders are welded to the flange of an I- or H-shape column, pairs of column-web stiffeners having an area given by Formula (12-1) shall be provided whenever the calculated value of $A_{st}$ is positive.

$$A_{st} \geq \frac{P_{bf} - F_{yc}\, t\,(t_b + 5k)}{F_{yst}} \qquad \text{(12-1)}$$

**WHERE:**

$A_{st}$ = area of pair of column-web stiffeners.

$A_f$ = area of flange delivering concentrated force.

$t$ = thickness of column web.

$k$ = distance between outerface of column flange and web toe of its fillet, if column is rolled shape, or equivalent distance if column is welded shape.

$t_b$ = thickness of flange or moment connection plate delivering concentrated force.

$t_f$ = thickness of column flange.

$d_c$ = column-web depth clear of fillets.

$P_{bf}$ = the computed force delivered by the flange or moment connection plate times ⅔ when the computed force is due to live and dead load only, or ⅘ when the computed force is due to live and dead load in conjunction with wind or earthquake forces in Seismic Zones Nos. 1 and 2, except that for ductile moment-resisting frames in Seismic Zone No. 2 and all moment-resisting frames in Seismic Zones Nos. 3 and 4, $P_{bf} = A_f F_{yb}$.

$F_{yb}$ = beam yield stress.

$F_{yc}$ = column yield stress.

$F_{yst}$ = stiffener yield stress.

In addition, stiffeners shall be provided opposite the compression flange when



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$$d_c > \frac{4100\, t^2 \sqrt{F_{yc}}}{P_{bf}} \quad \text{(12-2)}$$

and opposite the tension flange when

$$t_f < 0.4 \sqrt{\frac{P_{bf}}{F_{yc}}} \quad \text{(12-3)}$$

When required, the combined width of pair of stiffeners and the thickness of the column web shall be not less than two thirds the width of the flange or moment connection plate delivering the concentrated force. The thickness of stiffeners shall be not less than $t_b/2$. When the concentrated force delivered occurs on only one column flange, the stiffener need not exceed one half the column depth. The weld joining stiffeners to the column web shall be sized to carry the force in the stiffener caused by unbalanced moments on opposite sides of the column.

(f) **Fillers.** When rivets or bolts carrying computed stress pass through fillers thicker than ¼ inch, except in friction-type connections assembled with high-strength bolts, the fillers shall be extended beyond the splice material, and the filler extension shall be secured by enough rivets or bolts to distribute the total stress in the member uniformly over the combined section of the member and the filler, or an equivalent number of fasteners shall be included in the connection.

In welded construction, fillers ¼ inch or more in thickness shall extend beyond the edges of the splice plate and shall be welded to the part on which it is fitted with sufficient weld to transmit the splice plate stress applied at the surface of the filler as an eccentric load. The welds joining the splice plate to the filler shall be sufficient to transmit the splice plate stress and shall be long enough to avoid overstressing the filler along the toe of the weld. Fillers less than ¼ inch thick shall have edges flush with the edges of the splice plate, and the weld size shall be the sum of the size necessary to carry the splice plate stress plus the thickness of the filler plate.

(g) **Connections of Tension and Compression Members in Trusses.** The connections at ends of tension or compression members in trusses shall develop the force due to the design load, but not less than 50 percent of the effective strength of the member based upon the kind of stress that governs the selection of the member.

(h) **Compression Members with Bearing Joints.** Where columns bear on bearing plates or are finished to bear at splices, there shall be sufficient rivets, bolts or welds to hold all parts securely in place.

Where other compression members are finished to bear, the splice material and its riveting, bolting or welding shall be arranged to hold all parts in line and shall be proportioned for 50 percent of the computed stress.

Joints shall be proportioned to resist tension that would be developed by lateral forces acting in conjunction with 75 percent of the calculated dead load stress and no live load.

Gaps not exceeding 1/16 inch in a contact joint, such as bolted, riveted or partial



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penetration-welded milled column splice, shall be acceptable with no additional work required on the joint. If the gap exceeds 1/16 inch but is not more than 1/4 inch then the gap shall be filled with nontapered steel shims. Such shims need not be other than mild steel regardless of the column material.

(i) **Combination of Welds.** If two or more types of welds are combined in a joint, the effective capacity of each type weld shall be computed with reference to the axis of the group, in order to determine the allowable capacity of the combination.

(j) **Rivets and Bolts in Combination with Welds.** In new work, rivets, A307 bolts or high-strength bolts used in bearing-type connections shall not be considered as sharing the stress in combination with welds. Welds, if used, shall be provided to carry the entire stress in the connection. High-strength bolts installed in accordance with the provisions of Section 2713 (a) as a friction-type connection prior to welding may be considered as sharing common load with the welds, provided the connections are not subject to fatigue loading or used in a ductile moment-resisting frame.

In making welded alterations to structures, existing rivets and friction-type high-strength bolt connection may be utilized for carrying stresses resulting from existing dead loads, and the welding need be adequate only to carry all additional load.

(k) **High-strength Bolts (in Friction-type Joints) in Combination with Rivets.** High-strength bolts, installed in accordance with the provisions of Section 2713 (a) as friction-type connections, may be considered as sharing the stresses with rivets in a connection.

(l) **Field Connections.** Rivets, high-strength bolts or welds shall be used for the following connections:

Column splices in all tier structures 200 feet or more in height.

Column splices in tier structures 100 feet to 200 feet in height, if the least horizontal dimension is less than 40 percent of the height.

Column splices in tier structures less than 100 feet in height, if the least horizontal dimension is less than 25 percent of the height.

Connections of all beams and girders to columns and of any other beams and girders on which the bracing of columns is dependent, in structures over 125 feet in height.

Roof truss splices and connections of trusses to columns; column splices, column bracing, knee braces and crane supports, in all structures carrying cranes of over 5-ton capacity.

Connections for supports of running machinery or of other live loads which produce impact or reversal of stress.

For the purpose of this section, the height of a tier structure shall be taken as the vertical distance from the curb level to the highest point of the roof beams, in the case of flat roofs, or to the mean height of the gable, in the case of roofs having a rise of more than 2⅔:12. Where the curb level has not been established, or where the structure does not adjoin a street, the mean level of the adjoining land shall be



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used instead of curb level. Penthouses may be excluded in computing the height of structure.

### Rivets and Bolts

**Sec. 2713.** (a) **Rivets and High-strength Bolts.** Structural rivet steel shall conform to the provisions of U.B.C. Standard No. 27-5. High-strength bolts shall conform to the provisions of U.B.C. Standard No. 27-7.

(b) **Effective Bearing Area.** The effective bearing area of rivets and bolts shall be the diameter multiplied by the length in bearing, except that for countersunk rivets and bolts half the depth of the countersink shall be deducted.

(c) **Long Grips.** Rivets and A307 bolts which carry calculated stress, and the grip of which exceeds five diameters, shall have their number increased 1 percent for each additional 1/16 inch in the grip.

(d) **Minimum Spacing.** 1. The distance between centers of standard, oversized or slotted fastener holes shall be not less than $2\frac{2}{3}d$ nor less than that required by Subsection 2 below, if applicable.

**WHERE:**

$d$ = the nominal diameter of the fastener, inches.

2. Along a line of transmitted force, the distance between centers of holes shall be not less than the following:

A. **Standard holes:**

$$2P/F_u t + d/2$$

**WHERE:**

$P$ = force transmitted by one fastener to the critical connected part, kips.

$F_u$ = specified minimum tensile strength of the critieal connected part, kips per square inch.

$t$ = thickness of the critical connected part, inches.

B. **Oversized and slotted holes:** The distance required for standard holes in Item A above, plus the applicable increment $C_1$ in Table No. 27-D-2, but the clear distance between holes shall be not less than one bolt diameter.

(e) **Minimum Edge Distance.** 1. The distance from the center of a standard hole to an edge of a connected part shall be not less than the applicable value in Table No. 27-D-1 nor the value from Subsection 2 or 3 below, as applicable.

2. Along a line of transmitted force, in the direction of the force, the distance from the center of a standard hole to the edge of the connected part shall be not less than

$$2P/F_u t$$

3. At end connections bolted to the web of a beam and designed for beam shear reaction only (without use of an analysis which accounts for the effects induced by fastener eccentricity), the distance from the center of the nearest standard hole to



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the end of the beam web shall be not less than

$$2P_R/F_u t$$

**WHERE:**

$P_R$ = beam reaction, in kips, divided by the number of bolts.

Alternatively, this requirement may be waived, provided the bearing stress induced by the fastener is limited to not more than $0.90F_u$.

4. The distance from the center of any oversized or slotted hole to an edge of a connected part shall be not less than that required for a standard hole by Item No. 1, 2 or 3 above, as applicable, plus the applicable increment $C_2$ in Table No. 27-D-3.

(f) **Maximum Edge Distance.** The maximum distance from the center of any rivet or bolt to the nearest edge of parts in contact with one another shall be 12 times the thickness of the plate, but shall not exceed 6 inches.

## Welds

**Sec. 2714.** (a) **General.** Welder qualification requirements, welding procedure and welding electrodes for other than sheet steel shall conform to U.B.C. Standard No. 27-6. Welder qualification requirements, welding procedure and welding electrodes for sheet steel shall conform to U.B.C. Standard No. 27-13.

(b) **Maximum Effective Size of Fillet Welds.** The maximum size fillet welds that may be used along edges of connected parts shall be:

1. Along edges of material less than ¼ inch thick, the maximum size may be equal to the thickness of the material.
2. Along edges of material ¼ inch or more in thickness, the maximum size shall be 1/16 inch less than the thickness of the material, unless the weld is especially designated on the drawings to be built out to obtain full throat thickness.

(c) **Minimum Size of Fillet Welds and Partial Penetration Welds.** The minimum size of fillet weld shall be as shown in Table No. 27-E-1. The minimum effective throat of partial penetration groove weld shall be as shown in Table No. 27-E-2. Weld size is determined by the thicker of the two parts joined, except that the weld size need not exceed the thickness of the thinner part joined unless a larger size is required by calculated stress. For this exception, particular care should be taken to provide sufficient preheat for weld soundness.

(d) **Length of Fillet Welds.** The minimum effective length of a strength fillet weld shall be not less than four times the nominal size, or else the size of the weld shall be considered not to exceed one fourth of its effective length.

If longitudinal fillet welds are used alone in end connections of flat bar tension members, the length of each fillet weld shall be not less than the perpendicular distance between them. The transverse spacing of longitudinal fillet welds used in end connections shall not exceed 8 inches, except where transverse bending is provided for in the connection.

(e) **Intermittent Fillet Welds.** Intermittent fillet welds may be used to transfer calculated stress across a joint or faying surfaces, when the strength required is



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less than that developed by a continuous fillet weld of the smallest permitted size, and to join components of built-up members. The effective length of any segment of intermittent fillet welding shall be not less than four times the weld size with a minimum of 1½ inches.

(f) **Lap Joints.** The minimum amount of laps on lap joints shall be five times the thickness of the thinner part joined and not less than 1 inch. Lap joints joining plates or bars subjected to axial stress shall be fillet welded along the edge of both lapped parts except where the deflection of the lapped parts is sufficiently restrained to prevent opening of the joint under maximum loading.

(g) **End Returns of Fillet Welds.** Side or end fillet welds terminating at ends or sides, respectively, of parts or members shall, wherever practicable, be returned continuously around the corners for a distance not less than twice the nominal size of the weld. This provision shall apply to side and top fillet welds connecting brackets, beam seats and similar connections, on the plane about which bending moments are computed.

(h) **Fillet Welds in Holes and Slots.** Fillet welds in holes or slots may be used to transmit shear in lap joints or to prevent the buckling or separation of lapped parts and to join components of built-up members. Such fillet welds may overlap, subject to the provisions of Section 2702 (e). Fillet welds in holes or slots shall not be considered as plug or slot welds.

(i) **Plug and Slot Welds.** Plug or slot welds may be used to transmit shear in a lap joint or to prevent buckling of lapped parts and to join component parts of built-up members.

The diameter of the holes for a plug weld shall be not less than the thickness of the part containing it plus 5/16 inch, rounded to the next greater odd 1/16 inch, nor greater than two and one-fourth times the thickness of the weld metal.

The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

The length of slot for a slot weld shall not exceed 10 times the thickness of the weld. The width of the slot shall be not less than the thickness of the part containing it, plus 5/16 inch, rounded to the next greater odd 1/16 inch, nor shall it be greater than two and one-fourth times the thickness of the weld. The ends of the slot shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part containing it, except those ends which extend to the edge of the part.

The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum center-to-center spacing in a longitudinal direction on any line shall be two times the length of the slot.

The thickness of plug or slot welds in material 5/8 inch or less in thickness shall be equal to the thickness of the material. In material over 5/8 inch in thickness, it shall be at least one half the thickness of the material but not less than 5/8 inch.

(j) **Welding Sheet Steel.** Arc welding of sheet steels or strip steels, or both, including cold-formed members, 0.180 inch or less in thickness shall conform to U.B.C. Standard No. 27-13.



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## Built-up Members

**Sec. 2715.** (a) **Steel Joists, H, K, LH, and DLH Series, and Joist Girders.** Steel joists and joist girders shall be designed as set forth in U.B.C. Standard No. 27-4.

(b) **Open Box-type Beams and Grillages.** Where two or more rolled beams or channels are used side by side to form a flexural member, they shall be connected together at intervals of not more than 5 feet. Throughbolts and separators may be used, provided that in beams having a depth of 12 inches or more, no fewer than two bolts shall be used at each separator location. When concentrated loads are carried from one beam to the other, or distributed between the beams, diaphragms having sufficient stiffness to distribute the load shall be riveted, bolted or welded between the beams. Where beams are exposed, they shall be sealed against corrosion of interior surfaces, or spaced sufficiently far apart to permit cleaning and painting.

(c) **Compression Members.** All parts of built-up compression members and the transverse spacing of their lines of fasteners shall conform to the requirements of Sections 2705 and 2706.

At the ends of built-up compression members bearing on base plates or milled surfaces, all components in contact shall be connected by rivets or bolts spaced longitudinally not more than four diameters apart for a distance equal to one and one-half times the maximum width of the member or by continuous welds having a length not less than the maximum width of the member.

The longitudinal spacing for intermediate rivets, bolts or intermittent welds in built-up members shall be adequate to provide for the transfer of calculated stress. The spacing of connectors for outside plates of built-up compression members shall not exceed the values determined by the following formulas.

When rivets or bolts are provided on all gauge lines at each section, or when intermittent welds are provided along the edges of the components

$$\frac{127t}{\sqrt{F_y}}$$

but not more than 12 inches.

When rivets, bolts or welds are staggered

$$\frac{190t}{\sqrt{F_y}}$$

but not more than 18 inches on each gauge line.

**WHERE:**

$t$ = thickness of thinner outside plate in inches.

The maximum longitudinal spacing of rivets, bolts or intermittent welds connecting two rolled shapes in contact with one another shall not exceed 24 inches.



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Compression members composed of two or more rolled shapes separated by intermittent fillers shall be connected at intervals such that the slenderness ratio *l/r* of either shape, between the fasteners, does not exceed the governing slenderness ratio of the built-up member. The least radius of gyration *r* shall be used in computing the slenderness ratio of each component part.

Open sides of compression members built up from plates or shapes shall be provided with lacing having tie plates at each end, and at intermediate points if the lacing is interrupted. In main members carrying calculated stress, the end tie plates shall have a length of not less than the distance between the lines of rivets, bolts or welds connecting them to the components of the member. Intermediate tie plates shall have a length not less than one half of this distance. The thickness of tie plates shall be not less than one fiftieth of the distance between the lines of rivets, bolts or welds connecting them to the segments of the members. In riveted and bolted construction, the pitch in tie plates shall be not more than six diameters and the tie plates shall be connected to each segment by at least three fasteners. In welded construction, the welding on each line connecting a tie plate shall aggregate not less than one third the length of the plate.

Lacing, including flat bars, angles, channels or other shapes employed as lacing, shall be so spaced that the ratio *l/r* of the flange included between their connections shall not exceed the governing ratio for the member as a whole. Lacing shall be proportioned to resist a shearing stress normal to the axis of the member equal to 2 percent of the total compressive stress in the member. The ratio *l/r* for lacing bars arranged in single systems shall not exceed 140. For double lacing this ratio shall not exceed 200. Double lacing bars shall be joined at their intersections. Lacing bars in compression may be treated as secondary members, with *l* being taken as the unsupported length of the lacing bar between rivets or welds connecting it to the components of the built-up member for single lacing and 70 percent of that distance for double lacing. The inclination of lacing bars to the axis of the member shall be not less than 60 degrees for single lacing and 45 degrees for double lacing. When the distance between the lines of rivets or welds in the flanges is more than 15 inches, the lacing shall be double or be made of angles.

Tie plates and lacing bars are not required where the open sides of built-up compression members are enclosed with cover plates perforated with access holes. The net width of such plates across holes, as defined in Section 2706 (b), is assumed to resist axial stress, provided that: the width-to-thickness ratio conforms to the requirements of Section 2706 (b); the ratio of length, in direction of stress, to width of hole does not exceed two; the clear distance between holes in the direction of stress is not less than the transverse distance between nearest lines of connecting rivets, bolts or welds; and the periphery of the holes at all points has a minimum radius of 1½ inches.

(d) **Tension Members.** The longitudinal spacing of rivets, bolts and intermittent fillet welds connecting a plate and a rolled shape in a built-up tension member, or two plate components, shall not exceed 24 times the thickness of the thinner plate nor 12 inches. The longitudinal spacing of rivets, bolts and intermittent welds connecting two or more shapes in a tension member shall not exceed 24



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inches. Tension members composed of two or more shapes or plates separated by intermittent fillers shall be connected at intervals such that the slenderness ratio of either component between the fasteners does not exceed 240.

Either perforated cover plates or tie plates without lacing may be used on the open sides of built-up tension members. Tie plates shall have a length not less than two thirds the distance between the lines of rivets, bolts or welds connecting them to the components of the member. The thickness of such tie plates shall be not less than one fiftieth of the distance between these lines. The longitudinal spacing of rivets, bolts or intermittent welds at tie plates shall not exceed 6 inches. The spacing of tie plates shall be such that the slenderness ratio of any component in the length between tie plates will not exceed 240.

## Camber

**Sec. 2716.** (a) **General.** Horizontal framing members shall be designed for the deflection criteria and ponding requirements specified in Sections 2307 and 2305 (f).

(b) **Trusses and Girders.** Trusses of 80 feet or greater span shall be cambered for the dead load deflection. Crane girders of 75 feet or greater span shall be cambered for the dead plus half the live load deflection.

## Expansion

**Sec. 2717.** Adequate provision shall be made for expansion and contraction appropriate to the service conditions of the structure.

## Column Bases

**Sec. 2718.** (a) **Loads.** Adequate provision shall be made to transfer the column loads and moments, if any, to the footings and foundations.

(b) **Alignment.** Column bases shall be set level and to correct elevation with full bearing on the masonry.

(c) **Finishing.** Column bases shall be finished in accordance with the following requirements:

1. Rolled-steel bearing plates 2 inches or less in thickness may be used without planing, provided a satisfactory contact bearing is obtained; rolled-steel bearing plates over 2 inches but not over 4 inches in thickness may be straightened by pressing; or, if presses are not available, by planing for all bearing surfaces (except as noted under requirement 3 of this section), to obtain a satisfactory contact bearing; rolled-steel bearing plates over 4 inches in thickness shall be planed for all bearing surfaces (except as noted under requirement 3 of this section).
2. Column bases other than rolled-steel bearing plates shall be planed for all bearing surfaces (except as noted under requirement 3 of this section).
3. The bottom surfaces of bearing plates and column bases which are grouted to ensure full bearing contact on foundations need not be planed.

## Anchor Bolts

**Sec. 2719.** Anchor bolts shall be designed to provide resistance to all conditions of tension and shear at the bases of columns, including the net tensile



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components of any bending moments which may result from fixation or partial fixation of columns. Provisions shall be made for oversize holes. See U.B.C. Standard No. 27-2.

## Fabrication

**Sec. 2720.** The fabrication, erection and painting of structural steel shall conform to U.B.C. Standard No. 27-2.

## Plastic Design

**Sec. 2721.** (a) **Scope.** Subject to the requirements specified in this section, simple or continuous beams, braced and unbraced planar rigid frames, and similar portions of structures rigidly constructed so as to be continuous over at least one interior support may be proportioned on the basis of their maximum strength, otherwise known as plastic design. This strength, as determined by rational analysis, shall be not less than that required to support a factored load of 1.7 times the live load and dead load or 1.3 times these loads acting in conjunction with 1.3 times wind or earthquake forces.

For one- or two-story frames, the maximum strength may be determined by a plastic analysis procedure and the frame instability effect $P\Delta$ may be ignored. For braced multistory frames, provisions should be made to include the frame instability effect in the design of bracing system and frame members. For unbraced multistory frames, the frame instability effect shall be included directly in the calculations for maximum strength.

Plastically designed members of braced multistory steel frames shall not be part of the required seismic force resisting system in Seismic Zone No. 2, No. 3 or No. 4.

Rigid frames shall be assumed to have beam-to-column connections of sufficient rigidity to hold virtually unchanged the original angles between intersecting members in the plane of the frame. Members between rigid frames may be connected at ends of shear only and be free to rotate under loads.

Connections joining a portion of a structure designed on the basis of plastic behavior with a portion not so designed need be no more rigid than seat-and-cap angle or standard web connections.

Where plastic design is used as the basis for proportioning continuous beams and structural frames, the provisions relating to allowable stress contained in the other sections of this chapter are waived. The provisions of this chapter shall apply except as modified by this section.

Crane runways shall not be designed continuous over interior vertical supports on the basis of maximum strength. Rigid frame bents supporting crane runways may be considered as coming within the scope of this section.

(b) **Material.** Structural steel shall conform to U.B.C. Standard No. 27-1.

(c) **Stability of Braced Frames.** The vertical bracing system for a plastically designed braced multistory shall be adequate, as determined by a rational analysis, to prevent buckling of the structure under factored gravity loads and to maintain the lateral stability of the structure, including the overturning effects of drift, under factored gravity plus factored horizontal loads.



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The vertical bracing system may be considered to function together with in-plane shear-resisting exterior and interior walls, floor slabs and roof decks, if they are secured to the structural frames. The columns, girders, beams and diagonal members, when used as the vertical bracing system, may be considered to comprise a vertical-cantilever, simply-connected truss in the analyses for frame buckling and lateral stability. Axial deformation of all members in the vertical bracing system shall be included in the lateral stability analysis. The axial force in these members caused by factored gravity plus factored horizontal loads shall not exceed $0.85P_y$, where $P_y$ is the product of yield stress times area of the member.

Girders and beams included in the vertical bracing system of a braced multistory frame shall be proportioned for axial force and moment caused by the concurrent factored horizontal and gravity loads, in accordance with Formula (21-2), with $P_{cr}$ taken as the maximum axial strength of the beam, based on the actual slenderness ratio between braced points in the plane of bending.

(d) **Stability of Unbraced Frames.** The strength of an unbraced multistory frame shall be determined by a rational analysis which includes the effect of frame instability and column axial deformation. Such a frame shall be designed to be stable under (1) factored gravity loads and (2) factored gravity plus factored horizontal loads. The axial force in the columns at factored load levels shall not exceed $0.75\,P_y$.

(e) **Columns.** In the plane of bending of columns, which would develop a plastic hinge at ultimate loading, the slenderness ratio $l/r$ shall not exceed $C_c$, as defined in Section 2701 (c).

The maximum strength of an axially loaded compression member shall be:

$$P_{cr} = 1.7AF_a \qquad (21\text{-}1)$$

**WHERE:**

$A$ = gross area of the member

$F_a$ = See Formula (2-1) in Section 2702 (b).

Members subject to combined axial load and bending moment shall satisfy the following conditions:

$$\frac{P}{P_{cr}} + \frac{C_m M}{\left(1 - \frac{P}{P_e}\right) M_m} \leqq 1.0 \qquad (21\text{-}2)$$

$$\frac{P}{P_y} + \frac{M}{1.18M_p} \leqq 1.0;\ M \leqq M_p \qquad (21\text{-}3)$$

For columns braced in the weak direction:

$$M_m = M_p$$



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For columns unbraced in the weak direction:

$$M_m = \left[1.07 - \frac{(l/r_y)\sqrt{F_y}}{3160}\right] M_p \leqq M_p \quad \text{.....(21-4)}$$

(f) **Shear.** Unreinforced webs of columns, beams, and girders, including areas within the boundaries of the connections, shall be so proportioned that:

$$V_u \leqq 0.55 F_y t d \quad \text{.....(21-5)}$$

(g) **Web Crippling.** Web stiffeners are required on a member at a point of load application where a plastic hinge would form.

Web stiffeners are required at points where concentrated compression loads are delivered by the flanges to the web as required by Section 2712 (e).

(h) **Minimum Thickness (Width-thickness Ratios).** The width-thickness ratio for flanges of rolled "I," wide flange and similar built-up single-web shapes that would be subjected to compressions involving hinge rotation under ultimate loading shall not exceed the following values:

| $F_y$ | $b_f/2t_f$ |
|---|---|
| 36 | 8.5 |
| 42 | 8.0 |
| 45 | 7.4 |
| 50 | 7.0 |
| 55 | 6.6 |
| 60 | 6.3 |
| 65 | 6.0 |

The thickness of sloping flanges may be taken as their average thickness.

The width-thickness ratio of similarly compressed flange plates in box sections and cover-plates shall not exceed $190/\sqrt{F_y}$. For this purpose the width of a cover-plate shall be the distance between longitudinal lines of connecting rivets, high-strength bolts or welds.

The depth-thickness ratio of webs of members subjected to plastic bending shall not exceed the following:

$$\frac{P}{P_y} \leqq 0.27$$

$$\frac{d}{t} = \frac{412}{\sqrt{F_y}}\left(1 - 1.4\,\frac{P}{P_y}\right) \quad \text{.....(21-6a)}$$

**WHERE:**

$$\frac{P}{P_y} > 0.27$$

$$\frac{d}{t} = \frac{257}{\sqrt{F_y}} \quad \text{.....(21-6b)}$$



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(i) **Connections.** All connections shall be capable of resisting the moments, shears and axial loads to which they would be subjected by the full-factored loading or any partial distribution thereof.

Haunch-type connections, tapered or curved for architectural reasons, shall be so proportioned that the full plastic bending strength of the section adjacent to the connection can be developed.

Stiffeners shall be used, as required, to preserve the flange continuity of interrupted members at their junction with other members in a continuous frame. Such stiffeners shall be placed in pairs on opposite sides of the web of the member which extends continuously through the joint.

Rivets, welds and bolts shall be proportioned to resist the forces produced at factored load using allowable stresses equal to 1.7 times those permitted in other sections of this chapter.

High-strength bolts may be used in joints having painted contact surfaces when these joints are of such size that the slip required to produce bearing would not interfere with the formation at factored loading of the plastic hinges assumed in the design.

(j) **Lateral Bracing.** Members shall be adequately braced to resist lateral and torsional displacements at the plastic hinge locations. The laterally unsupported distance, $l_{cr}$, shall not exceed:

$$+1.0 > \frac{M}{M_p} > -0.5$$

$$\frac{l_{cr}}{r_y} = \frac{1375}{F_y} + 25 \qquad \text{(21-7a)}$$

**WHERE:**

$$-0.5 \geqq \frac{M}{M_p} > -1.0$$

$$\frac{l_{cr}}{r_y} = \frac{1375}{F_y} \qquad \text{(21-7b)}$$

**WHERE:**

$r_y$ = the radius of gyration of the member about its weak axis.

$M$ = the lesser of the moments at the ends of the unbraced segment.

$M/M_p$ = the end moment ratio, is positive when the segment is bent in reverse curvature and negative when bent in single curvature.

**EXCEPTION:** Laterally unsupported lengths greater than specified above may be justified by an analysis based upon the amount of restraint present at the ends of the segment in the plane of the computed bending moments.

The foregoing provisions need not apply in the region of the last hinge to form nor in members oriented with their weak axis normal to the plane of bending. However, in the region of the last hinge to form and in regions not adjacent to a plastic hinge, the maximum distance between points of lateral support shall be such as to satisfy the requirements of Formulas (2-6a), (2-6b), (2-7), (3-1a) and



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(3-1b) in this chapter. For this case the value of $f_a$ and $f_b$ shall be computed from the moment and axial force at factored loading, divided by the applicable load factor.

Members built into a masonry wall and having their web perpendicular to the wall can be assumed to be laterally supported with respect to their weak axis of bending.

(k) **Fabrication.** The provisions of U.B.C. Standard No. 27-2 with respect to workmanship shall govern the fabrication of structures, or portions of structures, designed on the basis of maximum strength, subject to the following limitations:

The use of sheared edges shall be avoided in locations subject to plastic hinge rotation of factored loading. If used they shall be finished smooth by grinding, chipping or planing.

In locations subject to plastic hinge rotation at factored loading, holes for rivets or bolts in the tension area shall be subpunched and reamed or drilled full size.

## Steel Structures Resisting Forces Induced by Earthquake Motions

**Sec. 2722.** (a) **General.** Design and construction of steel framing in lateral force-resisting systems in Seismic Zones Nos. 2, 3 and 4 shall conform to the requirements of the code and to all the requirements of this section.

(b) **Definitions.**

**ALLOWABLE STRESSES** are prescribed in Section 2702 (b), (c) and (d).

**CHEVRON BRACING** is that form of bracing where a pair of braces located either above or below a beam terminates at a single point within the clear beam span.

**CONNECTION** is the group of elements that connect the member to the joint.

**DIAGONAL BRACING** is that form of bracing that diagonally connects joints at different levels.

**ECCENTRICALLY BRACED FRAME (EBF)** is that form of braced frame where at least one end of each brace intersects a beam at a point away from the column girder joint.

**GIRDER** is the horizontal member in a seismic frame. The words beam and girder may be used interchangeably.

**JOINT** is the entire assemblage at the intersections of the members.

**K BRACING** is that form of bracing where a pair of braces located on one side of a column terminates at a single point within the clear column height.

**LINK BEAM** is that part of a beam in an eccentrically braced frame which is designed to yield in shear and/or bending so that buckling of the bracing members is prevented.

**STRENGTH** is the strength as prescribed in Section 2722 (c) 2.

**V BRACING** is that form of chevron bracing that intersects a beam from above and inverted V bracing is that form of chevron braeing that intersects a beam from below.



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**X BRACING** is that form of bracing where a pair of diagonal braces eross near midlength of the bracing members.

(c) **Materials.** 1. Structural steel used in lateral force-resisting systems shall conform to A 36, A 441, A 500, A 501, A 572 (Grades 42 and 50) and A 588. Structural steel conforming to A 283 (Grade D) may be used for basc plates and anchor bolts.

**EXCEPTION:** Other steels permitted in this code may be used for the following:

1. Ordinary moment frames in Seismic Zone No. 2 in accordance with Section 2722 (h).
2. One-story buildings.
3. Light-framed wall systems in accordance with Section 2722 (i).

2. **Member strength.** Where this section requires that the strength of the member be developed, the following shall be used:

| | STRENGTH |
|---|---|
| Flexure | $M_s = ZF_y$ |
| Shear | $V_s = 0.55 F_y dt$ |
| Axial eompression | $P_{sc} = 1.7 F_a A$ |
| Axial tension | $P_{st} = F_y A$ |
| Connectors | |
| Full penetration welds | $F_y A$ |
| Partial penetration welds | 1.7 Allowable |
| Bolts and fillet welds | 1.7 Allowable |

Members need not be compact unless otherwise required by this section.

(d) **Column Requirements.** 1. **Column strength.** Columns shall satisfy the load combinations required by Section 2303 (f) at allowable stress limits, with stress increases allowed by Section 2303 (d). In addition, in Seismic Zones Nos. 3 and 4, columns in frames shall have the strength to resist the axial loads resulting from the load combinations in Subsections A and B below.

A. Axial Compression

$$1.0 P_{DL} + 0.7 P_{LL} + 3(R_w/8)P_E$$

B. Axial Tension

$$0.85 P_{DL} + 3(R_w/8)P_E$$

**EXCEPTION:** The axial load combination as outlined in Subsections A and B above:

1. Need not exceed either the maximum force that can be transferred to the column, by clements of the structure, or the limit as determined by the overturning uplift which the foundation is capable of resisting.
2. Need not apply to columns in moment-resisting space frames complying with Formula (22-3) where $f_a$ is equal to or less than $0.3 F_y$ for all load combinations.

The load combinations from Subsections A and B need be used only when specifically referred to.



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2. **Column splices.** Column splices shall have sufficient strength to develop the column forces determined from Section 2722 (d) 1. Welded column splices subject to net tensile forces shall comply with the more critical of the following:

A. Partial penetration welds shall be designed to resist 150 percent of the force determined from Section 2722 (d) 1 B.

B. Welding shall develop not less than 50 percent of the flange area strength of the smaller column.

Splices employing partial penetration welds shall be located at least three feet from girder flanges.

3. **Slenderness evaluation.** This paragraph is applicable when the provisions of Formula (3-1a) and Section 2705 are applied to the effective length determination of columns of moment frames resisting earthquake forces in Seismic Zones Nos. 3 and 4. In the plane of the earthquake forces the factor $K$ may be taken as unity when all of the following conditions are met:

A. The column is either continuous or is fixed at each joint.

B. The maximum axial compressive stress, $f_a$, does not exceed 0.4 $F_y$ under design loads.

C. The calculated story drift ratios are less than the values given in Section 2312 (e) 8.

(e) **Ordinary Moment Frame Requirements.** Girder-to-column connections of ordinary moment frames shall meet the requirements of Section 2722 (f) 2 unless it can be shown that they are capable of resisting the combination of gravity loads and $3(R_w/8)$ times the design seismic forces. Ordinary moment frames in Seismic Zone No. 1 meeting these requirements may use a value of $R_w$ of 12.

(f) **Special Moment-resisting Space Frame (SMRSF) Requirements.** 1. **Scope.** The requirements of this section for SMRSF systems apply only in Seismic Zones Nos. 3 and 4. SMRSF systems in Seismic Zone No. 2 need comply only with paragraphs 2, 7, 8 and 10 below.

2. **Girder to column connection.** A. **Required strength.** The girder to column connection shall be adequate to develop the lesser of the following:

(i) The strength of the girder in flexure.

(ii) The moment corresponding to development of the panel zone shear strength as determined from Formula (22-1).

> **EXCEPTION:** Where a connection is not designed to contribute flexural resistance at the joint, it need not develop the required strength if it can be shown to meet the deformation compatibility requirements of Section 2312 (h) 2 D.

B. **Connection strength.** The girder-to-column connection may be considered to be adequate to develop the flexural strength of the girder if it conforms to the following:

(i) The flanges have full penetration butt welds to the columns.

(ii) The girder web to column connection shall be capable of resisting the girder shear determined for the combination of gravity loads and the seismic shear



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forces which result from compliance with Section 2722 (f).2.A. This connection strength need not exceed that required to develop gravity loads plus 3 ($R_w$/8) times the girder shear resulting from the prescribed seismic forces.

Where the flexural strength of the girder flanges is greater than 70 percent of the flexural strength of the entire section (i.e., $bt_f(d-t_f)F_y > 0.7Z_xF_y$) the web connection may be made by means of welding or high-strength bolting.

For girders not meeting the criteria in the paragraph above, the girder web-to-column connection shall be made by means of welding the web directly or through shear tabs to the column. That welding shall have a strength capable of developing at least 20 percent of the flexural strength of the girder web. The girder shear shall be resisted by means of additional welds or friction-type high-strength bolts or both.

C. **Alternate connection.** Connection configurations utilizing welds or high-strength bolts not conforming with paragraph B above may be used if they are shown by test or calculation to meet the criteria in paragraph A above. Where conformance is shown by calculation, 125 percent of the strengths of the connecting elements may be used.

D. **Flange detail limitations.** For steel whose specified ultimate strength is less than 1.5 times the specified yield strength, plastic hinges shall not form at locations in which the beam flange area has been reduced, such as for bolt holes. Bolted connections of flange plates of beam-column joints shall have the net-to-gross area ratio $A_e/A_g$ equal to or greater than $1.2\,F_y/F_u$.

3. **Panel Zone.** A. **Strength.** The panel zone of the joint shall be capable of resisting the shear induced by beam bending moments due to gravity loads plus 1.85 times the prescribed seismic forces, but the shear strength need not exceed that required to develop $0.8\Sigma M_s$ of the girders framing into the column flanges at the joint. The joint panel zone shear strength may be obtained from the following formula:

$$V = 0.55\,F_y d_c t \left[1 + \frac{3b_c t_{cf}^2}{d_b d_c t}\right] \quad (22\text{-}1)$$

**WHERE:**

$t$ = the total thickness of the joint panel zone including doubler plates.
$d_b$ = the depth of the beam.
$d_c$ = the column depth.
$b_c$ = is the width of the column flange.
$t_{cf}$ = is the thickness of the column flange.

B. **Thickness.** The panel zone thickness, $t_z$, shall conform to the following formula:

$$t_z \geq (d_z + w_z)/90 \quad (22\text{-}2)$$

**WHERE:**

$d_z$ = the panel zone depth between continuity plates.
$w_z$ = the panel zone width between column flanges.



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For this purpose, $t_c$ shall not include any double plate thickness unless the doubler plate is connected to the column web with plug welds adequate to prevent local buckling of the plate.

C. **Doubler plates.** Doubler plates provided to reduce panel zone shear stress or to reduce the web depth thickness ratio shall be placed not more than 1/16 inch from the column web and shall be welded across the plate width top and bottom with at least a 3/16-inch fillet weld. They shall be either butt or fillet welded to the column flanges to develop the shear strength of the doubler plate. Weld strength shall be as given in Section 2722 (c) 2.

4. **Flange width-thickness ratio.** Girders shall comply with Section 2702 (b) 4, except that the flange width-thickness ratio, $b_f/2t_f$, shall not exceed $52/\sqrt{F_y}$.

5. **Continuity plates.** When determining the need for girder tension flange continuity plates, the value of $P_{bf}$ in Formula (12-3) shall be taken as $1.8\ (bt_f)F_{yb}$.

6. **Strength ratio.** At any moment frame joint, the following relationship shall be satisfied:

$$\Sigma Z_c(F_{yc} - f_a)/\Sigma Z_b F_{yb} > 1.0 \qquad (22\text{-}3)$$

, where $(f_a \geq 0)$

**EXCEPTION:** This requirement need not apply in any of the following cases, provided the compactness limitations for beams given in Section 2722 (f) 4 shall apply to columns as well:

1. For columns with $f_a$ less than $0.4F_y$ for all load combinations, except for loads specified in Section 2722 (d) 1.
2. For columns in any story which has lateral shear strength 50 percent greater than that of the story above.
3. For any column whose lateral shear strength is not included in the design to resist code-required seismic shears.

7. **Trusses in SMRSF.** Trusses may be used as horizontal members in SMRSF if the sum of the truss seismic force flexural strength exceeds the sum of the column seismic force flexural strength immediately above and below the truss by a factor of at least 1.25. For this determination the strengths of the members shall be reduced by the gravity load effects. In buildings of more than one story, the column axial stress shall not exceed $0.4F_y$ and the ratio of the unbraced column height to the least radius of gyration shall not exceed 60. The connection of the truss chords to the column shall develop the lesser of the following:

A. The strength of the truss chord.

B. The chord force necessary to develop 125 percent of the flexural strength of the column.

8. **Girder-column joint restraint.** A. **Restrained joint.** Where it can be shown that the columns of SMRSF remain elastic, the flanges of the columns need be laterally supported only at the level of the girder top flange.

Columns may be assumed to remain elastic if one of the following conditions is satisfied:

(i) The ratio in Formula (22-3) is greater than 1.25.



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(ii) The flexural strength of the column is at least 1.25 times the moment that corresponds to the panel zone shear strength.

(iii) Girder flexural strength or panel zone strength will limit column stress ($f_a + f_{bx} + f_{by}$) to $F_y$ of the column.

(iv) The column will remain elastic under gravity loads plus $3(R_w/8)$ times the prescribed seismic forces.

Where the column cannot be shown to remain elastic, the column flanges shall be laterally supported at the levels of the girder top and bottom flanges. The column flange lateral support shall be capable of resisting a force equal to one percent of the girder flange capacity at allowable stresses and at a limiting displacement perpendicular to the frame of 0.2 inch. Required bracing members may brace the column flanges directly or indirectly through the column web or the girder flanges.

B. **Unrestrained joint.** Columns without lateral support transverse to a joint shall conform to the requirements of Section 2703, Formula (3-2), with the column considered as pin ended and the length taken as the distance between lateral supports conforming with A above. The column stress, $f_a$, shall be determined from gravity loads plus the lesser of the following:

(i) $3(R_w/8)$ times the prescribed seismic forces.

(ii) The forces corresponding to either 125 percent of the girder flexural strength or the panel zone shear strength.

The stress $f_{by}$, shall include the effects of the bracing force specified in Section 2722 (f) 8 A and P-delta.

$l/r$ for such columns shall not exceed 60.

At truss frames the column shall be braced at each truss chord for a lateral force equal to one percent of the compression yield strength of the chord.

9. **Beam bracing.** Both flanges of beams shall be braced directly or indirectly. The beam bracing between column center lines shall not exceed $96r_y$. In addition, braces shall be placed at concentrated loads where a hinge may form.

10. **Changes in beam flange area.** Abrupt changes in beam flange area are not permitted within possible plastic hinge regions of special moment-resistant frames.

11. **Moment frame drift calculations.** Moment frame drift calculations shall include bending and shear contributions from the clear girder and column spans, column axial deformation and the rotation and distortion of the panel zone.

**EXCEPTIONS:** 1. Drift calculations may be based on column and girder center lines where either of the following conditions is met:

(i) It can be demonstrated that the drift so computed for frames of similar configuration is typically within 15 percent of that determined above.

(ii) The column panel zone strength can develop $0.8 \Sigma M_s$ of girders framing to the column flanges at the joint.

2. Column axial deformations may be neglected if they contribute less than 10 percent to the total drift.



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(g) **Requirements for Braced Frames.** 1. **General.** The provisions of this section apply to all braced frames except eccentrically braced frames (EBF) designed in accordance with Section 2722 (h). Those members which resist seismic forces totally or partially by shear or flexure shall be designed in accordance with Section 2722 (f) except Subsection 3.

2. **Bracing members.** A. **Slenderness.** In Seismic Zones Nos. 3 and 4 the $l/r$ ratio for bracing members shall not exceed $720/\sqrt{F_y}$ except as permitted in Subsection 5 below.

B. **Stress reduction.** The allowable stress, $F_{as}$, for bracing members resisting seismic forces in compression shall be determined from the following formula:

$$F_{as} = \beta F_a \quad \text{.....(22-4)}$$

**WHERE:**

$F_a$ = the allowable axial compressive stress allowed in Section 2702 (b) 3 and Section 2303 (d).

$\beta$ = the stress reduction factor determined from the following formula:

$$\beta = 1/[1 + ([Kl/r]/2C_c)] \quad \text{.....(22-5)}$$

**EXCEPTION:** In Seismic Zone No. 2 the value of $\beta$ need not be less than 0.8.

C. **Lateral force distribution.** In Seismic Zones Nos. 3 and 4, the seismic lateral force along any line of bracing shall be distributed to the various members so that neither the sum of the horizontal components of the forces in members acting in tension nor the sum of the horizontal components of forces in members acting in compression exceed 70 percent of the total force.

**EXCEPTION:** Where compression bracing acting alone has the strength, neglecting the strength reduction factor $\beta$, to resist $3(R_w/8)$ times the prescribed seismic force such distribution is not required.

A line of bracing is defined, for the purpose of this provision as a single line, or parallel lines within 10 percent of the dimension of the structure perpendicular to the line of bracing.

D. **Built-up members.** The $l/r$ of individual parts of built-up bracing members between stitches, when computed about a line perpendicular to the axis through the parts, shall not be greater than 75 percent of the $l/r$ of the member as a whole.

E. **Compression elements in braces.** The width-thickness ratio of stiffened and unstiffened compression elements used in braces shall be as shown in Section 2706.

3. **Bracing connections.** A. **Forces.** Bracing connections shall be designed for the lesser of the following:

(i) The tensile strength of the bracing.

(ii) $3(R_w/8)$ times the force in the brace due to the prescribed seismic forces.

(iii) The maximum force that can be transferred to the brace by the system.

Beam-to-column connections for beams that are part of the bracing system shall have the capacity to transfer the force determined above.



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B. **Net area.** In bolted brace connections, the ratio of effective net section area to gross section area shall satisfy the formula:

$$\frac{A_e}{A_g} = \frac{1.2\ \alpha F^*}{F_u} \qquad (22\text{-}6)$$

**WHERE:**

$A_e$ = effective net area as defined in Section 2711 (b) 2.

$F^*$ = stress in brace as determined in Section 2722 (g) 3 A.

$F_u$ = minimum tensile strength.

$\alpha$ = fraction of the member force from Section 2722 (g) 2 A that is transferred across a particular net section.

4. **Bracing configuration.** A. **Chevron bracing.** Chevron bracing shall conform with the following:

(i) Bracing members shall be designed for 1.5 times the otherwise prescribed forces.

(ii) The beam intersected by chevron braces shall be continuous between columns.

(iii) Where chevron braces intersect a beam from below, i.e., inverted V brace, the beam shall be capable of supporting all tributary gravity loads presuming the bracing not to exist.

**EXCEPTION:** This limitation need not apply to penthouses, one-story buildings or the top story of buildings.

B. **K bracing.** In Seismic Zones Nos. 3 and 4, K bracing is prohibited except as permitted in Subsection 5 below. In Seismic Zone No. 2 the requirements of paragraph A above shall be met.

5. **One- and two-story buildings.** Braced frames not meeting the requirements of Sections 2722 (g) 2 to 2722 (g) 4 may be used in buildings not over two stories in height and in roof structures as defined in Chapter 36 if they are designed for forces of $3(R_w/8)$ times the code equivalent static forces at code allowable seismic stresses.

(h) **Eccentrically Braced Frame (EBF) Requirements.** EBFs shall be designed in accordance with the following:

1. **Link beam.** There shall be a link beam provided at least at one end of each brace. Beams in EBFs shall comply with the requirements of Section 2702 (b) 4 except that the flange width-thickness ratio, $b_f/2t_f$, shall not exceed $52/\sqrt{F_y}$.

2. **Link beam strength.** A. Link beam shear strength, $V_s$, and flexural strength, $M_s$, are the strengths as defined in Section 2722 (c) 2. Where link beam strength is governed by shear, the flexural and axial capacities within the link shall be calculated using the beam flanges only.

B. A reduced flexural strength, $M_{rs}$, for use in Sections 2722 (h) 7 and 2722 (h) 12 is defined as $Z(F_y - F_a)$. Where $f_a$ is less than $0.15F_y$, $f_a$ may be neglected.

3. **Link beam rotation.** The rotation of the link segment relative to the rest of



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the beam, at a total frame drift of $3(R_w/8)$ times the drift determined for prescribed seismic forces, shall not exceed the following:

A. 0.060 radians for link segments having clear lengths of $1.6\ M_s/V_s$ or less.

B. 0.015 radians for link segments having clear lengths of $2.6\ M_s/V_s$ or greater.

C. A value obtained by linear interpolation for clear lengths between the above limits.

4. **Link beam web.** The web of the link beam shall be single thickness without doubler plate reinforcement. No openings shall be placed in the web of a link beam. The web shear shall not exceed $0.8V_s$ under prescribed lateral forces.

5. **Beam connection braces.** Brace-to-beam connections shall develop the compression strength of the brace and transfer this force to the beam web. No part of the brace-to-beam connection shall extend into the web area of a link beam.

6. **Link beam stiffeners.** Link beams shall have full depth web stiffeners on both sides of the beam web at the brace end of the link beam. In addition, for link beams with clear lengths within the limits in Section 2722 (h) 3 C, full-depth stiffeners shall be placed at a distance $b_f$ from each end of the link. The stiffeners shall have a combined width not less than $b_f - 2t_w$ and a thickness not less than $0.75\ t_w$ nor 3/8 inch.

7. **Intermediate stiffeners.** Intermediate full-depth web stiffeners shall be provided in either of the following conditions:

A. Where the link beam strength is controlled by $V_s$.

B. Where the link beam strength is controlled by flexure and the shear determined by applying the reduced flexural strength, $M_{rs}$, exceeds $0.45\ F_y dt$.

8. **Web stiffener spacing.** Where intermediate web stiffeners are required the spacing shall conform to the requirements given below.

A. For link beams with rotation angle of 0.06 radians the spacing shall not exceed $38t_w - d/5$.

B. For link beams with a rotation angle of 0.03 radians or less the spacing shall not exceed $56t_w - d/5$. Interpolation may be used for rotation angles between 0.03 and 0.06 radians.

9. **Web stiffener location.** For beams 24 inches in depth and greater, intermediate full-depth web stiffeners are required on both sides of the web. Such web stiffeners are required only on one side of the beam web for beams less than 24 inches in depth. The stiffener thickness, $t_w$, of one side stiffeners shall be not less than 3/8 inch and the width shall be not less than $(b_f/2) - t_w$.

10. **Stiffener welds.** Fillet welds connecting the stiffener to the beam web shall develop a stiffener force of $A_{st} F_y$. Fillet welds connecting the stiffener to the flanges shall develop a stiffener force of $A_{st} F_y/4$, where $A_{st} = bt$ of stiffener and $b$ = width of stiffener plate.

11. **Link beam-column connections.** A. Where a link beam is connected to the column flange, the following requirements shall be met:

(i) The beam flanges shall have full-penetration welds to the column.

(ii) Where the link beam strength is controlled by shear in conformance with



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Section 2722 (h) 7, the web connection shall be welded to develop the full link beam web shear strength.

B. Where the link beam is connected to the column web, the beam flanges shall have full-penetration welds to the connection plates and the web connection shall be welded to develop the link beam web shear strength.

12. **Brace strength.** Each brace shall have a compressive strength at least 1.5 times the axial force corresponding to the controlling link beam strength. The controlling link beam strength is either the shear strength, $V_s$, or the reduced flexural strength, $M_{rs}$, whichever results in the lesser force in the brace.

13. **Column strength.** Columns shall be designed to remain elastic at 1.25 times the strength of the EBF bay, as defined in paragraph 12 above.

14. **Roof link beam.** A link beam is not required in roof beams for EBF over five stories.

15. **Concentric brace in combination.** The first story of an EBF bay over five stories in height may be concentrically braced if this story can be shown to have an elastic capacity 50 percent greater than the yield capacity of the story frames above the first story.

16. **Axial forces.** Axial forces in beams of EBF frames due to braces and due to transfer of seismic force to the end of the frames shall be included in the frame calculations.

17. **Beam flanges.** Top and bottom flanges of EBF frame beams shall be laterally braced at the ends of link beams and at intervals not exceeding $76/\sqrt{F_y}$ times the beam flange width. End bracing shall be designed to resist 1.5 percent of the beam flange strength, defined as $F_y b_f t_f$. Intermediate bracing shall be designed to resist 1.0 percent of the beam flange force at the brace point using the link beam strength determined in Section 2722 (h) 12.

18. **Beam-column connection.** Beam connections to columns may be designed as pins in the plane of the beam web if the link beam is not adjacent to the column. Such connection shall have the capacity to resist a torsional moment of $0.01F_y b_f t_f d$.

(i) **Stud Wall Systems.** Stud wall systems may be used to resist the specified seismic forces in buildings not over five stories in height. In Seismic Zones Nos. 3 and 4 these systems shall comply with the following:

1. The $l/r$ of the brace may exceed 200 and is unlimited.
2. All boundary members, chords and collectors shall be designed and detailed to transmit the induced axial forces.
3. Connection of the diagonal bracing member, top chord splices, boundary members and collectors shall be designed to develop the full tensile strength of the member or $3(R_w/8)$ times the otherwise prescribed seismic forces.
4. Vertical and diagonal members of the braced bay shall be anchored so the bottom track is not required to resist uplift forces by bending of the track web.
5. Both flanges of studs in a bracing panel shall be braced to prevent lateral



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torsional buckling. Wire tied bridging shall not be considered to provide such restraint.

6. Screws shall not be used to resist lateral forces by pullout resistance.

7. Provision shall be made for pretensioning or other methods of installation of tension only bracing to guard against loose diagonal straps.

(j) **Nondestructive Testing.** Welded connections between the primary members of ductile moment-resisting space frames shall be tested by nondestruetive methods for compliance with U.B.C. Standard No. 27-6 and job specifications. This testing shall be a part of the special inspection requirements of Section 306. A program for this testing shall be established by the person responsible for structural design and as shown on plans and speeifieations.

As a minimum, this program shall include the following: 1. All complete penetration groove welds contained in joints and splices shall be tested 100 percent either by ultrasonic testing or by radiography.

**EXCEPTION:** When approved, the nondestructive testing rate for an individual welder or welding operator may be reduced to 25 percent, provided the reject rate is demonstrated to be 5 percent or less of the welds tested for the welder or welding operator. A sampling of at least 40 completed welds for a job shall be made for such reduction evaluation. Reject rate is defined as the number of welds containing rejectable defects divided by the number of welds completed. For evaluating the reject rate of continuous welds over 3 feet in length where the effective throat thickness is 1 inch or less, each 12-inch increment or fraction thereof shall be considered as one weld. For evaluating the reject rate on continuous welds over 3 feet in length where the effective throat thickness is greater than 1 inch, each 6 inches of length or fraction thereof shall be considered one weld.

When approved by the building official and outlined in the project plans and specifications, this nondestructive ultrasonic testing may be performed in the shop of an approved fabricator utilizing qualified test techniques in the employment of the fabricator.

2. Partial penetration groove welds when used in column spliees shall be tested either by ultrasonic testing or radiography when required by the plans and specifications.

3. Base metal thicker than 1 1/2 inches, when subjected to through-thickness weld shrinkage strains, shall be ultrasonically inspected for discontinuities directly behind such welds after joint completion.

Any material discontinuities shall be accepted or rejected on the basis of the defect rating in accordance with the (larger reflector) criteria of U.B.C. Standard No. 27-6.

## Load and Resistance Factor Design

**Sec. 2723.** As an alternative to the allowable stress design provisions of this chapter, steel structures may be designed in accordance with the provisions of U.B.C. Standard No. 27-14.

Load and resistanee factor design may be used in the design of seismie-resisting frames in Seismic Zones Nos. 2, 3 and 4 when approved by the building official



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and when special detailing is used to provide results equivalent to those obtained by the use of the allowable stress provisions of Section 2722.

## Steel Storage Racks

**Sec. 2724.** Steel storage racks may be designed in conformance with U.B.C. Standard No. 27-11.

## Steel Cables

**Sec. 2725.** Structural use of steel cables shall conform with the provisions of U.B.C. Standard No. 27-12.



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## TABLE NO. 27-A—ALLOWABLE STRESSES FOR RIVETS AND BOLTS

| DESCRIPTION OF FASTENERS | TENSION ($F_t$) | SHEAR ($F_v$) FRICTION-TYPE CONNECTIONS[8] [7] | | | BEARING-TYPE CONNECTIONS |
|---|---|---|---|---|---|
| | | Standard Size Holes | Oversize and Short-slotted | Long-slotted Holes | |
| 1. A502, Grade 1, hot-driven rivets | 20.0[1] | — | — | — | 17.5 |
| 2. A502, Grade 2, hot-driven rivets | 27.0[1] | — | — | — | 22.0 |
| 3. A307, Type A, bolts | 20.0[1] | — | — | — | 10.0[2] |
| 4. Threaded parts meeting the requirements of Section 2701 and A449 bolts when threads are not excluded from the shear plane[8] | $0.33F_u$[1] [3] | — | — | — | $0.17F_u$ |
| 5. Threaded parts meeting the requirements of Section 2701 and A449 bolts when threads are excluded from the shear plane[8] | $0.33F_u$[1] | — | — | — | $0.22F_u$ |
| 6. A325 bolts, when threading is not excluded from the shear planes | 44.0[4] | 17.5 | 15.0 | 12.5 | 22.0[6] |
| 7. A325 bolts, when threading is excluded from the shear planes | 44.0[4] | 17.5 | 15.0 | 12.5 | 30.0[6] |
| 8. A490 bolts, when threading is not excluded from the shear planes | 54.0[4] | 22.0 | 19.0 | 16.0 | 28.0[6] |
| 9. A490 bolts, when threading is excluded from the shear planes | 54.0[4] | 22.0 | 19.0 | 16.0 | 40.0[6] |

[1]Static loading only

[2]Threads permitted in shear planes.

[3]The tensile capacity on the threaded portion of an upset rod shall be larger than the body area times $0.6F_y$.

[4]For A325 and A490 bolts subject to tensile fatigue loading. See U.B.C. Standard No. 27-3.

[5]When specified by the designer the working stress $F_v$ for friction-type shear connections may have the applicable value given in U.B.C. Standard No. 27-7.

[6]In bearing-type connections whose length between extreme fasteners measured parallel to the line of axial force exceeds 50 inches, tabulated values shall be reduced 20 percent.

[7]See Section 2303 (d).

[8]A449 bolts shall be limited to the following applications: Bearing-type high-strength structural joints requiring diameters greater than 1½ inches, or high-strength material for anchor bolts or threaded rods.



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## TABLE NO. 27-B—ALLOWABLE STRESS

| TYPE OF WELD AND STRESS[1] | ALLOWABLE STRESS | REQUIRED WELD STRENGTH LEVEL[2,3] |
|---|---|---|
| **COMPLETE PENETRATION GROOVE WELDS** | | |
| 1. Tension normal to the effective area | Same as base metal | "Matching" weld metal must be used; see U.B.C. Standard No. 27-6 |
| 2. Compression normal to the effective area | Same as base metal | Weld metal with a strength level equal to or less than "matching" weld metal may be used |
| 3. Tension or compression parallel to the axis of the weld | Same as base metal | |
| 4. Shear on the effective area | 0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal | |
| **PARTIAL PENETRATION GROOVE WELDS[4]** | | |
| 5. Compression normal to effective area | Same as base metal | Weld metal with a strength level equal to or less than "matching" weld metal may be used |
| 6. Tension or compression parallel to axis of the weld[5] | Same as base metal | |
| 7. Shear parallel to axis of weld | 0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal | |
| 8. Tension normal to effective area | 0.30 × nominal tensile strength of weld metal (ksi), except tensile stress on base metal shall not exceed 0.60 × yield stress of base metal | |



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| | | |
|---|---|---|
| **FILLET WELDS** | | |
| 9. Shear on effective area | 0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal | Weld metal with a strength level equal to or less than "matching" metal may be used |
| 10. Tension or compression parallel to axis of weld[5] | Same as base metal | |
| **PLUG AND SLOT WELDS** | | |
| 11. Shear parallel to faying surfaces (on effective area) | 0.30 × nominal tensile strength of weld metal (ksi), except shear stress on base metal shall not exceed 0.40 × yield stress of base metal | Weld metal with a strength level equal to or less than "matching" weld metal may be used |

[1]For definition of effective area see Section 2702 (e).

[2]For "matching" weld metal, see U.B.C. Standard No. 27-6.

[3]Weld metal one strength level stronger than "matching" weld metal will be permitted.

[4]See Section 2707 (h) for a limitation on use of partial penetration groove-welded joints.

[5]Fillet welds and partial penetration groove welds joining the component elements of built-up members, such as flange-to-web connections, may be designed without regard to the tensile or compressive stress in these elements parallel to the axis of the welds.





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## TABLE NO. 27-C—ALLOWABLE HORIZONTAL SHEAR LOADS FOR SHEAR CONNECTIONS

| CONNECTOR[1] | ALLOWABLE HORIZONTAL SHEAR LOAD *(q)* (kips) (Applicable only to concrete made with aggregates conforming to U.B.C. Standard No. 26-2)[2] $f'_c$ (kips per square inch) | | |
|---|---|---|---|
| | 3.0 | 3.5 | ≧ 4.0 |
| 1. ½" diam. x 2" hooked or headed stud | 5.1 | 5.5 | 5.9 |
| 2. ⅝" diam. x 2½" hooked or headed stud | 8.0 | 8.6 | 9.2 |
| 3. ¾" diam. x 3" hooked or headed stud | 11.5 | 12.5 | 13.3 |
| 4. ⅞" diam. x 3½" hooked or headed stud | 15.6 | 16.8 | 18.0 |
| 5. 3" channel, 4.1 lb. | 4.3*w* | 4.7*w* | 5.0*w* |
| 6. 4" channel, 5.4 lb. | 4.6*w* | 5.0*w* | 5.3*w* |
| 7. 5" channel, 6.7 lb. | 4.9*w* | 5.3*w* | 5.6*w* |

$w$ = length of channel in inches.

[1]The allowable horizontal loads tabulated may also be used for studs longer than shown.

[2]For lightweight concrete made with aggregates conforming to U.B.C. Standard No. 26-3, multiply values above by appropriate reduction coefficient as follows:

| Air Dry Unit Weight, pcf. | 90 | 95 | 100 | 105 | 110 | 115 | 120 |
|---|---|---|---|---|---|---|---|
| Coefficient, $f'_c \leq 4.0$ ksi. | 0.73 | 0.76 | 0.78 | 0.81 | 0.83 | 0.86 | 0.88 |
| Coefficient, $f'_c \geq 5.0$ ksi. | 0.82 | 0.85 | 0.87 | 0.91 | 0.93 | 0.96 | 0.99 |

## TABLE NO. 27-D-1—MINIMUM DISTANCE, INCHES (CENTER OF STANDARD HOLE[1] TO EDGE OF CONNECTED PART)

| NOMINAL RIVET OR BOLT DIAMETER | AT SHEARED EDGES | AT ROLLED EDGES OF PLATES, SHAPES OR BARS OR GAS CUT EDGES[2] |
|---|---|---|
| ½ | ⅞ | ¾ |
| ⅝ | 1⅛ | ⅞ |
| ¾ | 1¼ | 1 |
| ⅞ | 1½[3] | 1⅛ |
| 1 | 1¾[3] | 1¼ |
| 1⅛ | 2 | 1½ |
| 1¼ | 2¼ | 1⅝ |
| Over 1¼ | 1¾ x Diameter | 1¼ x Diameter |

[1]For oversized or slotted holes, see Section 2713 (e) 4.

[2]All edge distanees in this column may be reduced ⅛ inch when the hole is at a point where stress does not exceed 25 percent of the maximum allowed stress in the element.

[3]These may be 1¼ inch at the ends of beam connection angles.



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## TABLE NO. 27-D-2—VALUES OF SPACING INCREMENT $C_1$, IN INCHES

| NOMINAL DIAMETER OF FASTENER | OVERSIZED HOLES | SLOTTED HOLES | | |
|---|---|---|---|---|
| | | Perpendicular to Line of Force | Parallel to Line of Force | |
| | | | Short Slots | Long Slots[1] |
| ≤ 7/8 | 1/8 | 0 | 3/16 | 1 1/2$d$ – 1/16 |
| 1 | 3/16 | 0 | 1/4 | 1 7/16 |
| ≥ 1 1/8 | 1/4 | 0 | 5/16 | 1 1/2$d$ – 1/16 |

[1]When length of slot is less than maximum allowable, $C_1$ may be reduced by the difference between the maximum and actual slot lengths.

## TABLE NO. 27-D-3—VALUES OF EDGE DISTANCE INCREMENT $C_2$, IN INCHES

| NOMINAL DIAMETER OF FASTENER | OVERSIZED HOLES | SLOTTED HOLES | | PARALLEL TO EDGE |
|---|---|---|---|---|
| | | Perpendicular to Edge | | |
| | | Short Slots[1] | Long Slots[1] | |
| ≤ 7/8 | 1/16 | 1/8 | | |
| 1 | 1/8 | 1/8 | 3/4$d$ | 0 |
| ≥ 1 1/8 | 1/8 | 3/16 | | |

[1]When length of slot is less than maximum allowable, $C_2$ may be reduced by one-half the difference between the maximum and actual slot lengths.

## TABLE NO. 27-E-1—MINIMUM-SIZE FILLET WELD

| MATERIAL THICKNESS OF THICKER PART JOINED (Inches) | MINIMUM SIZE OF WELD[1] (Inches) |
|---|---|
| To 1/4 inclusive | 1/8 |
| Over 1/4 to 1/2 | 3/16 |
| Over 1/2 to 3/4 | 1/4 |
| Over 3/4 | 5/16 |

[1]Leg dimension of fillet welds.



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## TABLE NO. 27-E-2—MINIMUM EFFECTIVE THROAT OF PARTIAL PENETRATION GROOVE WELD

| MATERIAL THICKNESS OF THICKER PART JOINED (Inches) | MINIMUM EFFECTIVE[1] THROAT (Inches) |
|---|---|
| To 1/4 inclusive | 1/8 |
| Over 1/4 to 1/2 | 3/16 |
| Over 1/2 to 3/4 | 1/4 |
| Over 3/4 to 1 1/2 | 5/16 |
| Over 1 1/2 to 2 1/4 | 3/8 |
| Over 2 1/4 to 6 | 1/2 |
| Over 6 | 5/8 |

[1]See Section 2702 (e).

## TABLE NO. 27-F—EFFECTIVE THROATS OF FLARE GROOVE WELDS

| FLARE BEVEL GROOVE WELDS | FLARE V GROOVE WELDS |
|---|---|
| All diameter bars | |
| $5/16R$ | $1/2R$[1] |

NOTE: $R$ = radius of bar.

[1]Except $3/8R$ for GMAW (except short circuiting transfer) process with bar sizes 1 inch and over.



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# Chapter 28
# ALUMINUM

## Material Standards and Symbols

**Sec. 2801.** (a) **General.** The quality, design, fabrication and erection of aluminum used structurally in buildings and structures shall conform to the requirements of this chapter, to other applicable requirements of this code and to U.B.C. Standard No. 28-1.

(b) **Alloys.** The use of aluminum alloys and tempers other than those covered by this chapter shall be permitted for structural members and assemblies, provided standards of performance not less than those required by this chapter are substantiated to the satisfaction of the building official. When required by the building official, certification that the alloys and tempers called for on the plans have been furnished shall be provided.

(c) **Symbols and Notations.** The symbols and notations used in these regulations are defined as follows:

$A$ = area, inches$^2$.

$A_w$ = area of cross section lying within 1.0 inch of a weld, inches$^2$.

$a_1$ = shorter dimension of rectangular panel, inches.

$a_2$ = longer dimension of rectangular panel, inches.

$a_e$ = equivalent width of rectangular panel, inches.

$B, D, C,$ = buckling formula constants, with following subscript:
- $c$ — compression in columns
- $p$ — compression in flat plates
- $t$ — compression in round tubes
- $tb$ — bending in round tubes
- $b$ — bending in rectangular bars
- $s$ — shear in flat plates

$b$ = width of sections, inches.

$b/t$ = width-to-thickness ratio or rectangular element of a cross section.

$c$ = distance from neutral axis to extreme fiber, inches.

$D$ = diameter, inches.

$d$ = depth of section or beam, inches.

$E$ = compressive modulus of elasticity, ksi.

$f$ = calculated stress, ksi.

$f_a$ = average compressive stress on cross section of member produced by axial compressive load, ksi.

$f_b$ = maximum bending stress (compressive) caused by transverse loads or end moments, ksi.

$f_s$ = shear stress caused by torsion or transverse shear, ksi.

$F$ = allowable stress, ksi.



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$F_a$ = allowable compressive stress for member considered as an axially loaded column, ksi.

$F_b$ = allowable compressive stress for member considered as a beam, ksi.

$F_{bu}$ = bearing ultimate strength, ksi.

$F_{buw}$ = bearing ultimate strength within 1.0 inch of a weld, ksi.

$F_{by}$ = bearing yield strength, ksi.

$F_{byw}$ = bearing yield strength within 1.0 inch of a weld, ksi.

$F_c$ = allowable compressive stress, ksi.

$F_{cy}$ = compressive yield strength, ksi.

$F_{cyw}$ = compressive yield strength across a butt weld (0.2 percent offset in 10-inch gauge length), ksi.

$F_{ec}$ = $\pi^2 E/[n_u(L/r)^2]$, where $L/r$ is slenderness ratio for member considered as a column tending to fail in the plane of the applied bending moments, ksi.

$F_n$ = allowable stress for cross section 1.0 inch or more from weld, ksi.

$F_{pw}$ = allowable stress on cross section, part of whose area lies within 1.0 inch of a weld, ksi.

$F_s$ = allowable shear stress for members subjected only to torsion or shear, ksi.

$F_{su}$ = shear ultimate strength, ksi.

$F_{suw}$ = shear ultimate strength within 1.0 inch of a weld, ksi.

$F_{sy}$ = shear yield strength, ksi.

$F_{syw}$ = shear yield strength within 1.0 inch of a weld, ksi.

$F_{tu}$ = tensile ultimate strength, ksi.

$F_{tuw}$ = tensile ultimate strength across a butt weld, ksi.

$F_{ty}$ = tensile yield strength, ksi.

$F_{tyw}$ = tensile yield strength across a butt weld (0.2 percent offset in 10-inch gauge length), ksi.

$F_y$ = either $F_{ty}$ or $F_{cy}$, whichever is smaller, ksi.

$g$ = spacing of rivet or bolt holes perpendicular to direction of load, inches.

$G$ = modulus of elasticity in shear, ksi.

$h$ = clear height of shear web, inches.

$I$ = moment of inertia, inches$^4$.

$I_h$ = moment of inertia of horizontal stiffener, inches$^4$.

$I_s$ = moment of inertia of transverse stiffener to resist shear buckling, inches$^4$.

$I_x$ = moment of inertia of a beam about axis perpendicular to web, inches$^4$.

$I_y$ = moment of inertia of a beam about axis parallel to web, inches$^4$.

$J$ = torsion constant, inches$^4$.



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$k_1$ = coefficient for determining slenderness limit $S_2$ for sections for which the allowable compressive stress is based on crippling strength.

$k_2$ = coefficient for determining allowable compressive stress in sections with slenderness ratio above $S_2$ for which the allowable compressive stress is based on crippling strength.

$k_c$ = coefficient for compression members.

$k_t$ = coefficient for tension members.

$L$ = length of compression member between points of lateral support, or twice the length of a cantilever column (except where analysis shows that a shorter length can be used), inches.

$L/r$ = slenderness ratio for columns.

$L_b$ = length of beam between points at which the compression flange is supported against lateral movement, or length of cantilever beam from free end to point at which the compression flange is supported against lateral movement, inches.

$L_h$ = total length of portion of column lying within 1.0 inch of a weld (excluding welds at ends of columns that are supported at both ends), inches.

$L_w$ = increased length to be substituted in column formula to determine allowable stress for welded column, inches.

$M$ = bending moment, inch-kips.

$M_c$ = bending moment at center of span resulting from applied bending loads, inch-kips.

$M_m$ = maximum bending moment in span resulting from applied bending loads, inch-kips.

$M_1, M_2$ = bending moments at two ends of a beam, inch-kips.

$n_a$ = factor of safety on appearance of buckling.

$n_u$ = factor of safety on ultimate strength.

$n_y$ = factor of safety on yield strength.

$P$ = local load concentration on bearing stiffener, kips.

$r$ = least radius of gyration of a column, inches.

$r_L$ = radius of gyration of lip or bulb about face of flange from which lip projects, inches.

$r_y$ = radius of gyration of a beam (about axis parallel to web), inches. (For beams that are unsymmetrical about the horizontal axis, $r_y$ should be calculated as though both flanges were the same as the compression flange).

$R$ = outside radius of round tube or maximum outside radius for an oval tube, inches.

$R_b$ = radius of curvature of tubular members, inches.



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$s$ = spacing of transverse stiffeners (clear distance between stiffeners for stiffeners consisting of a pair of members, one on each side of the web, center-to-center distance between stiffeners consisting of a member on one side of the web only), inches; spacing of rivet or bolt holes parallel to direction of load, inches.

$S_c$ = section modulus of a beam, compression side, inches$^3$.

$S_t$ = section modulus of a beam, tension side, inches$^3$.

$S_1, S_2$ = slenderness limits.

$t$ = thickness of flange, plate, web or tube, inches. (For tapered flanges, $t$ is the average thickness.)

$V$ = shear force on web at stiffener location, kips.

$\alpha$ = a factor equal to unity for a stiffener consisting of equal members on both sides of the web and equal to 3.5 for a stiffener consisting of a member on one side only.

(d) **Identification.** Aluminum for structural elements shall at all times be segregated or otherwise handled in the fabricator's plant so that the separate alloys and tempers are positively identified and, after completion of fabrication, shall be marked to identify the alloy and temper. Such markings shall be affixed to complete members and assemblies or to boxed or bundled shipments of multiple units prior to shipment from the fabricator's plant.

## Allowable Stresses for Members and Fasteners

**Sec. 2802.** (a) **Allowable Unit Stresses.** Except as modified by U.B.C. Standard No. 28-1, allowable unit stresses in aluminum alloy structural members shall be determined in accordance with the formulas of Table No. 28-C utilizing the safety factors listed in Table No. 28-D and the constants and coefficients listed in Tables Nos. 28-E, 28-F and 28-G. Where two formulas are given, the smaller of the resulting stresses shall be used.

(b) **Welded Structural Members.** Allowable unit stresses for structural members whose entire cross-sectional area lies within 1 inch of the center line of a butt weld of the heel of a fillet weld shall be determined by means of the formulas of Table No. 28-C utilizing the applicable minimum expected mechanical properties for welded aluminum alloys listed in U.B.C. Standard No. 28-1. The tensile ultimate strength, $F_{tuw}$, shall be 90 percent of the ASME weld qualification test value of ultimate strength. Except as modified by U.B.C. Standard No. 28-1, buckling constants determined in accordance with the formulas of Tables Nos. 28-E and 28-G shall be calculated using the nonwelded mechanical properties of the respective aluminum alloys.

If less than 15 percent of the area of a given cross section lies within 1 inch of the center line of a butt weld or the heel of a fillet weld, the effect of the weld may be neglected and allowable stresses for nonwelded structural members may be used.

If the area of a cross section that lies within 1 inch of a weld is between 15 percent and 100 percent of the total area of the cross section, the allowable stress shall be calculated by the following formula:



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$$F'_{pw} = F_n - \frac{A_w}{A}(F_n - F_w)$$

**WHERE:**

$F_{pw}$ = allowable stress on cross section part of whose area lies within 1.0 inch of a weld.

$F'_n$ = allowable stress for cross section 1.0 inch or more from weld.

$F_w$ = allowable stress on cross section if entire area were to lie within 1.0 inch of a weld.

$A_w$ = area of cross section lying within 1.0 inch of a weld.

$A$ = net area of cross section of a tension member or tension flange of a beam, or gross area of cross section of a compression member or compression flange of a beam, inches$^2$. (A beam flange is considered to consist of that portion of the member further than $2c/3$ from the neutral axis, where $c$ is the distance from the neutral axis to the extreme fiber.)

For columns and beams with welds at locations other than at their supported ends (not farther from the supports than 0.05 $L$ from the ends), and for cantilever columns and single web beams with transverse welds at or near the supported end, the effect of welding on allowable stresses shall be determined in accordance with the provisions of U.B.C. Standard No. 28-1.

(c) **Rivets and Bolts.** Allowable stresses in aluminum rivets and bolts shall be as set forth in Table No. 28-A.

(d) **Fillet Welds.** Allowable sheer stresses in fillet welds shall be as set forth in Table No. 28-**B**.

## Design

**Sec. 2803.** (a) **Combined Stresses.** Members subjected to combinations of compression and bending or shear, compression and bending shall be proportioned in accordance with the provisions of U.B.C. Standard No. 28-1.

(b) **Light Gauge Members.** Where the design of light gauge structural members is involved, the special provisions of U.B.C. Standard No. 28-1 shall be applied.

(c) **Structural Roofing and Siding.** The live load deflection of structural roofing and siding made of formed sheet shall not exceed one sixtieth of the span length.

(d) **Connections.** The design of mechanical and welded connections shall be in accordance with this chapter and the provisions of U.B.C. Standard No. 28-1.

## Fabrication and Erection

**Sec. 2804.** (a) **Cutting.** Oxygen cutting of aluminum alloys shall not be permitted.



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(b) **Fasteners.** Bolts and other fasteners shall be aluminum, stainless steel or aluminized, hot-dip galvanized or electrogalvanized steel. Double cadmium-plated AN steel bolts may also be used. Steel rivets shall not be used except where aluminum is to be joined to steel or where corrosion resistance of the structure is not a requirement or where the structure is to be protected against corrosion.

(c) **Dissimilar Materials.** Where aluminum alloy parts are in contact with dissimilar metals, other than stainless, aluminized or galvanized steel or absorbent building materials likely to be continuously or intermittently wet, the faying surfaces shall be painted or otherwise separated in accordance with U.B.C. Standard No. 28-1.

(d) **Painting.** Except as prescribed in Section 2804 (c), painting or coating of aluminum alloy parts shall be required only when called for on the plans.

(e) **Welding.** Aluminum parts shall be welded with an inert gas shielded arc or resistance welding process. No welding process that requires a welding flux shall be used. Filler alloys complying with the requirements of U.B.C. Standard No. 28-1 shall be used.

(f) **Welder Qualification.** All welds of structural members shall be performed by welders qualified in accordance with the procedures of U.B.C. Standard No. 28-1.

(g) **Erection.** During erection, structural aluminum shall be adequately braced and fastened to resist dead, wind and erection loads.



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## TABLE NO. 28-A
## ALLOWABLE STRESSES FOR RIVETS

| DESIGNATION BEFORE DRIVING | DRIVING PROCEDURE | DESIGNATION AFTER DRIVING | MINIMUM EXPECTED SHEAR STRENGTH ksi | ALLOWABLE SHEAR STRESS ON EFFECTIVE AREA ksi |
|---|---|---|---|---|
| 1100-H14 | Cold, as received | 1100-F | 9.5 | 4 |
| 2017-T4 | Cold, as received | 2017-T3 | 34 | 14.5 |
| 2117-T4 | Cold, as received | 2117-T3 | 29 | 12 |
| 5056-H32 | Cold, as received | 5056-H321 | 26 | 11 |
| 6053-T61 | Cold, as received | 6053-T61 | 20 | 8.5 |
| 6061-T4 | Hot, 990° to 1050°F. | 6061-T43 | 21 | 9 |
| 6061-T6 | Cold, as received | 6061-T6 | 26 | 11[1] |

## ALLOWABLE STRESSES FOR BOLTS

| ALLOY AND TEMPER | MINIMUM EXPECTED SHEAR STRENGTH ksi | ALLOWABLE[2] SHEAR STRESS ON EFFECTIVE AREA ksi | ALLOWABLE TENSILE STRESS ON ROOT AREA ksi |
|---|---|---|---|
| 2024-T4 | 37 | 16 | 26 |
| 6061-T6 | 27 | 12 | 18 |
| 7075-T73 | 40 | 17 | 28 |

[1]Also applies to 6061-T6 pins.

[2]Values apply to either turned bolts or unfinished bolts in holes not more than 1/16 inch oversized.

## TABLE NO. 28-B
## ALLOWABLE SHEAR STRESSES IN FILLET WELDS—ksi
## (Shear Streas Is Considered to Equsl to the Load Divided by ths Throat Area)

| FILLER ALLOY | 1100 | 4043 | 5356 5554 | 5556 |
|---|---|---|---|---|
| Parent Alloy | | | | |
| 1100 | 3.2 | 4.8 | * | * |
| 3003 | 3.2 | 5 | * | * |
| Alclad 3004 | * | 5 | 7 | 8 |
| 5052 | * | 5 | 7 | * |
| 5083 | * | * | * | 8.5 |
| 5086 | * | * | 7 | 8.5 |
| 5454 | * | * | 7 | 8.5 |
| 5456 | * | * | * | 8.5 |
| 6061 | * | 5 | 7 | 8.5 |
| 6063 | * | 5 | 6.5 | 6.5 |

*Not permitted.



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## TABLE NO. 28-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES

| TYPE OF STRESS | TYPE OF MEMBER OR COMPONENT | SPEC. NO. | ALLOWABLE STRESS, KSI |
|---|---|---|---|
| TENSION, axial, net section | Any tension member: | 1 | $F_{tu}/n_u$ or $F_{ty}/(k_y n_y)$ |
| TENSION IN BEAMS, extreme fiber, net section | Rectangular tubes, structural shapes bent about strong axis | 2 | $F_{tu}/n_u$ or $F_{ty}/(k_y n_y)$ |
| | Round or oval tubes | 3 | $1.17F_{tu}/n_u$ or $1.24F_{ty}/(k_y n_y)$ |
| | Rectangular bars, plates, shapes bent about weak axis | 4 | $1.30F_{tu}/n_u$ or $1.42F_{ty}/(k_y n_y)$ |
| BEARING | On rivets and bolts | 5 | $F_{su}/n_u$ or $F_{sy}/(1.2n_y)$ |
| | On flat surfaces and pins | 6 | $F_{su}/(1.5n_u)$ or $F_{sy}/(1.8n_y)$ |

| TYPE OF STRESS | TYPE OF MEMBER OR COMPONENT | SPEC. NO. | ALLOWABLE STRESS, KSI, SLENDERNESS $< S_1$ | SLENDERNESS LIMIT, $S_1$ | ALLOWABLE STRESS, KSI SLENDERNESS BETWEEN $S_1$ AND $S_2$ | SLENDERNESS LIMIT, $S_2$ | ALLOWABLE STRESS, KSI SLENDERNESS $> S_2$ |
|---|---|---|---|---|---|---|---|
| COMPRESSION IN COLUMNS, axial, gross section | All columns | 7 | $\frac{F_{cy}}{k_c n_y}$ | $\frac{L}{r} = \frac{B_c - n_u F_{cy}/k_c n_y}{D_c}$ | $\frac{1}{n_u}\left(B_c - D_c\frac{L}{r}\right)$ | $\frac{L}{r} = C_c$ | $\frac{\pi^2 E}{n_u (L/r)^2}$ |
| COMPRESSION IN COMPONENTS OF COLUMNS, gross section | Outstanding flanges and legs | 8 | $\frac{F_{cy}}{k_c n_y}$ | $\frac{b}{t} = \frac{B_p - n_u F_{cy}/k_c n_y}{5.1D_p}$ | $\frac{1}{n_u}\left(B_p - 5.1D_p\frac{b}{t}\right)$ | $\frac{b}{t} = \frac{C_p}{5.1}$ | $\frac{\pi^2 E}{n_u (5.1b/t)^2}$ |
| | Flat plates with both edges supported | 9 | $\frac{F_{cy}}{k_c n_y}$ | $\frac{b}{t} = \frac{B_p - n_u F_{cy}/k_c n_y}{1.6D_p}$ | $\frac{1}{n_u}\left(B_p - 1.6D_p\frac{b}{t}\right)$ | $\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$ | $\frac{k_0\sqrt{B_p E}}{n_u(1.6b/t)}$ |
| | Curved plates supported on both edges, walls of round or oval tubes | 10 | $\frac{F_{cy}}{k_c n_y}$ | $\frac{R}{t} = \left(\frac{B_t - n_u F_{cy}/k_c n_y}{D_t}\right)^2$ | $\frac{1}{n_u}\left(B_t - D_t\sqrt{\frac{R}{t}}\right)$ | $\frac{R}{t} = C_t$ | $\frac{\pi^2 E}{16 n_u\left(\frac{R}{t}\right)\left(1 + \frac{\sqrt{Rt}}{35}\right)^2}$ |



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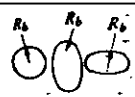
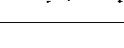
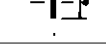
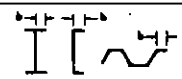
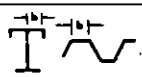
| TYPE OF STRESS | TYPE OF MEMBER OR COMPONENT | SPEC. NO. | ALLOWABLE STRESS, KSI, SLENDERNESS $< S_1$ | SLENDERNESS LIMIT, $S_1$ | ALLOWABLE STRESS, KSI SLENDERNESS BETWEEN $S_1$ AND $S_2$ | SLENDERNESS LIMIT, $S_2$ | ALLOWABLE STRESS, KSI SLENDERNESS $> S_2$ |
|---|---|---|---|---|---|---|---|
| COMPRESSION IN BEAMS, extreme fiber, gross section | Single web beams bent about strong axis | 11 | $\frac{F_{cy}}{n_y}$ | $\frac{L_b}{r_y} = \frac{1.2(B_c - F_{cy})}{D_c}$ | $\frac{1}{n_y}\left(B_c - \frac{D_c L_b}{1.2 r_y}\right)$ | $\frac{L_b}{r_y} = 1.2C_c$ | $\frac{\pi^2 E}{n_y (L_b/1.2r_y)^2}$ |
| | Round or oval tubes  | 12 | $\frac{1.17F_{cy}}{n_y}$ | $\frac{R_b}{t} = \left(\frac{B_{tb} - 1.17F_{cy}}{D_{tb}}\right)^2$ | $\frac{1}{n_m}\left(B_{tb} - D_{tb}\sqrt{\frac{R_b}{t}}\right)$ | $\frac{R_b}{t} = \left(\frac{\frac{n_m}{n_y}B_{tb} - B_t}{\frac{n_m}{n_y}D_{tb} - D_t}\right)^2$ | Same as Specification 10[1] |
| | Curved Sections  | 12 | $\frac{1.17F_{cy}}{n_y}$ | $\frac{R}{t} = \left(\frac{B_t - 1.17F_{cy}}{D_t}\right)^2$ | $\frac{1}{n_y}\left(B_t - D_t\sqrt{\frac{R}{t}}\right)$ | $\frac{R}{t} = C_t$ | $\frac{\pi^2 E}{16 n_y \left(\frac{R}{t}\right)\left(1 + \frac{\sqrt{R/t}}{35}\right)^2}$ |
| | Solid rectangular beams | 13 | $\frac{1.3F_{cy}}{n_y}$ | $\frac{d}{t}\sqrt{\frac{L_b}{d}} = \frac{B_b - 1.3F_{cy}}{2.3D_b}$ | $\frac{1}{n_y}\left(B_b - 2.3D_b\frac{d}{t}\sqrt{\frac{L_b}{d}}\right)$ | $\frac{d}{t}\sqrt{\frac{L_b}{d}} = \frac{C_b}{2.3}$ | $\frac{\pi^2 E}{3.29 n_y (d/t)^2 (L_b/d)}$ |
| | Rectangular tubes and box sections  | 14 | $\frac{F_{cy}}{n_y}$ | $\frac{L_b S_c}{I_y} = \left(\frac{B_c - F_{cy}}{1.6D_c}\right)^2$ | $\frac{1}{n_y}\left(B_c - 1.6D_c\sqrt{\frac{L_b S_c}{I_y}}\right)$ | $\frac{L_b S_c}{I_y} = \left(\frac{C_c}{1.6}\right)^2$ | $\frac{\pi^2 E}{2.56 n_y (L_b S_c / I_y)}$ |
| COMPRESSION IN COMPONENTS OF BEAMS, (component under uniform compression), gross section | Outstanding flanges  | 15 | $\frac{F_{cy}}{n_y}$ | $\frac{b}{t} = \frac{B_p - F_{cy}}{5.1D_p}$ | $\frac{1}{n_y}\left(B_p - 5.1D_p\frac{b}{t}\right)$ | $\frac{b}{t} = \frac{k_1 B_p}{5.1D_p}$ | $\frac{k_b\sqrt{B_p E}}{n_y (5.1b/t)}$ |
| | Flat plates with both edges supported  | 16 | $\frac{F_{cy}}{n_y}$ | $\frac{b}{t} = \frac{B_p - F_{cy}}{1.6D_p}$ | $\frac{1}{n_y}\left(B_p - 1.6D_p\frac{b}{t}\right)$ | $\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$ | $\frac{k_b\sqrt{B_p E}}{n_y (1.6b/t)}$ |

*(Continued)*





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## TABLE NO. 28-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES—(Continued)

| TYPE OF STRESS | TYPE OF MEMBER OR COMPONENT | SPEC. NO. | ALLOWABLE STRESS, KSI, SLENDERNESS $< S_1$ | SLENDERNESS LIMIT, $S_1$ | ALLOWABLE STRESS, KSI SLENDERNESS BETWEEN $S_1$ AND $S_2$ | SLENDERNESS LIMIT, $S_2$ | ALLOWABLE STRESS, KSI SLENDERNESS $> S_2$ |
|---|---|---|---|---|---|---|---|
| COMPRESSION IN COMPONENTS OF BEAMS, (compoaent under bending in own plane), gross section | Flat plates with compressed edge free tension, edge supported | 17 | $\frac{1.3F_{cy}}{n_y}$ | $\frac{b}{t}=\frac{B_b-1.3F_{cy}}{3.5D_b}$ | $\frac{1}{n_y}\left(B_b-3.5D_b\frac{b}{t}\right)$ | $\frac{b}{t}=\frac{C_b}{3.5}$ | $\frac{\pi^2E}{n_w(3.5b/t)^2}$ |
| | Flat plates with both edges supported | 18 | $\frac{1.3F_{cy}}{n_y}$ | $\frac{h}{t}=\frac{B_b-1.3F_{cy}}{0.67D_b}$ | $\frac{1}{n_y}\left(B_b-0.67D_b\frac{h}{t}\right)$ | $\frac{h}{t}=\frac{k_1B_b}{0.67D_b}$ | $\frac{k_2\sqrt{B_bE}}{n_y(0.67h/t)}$ |
| | Flat plates with horizontal stiffener, both edges supported | 19 | $\frac{1.3F_{cy}}{n_y}$ | $\frac{h}{t}=\frac{B_b-1.3F_{cy}}{0.29D_b}$ | $\frac{1}{n_y}\left(B_b-0.29D_b\frac{h}{t}\right)$ | $\frac{h}{t}=\frac{k_1B_b}{0.29D_b}$ | $\frac{k_2\sqrt{B_bE}}{n_y(0.29h/t)}$ |
| SHEAR IN WEBS, gross section | Unstiffened flat webs | 20 | $\frac{F_{sy}}{n_y}$ | $\frac{h}{t}=\frac{B_s-F_{sy}}{1.25D_s}$ | $\frac{1}{n_y}\left(B_s-1.25D_s\frac{h}{t}\right)$ | $\frac{h}{t}=\frac{C_s}{1.25}$ | $\frac{\pi^2E}{n_y(1.25h/t)^2}$ |
| | Stiffened flat webs $a_0=a_1\Big/\sqrt{1+0.7(a_1/a_2)^2}$ | 21 | $\frac{F_{sy}}{n_y}$ | $\frac{a_0}{t}=\frac{B_s-\frac{n_yF_{sy}}{n_y}}{1.25D_s}$ | $\frac{1}{n_y}\left(B_s-1.25D_s\frac{a_0}{t}\right)$ | $\frac{a_0}{t}=\frac{C_s}{1.25}$ | $\frac{\pi^2E}{n_y(1.25a_0/t)^2}$ |

[1]For $F_b/t$ values greater than $S_2$, the allowable bending shall be determined from the formula for tubes in compression, Specification 10, using the formula that is appropriate for the particular value of $R_b/t$. Note that in this case $R_b/t$ may be either less or greater than the value of $S_2$ for tubes in compression.



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## TABLE NO. 28-D—FACTORS OF SAFETY FOR USE WITH ALUMINUM ALLOWABLE STRESS SPECIFICATIONS

| | Building And Similar Type Structures |
|---|---|
| 1. *Tension Members* | |
| F.S. on tensile strength, $n_u$ | 1.95 |
| F.S. on yield strength, $n_y$ | 1.65 |
| 2. *Columns* | |
| F.S. on buckling strength, $n_u$ | 1.95 |
| F.S. on crippling strength of thin sections, $n_u$ | 1.95 |
| F.S. on yield strength for short columns, $n_y$ | 1.65 |
| 3. *Beams* | |
| F.S. on tensile strength, $n_u$ | 1.95 |
| F.S. on tensile yield strength, $n_y$ | 1.65 |
| F.S. on compressive yield strength for short beams, $n_y$ | 1.65 |
| F.S. on buckling strength, $n_y$ | 1.65 |
| F.S. on crippling strength of thin sections, $n_y$ | 1.65 |
| F.S. on shear buckling of webs, $n_a$ | 1.20 |
| 4. *Connections* | |
| F.S. on bearing strength | 1.2 x 1.95 = 2.34 |
| F.S. on bearing yield strength, $n_y$ | 1.65 |
| F.S. on shear strength of rivets and bolts | 1.2 x 1.95 = 2.34 |
| F.S. on shear strength of fillet welds | 1.2 x 1.95 = 2.34 |
| F.S. on tensile strength of butt welds, $n_u$ | 1.95 |
| F.S. on tensile yield strength of butt welds, $n_y$ | 1.65 |

## TABLE NO. 28-E—FORMULAS FOR BUCKLING CONSTANTS
### For All Products Whose Temper Designation Begins with -O, -H, -T1, -T2, -T3 or -T4

| TYPE OF MEMBER AND STRESS | INTERCEPT, KSI | SLOPE, KSI | INTERSECTION |
|---|---|---|---|
| 1. Compression in Columns and Beam Flanges | $B_c = F_{cy}\left[1+\left(\frac{F_{cy}}{1000}\right)^{1/2}\right]$ | $D_c = \frac{B_c}{20}\left(\frac{6B_c}{E}\right)^{1/2}$ | $C_c = \frac{2B_c}{3D_c}$ |
| 2. Compression in Flat Plates | $B_p = F_{cy}\left[1+\frac{(F_{cy})}{7.6}^{1/3}\right]$ | $D_p = \frac{B_p}{20}\left(\frac{6B_p}{E}\right)^{1/2}$ | $C_p = \frac{2B_p}{3D_p}$ |
| 3. Compression in Round Tubes Under Axial End Load | $B_t = F_{cy}\left[1+\frac{(F_{cy})}{5.8}^{1/5}\right]$ | $D_t = \frac{B_t}{3.7}\left(\frac{B_t}{E}\right)^{1/3}$ | $C_t$ * |
| 4. Compressive Bending Stress in Solid Rectangular Bars | $B_b = 1.3F_{cy}\left[1+\frac{(F_{cy})}{7}^{1/3}\right]$ | $D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$ | $C_b = \frac{2B_b}{3D_b}$ |
| 5. Compressive Bending Stress in Round Tubes | $B_{tb} = 1.5F_y\left[1+\frac{(F_y)}{5.8}^{1/5}\right]$ | $D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$ | $C_{tb} = \left(\frac{B'_{tb}-B_t}{D_{tb}-D_t}\right)^2$ |
| 6. Shear Stress in Flat Plates | $B_s = F_{sy}\left[1+\frac{(F_{sy})}{6.2}^{1/3}\right]$ | $D_s = \frac{B_s}{20}\left(\frac{6B_s}{E}\right)^{1/2}$ | $C_s = \frac{2B_s}{3D_s}$ |
| 7. Crippling of Flat Plates in Compression or Bending | $k_1 = 0.50$ | $k_2 = 2.04$ | |

*$C_t$ can be found from a plot of the curves of allowable stress based on elastic and inelastic buckling or by a trial-and-error solution.



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## TABLE NO. 28-F
## VALUES OF COEFFICIENTS $k_t$ and $k_c$

| ALLOY AND TEMPER | NONWELDED OR REGIONS FARTHER THAN 1.0 INCH FROM A WELD | | REGIONS WITHIN 1.0 INCH OF A WELD | |
|---|---|---|---|---|
| | $k_t$ | $k_c$ | $k_t$ | $k_c$[1] |
| 2014-T6, -T651 | 1.25 | 1.12 | — | — |
| Alclad 2014-T6, -T651 | 1.25 | 1.12 | — | — |
| 6061-T6, -T651 | 1.0 | 1.12 | 1.0 | 1.0 |
| 6063-T5, -T6, -T83 | 1.0 | 1.12 | 1.0 | 1.0 |
| All Others Listed in U.B.C. Standard No. 28-1 | 1.0 | 1.10 | 1.0 | 1.0 |

[1]If the weld yield strength exceeds 0.9 of the parent metal yield strength, the allowable compressive stress within 1.0 inch of a weld should be taken equal to the allowable stress for nonwelded material.

## TABLE NO. 28-G—FORMULAS FOR BUCKLING CONSTANTS
## For All Products Whose Temper Designation Begins with -T5, -T6, -T7, -T8 or -T9

| TYPE OF MEMBER AND STRESS | INTERCEPT, KSI | SLOPE, KSI | INTERSECTION |
|---|---|---|---|
| 1. Compression in Columns and Beam Flanges | $B_c = F_{cy}\left[1+\left(\frac{F_{cy}}{2250}\right)^{1/2}\right]$ | $D_c = \frac{B_c}{10}\left(\frac{B_c}{E}\right)^{1/2}$ | $C_c = 0.4\frac{B_c}{D_c}$ |
| 2. Compression in Flat Plates | $B_p = F_{cy}\left[1+\frac{(F_{cy})}{11.4}^{1/3}\right]$ | $D_p = \frac{B_p}{10}\left(\frac{B_p}{E}\right)^{1/2}$ | $C_p = 0.4\frac{B_p}{D_p}$ |
| 3. Compression in Round Tubes Under Axial End Load | $B_t = F_{cy}\left[1+\frac{(F_{cy})}{8.7}^{1/5}\right]$ | $D_t = \frac{B_t}{4.5}\left(\frac{B_t}{E}\right)^{1/3}$ | $C_t$ * |
| 4. Compressive Bending Stress in Solid Rectangular Bars | $B_b = 1.3F_{cy}\left[1+\frac{(F_{cy})}{7}^{1/3}\right]$ | $D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$ | $C_b = \frac{2B_b}{3D_b}$ |
| 5. Compressive Bending Stress in Round Tubes | $B_{tb} = 1.5F_y\left[1+\frac{(F_y)}{8.7}^{1/5}\right]$ | $D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$ | $C_{tb} = \left(\frac{B_{tb}-B_t}{D_{tb}-D_t}\right)^2$ |
| 6. Shear Stress in Flat Plates | $B_s = F_{sy}\left[1+\frac{(F_{sy})}{9.3}^{1/3}\right]$ | $D_s = \frac{B_s}{10}\left(\frac{B_s}{E}\right)^{1/2}$ | $C_s = 0.4\frac{B_s}{D_s}$ |
| 7. Crippling of Flat Plates in Compression | $k_1 = 0.35$ | $k_2 = 2.27$ | |
| 8. Crippling of Flat Plates in Bending | $k_1 = 0.50$ | $k_2 = 2.04$ | |

*$C_t$ can be found from a plot of the curves of allowable stress based on elastic and inelastic buckling or by a trial-and-error solution.



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# Part VI

# DETAILED REGULATIONS

## Chapter 29

## EXCAVATIONS, FOUNDATIONS AND RETAINING WALLS

### Scope

**Sec. 2901.** This chapter sets forth requirements for excavation and fills for any building or structure and for foundations and retaining structures.

Reference is made to Appendix Chapter 70 for requirements governing excavation, grading and earthwork construction, including fills and embankments.

### Quality and Design

**Sec. 2902.** The quality and design of materials used structurally in excavations, footings and foundations shall conform to the requirements specified in Chapters 23, 24, 25, 26 and 27 of this code.

### Excavations and Fills

**Sec. 2903.** (a) **General.** Excavation or fills for buildings or structures shall be so constructed or protected that they do not endanger life or property.

Slopes for permanent fills shall be not steeper than 2 horizontal to 1 vertical. Cut slopes for permanent excavations shall be not steeper than 2 horizontal to 1 vertical unless substantiating data justifying steeper cut slopes are submitted. Deviation from the foregoing limitations for cut slopes shall be permitted only upon the presentation of a soil investigation report acceptable to the building official.

No fill or other surcharge loads shall be placed adjacent to any building or strueture unless such building or structure is capable of withstanding the additional loads caused by the fill or surcharge.

Existing footings or foundations which may be affected by any excavation shall be underpinned adequately or otherwise protected against settlement and shall be protected against lateral movement.

Fills to be used to support the foundations of any building or structure shall be placed in accordance with accepted engineering practice. A soil investigation report and a report of satisfactory placement of fill, both acceptable to the building official, shall be submitted.

(b) **Protection of Adjoining Property.** The requirements for protection of adjacent property and depth to which protection is required shall be as defined by prevailing law. Where not defined by law, the following shall apply: Any person making or causing an excavation to be made to a depth of 12 feet or less below the grade shall protect the excavation so that the soil of adjoining property will not cave in or settle, but shall not be liable for the expense of underpinning or extending the foundation of buildings on adjoining properties where his excavation is not in excess of 12 feet in depth. Before commencing the excavation, the



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person making or causing the excavation to be made shall notify in writing the owners of adjoining buildings not less than 10 days before such excavation is to be made that the excavation is to be made and that the adjoining buildings should be protected.

The owners of the adjoining properties shall be given access to the excavation for the purpose of protecting such adjoining buildings.

Any person making or causing an excavation to be made exceeding 12 feet in depth below the grade shall protect the excavation so that the adjoining soil will not cave in or settle and shall extend the foundation of any adjoining buildings below the depth of 12 feet below grade at his own expense. The owner of the adjoining buildings shall extend the foundation of these buildings to a depth of 12 feet below grade at his own expense, as provided in the preceding paragraph.

## Soil Classification—Expansive Soil

**Sec. 2904.** (a) **Soil Classification: General.** For the purposes of this chapter, the definition and classification of soil materials for use in Table No. 29-B shall be according to U.B.C. Standard No. 29-1.

(b) **Expansive Soil.** When the expansive characteristics of a soil are to be determined, the procedures shall be in accordance with U.B.C. Standard No. 29-2 and the soil shall be classified according to Table No. 29-C. Foundations for structures resting on soils with an expansion index greater than 20, as determined by U.B.C. Standard No. 29-2, shall require special design consideration. In the event the soil expansion index varies with depth, the weighted index shall be determined according to Table No. 29-D.

## Foundation Investigation

**Sec. 2905.** (a) **General.** The classification of the soil at each building site shall be determined when required by the building official. The building official may require that this determination be made by an engineer or architect licensed by the state to practice as such.

(b) **Investigation.** The classification shall be based on observation and any necessary tests of the materials disclosed by borings or excavations made in appropriate locations. Additional studies may be necessary to evaluate soil strength, the effect of moisture variation on soil-bearing capacity, compressibility and expansiveness.

(c) **Reports.** The soil classification and design bearing capacity shall be shown on the plans, unless the foundation conforms to Table No. 29-A. The building official may require submission of a written report of the investigation which shall include, but need not be limited to, the following information:

1. A plot showing the location of all test borings and/or excavations.
2. Descriptions and classifications of the materials encountered.
3. Elevation of the water table, if encountered.
4. Recommendations for foundation type and design criteria including bearing capacity, provisions to minimize the effects of expansive soils and the effects of adjacent loads.
5. Expected total and differential settlement.



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(d) **Expansive Soils.** When expansive soils are present, the building official may require that special provisions be made in the foundation design and construction to safeguard against damage due to this expansiveness. He may require a special investigation and report to provide this design and construction criteria.

(e) **Adjacent Loads.** Where footings are placed at varying elevations the effect of adjacent loads shall be included in the foundation design.

(f) **Drainage.** Provisions shall be made for the control and drainage of surface water around buildings. [See also Section 2907 (d) 5.]

## Allowable Foundation and Lateral Pressures

**Sec. 2906.** The allowable foundation and lateral pressures shall not exceed the values set forth in Table No. 29-B unless data to substantiate the use of higher values are submitted. Table No. 29-B may be used for design of foundations on rock or nonexpansive soil for Types II One-hour, II-N and V buildings which do not exceed three stories in height or for structures which have continuous footings having a load of less than 2000 pounds per lineal foot and isolated footings with loads of less than 50,000 pounds.

## Footings

**Sec. 2907.** (a) **General.** Footings and foundations, unless otherwise specifically provided, shall be constructed of masonry, concrete or treated wood in conformance with U.B.C. Standard No. 29-3 and in all cases shall extend below the frost line. Footings of concrete and masonry shall be of solid material. Foundations supporting wood shall extend at least 6 inches above the adjacent finish grade. Footings shall have a minimum depth as indicated in Table No. 29-A unless another depth is recommended by a foundation investigation.

(b) **Bearing Walls.** Bearing walls shall be supported on masonry or concrete foundations or piles or other approved foundation system which shall be of sufficient size to support all loads. Where a design is not provided, the minimum foundation requirements for stud bearing walls shall be as set forth in Table No. 29-A.

**EXCEPTIONS:** 1. A one-story wood or metal frame building not used for human occupancy and not over 400 square feet in floor area may be constructed with walls supported on a wood foundation plate when approved by the building official.

2. The support of buildings by posts embedded in earth shall be designed as specified in Section 2907 (g). Wood posts or poles embedded in earth shall be pressure treated with an approved preservative. Steel posts or poles shall be protected as specified in Section 2908 (i).

(c) **Stepped Foundations.** Foundations for all buildings where the surface of the ground slopes more than 1 foot in 10 feet shall be level or shall be stepped so that both top and bottom of such foundation are level.

(d) **Footings on or Adjacent to Slopes.** 1. **Scope.** The placement of buildings and structures on or adjacent to slopes steeper than 3 horizontal to 1 vertical shall be in accordance with this section.

2. **Building clearance from ascending slopes.** In general, buildings below slopes shall be set a sufficient distance from the slope to provide protection from



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slope drainage, erosion and shallow failures. Except as provided for in Subsection 6 of this section and Figure No. 29-1, the following criteria will be assumed to provide this protection. Where the existing slope is steeper than 1 horizontal to 1 vertical, the toe of the slope shall be assumed to be at the interseetion of a horizontal plane drawn from the top of the foundation and a plane drawn tangent to the slope at an angle of 45 degrees to the horizontal. Where a retaining wall is constructed at the toe of the slope, the height of the slope shall be measured from the top of the wall to the top of the slope.

3. **Footing setback from descending slope surface.** Footing on or adjacent to slope surfaces shall be founded in firm material with an embedment and setback from the slope surface sufficient to provide vertical and lateral support for the footing without detrimental settlement. Except as provided for in Subsection 6 of this section and Figure No. 29-1, the following setback is deemed adequate to meet the criteria. Where the slope is steeper than 1 horizontal to 1 vertical, the required setback shall be measured from an imaginary plane 45 degrees to the horizontal, projected upward from the toe of the slope.

4. **Pools.** The setback between pools regulated by this code and slopes shall be equal to one half the building footing setback distance required by this section. That portion of the pool wall within a horizontal distance of 7 feet from the top of the slope shall be capable of supporting the water in the pool without soil support.

5. **Foundation elevation.** On graded sites, the top of any exterior foundation shall extend above the elevation of the street gutter at point of discharge or the inlet of an approved drainage device a minimum of 12 inches plus 2 percent. The building official may approve alternate elevations, provided it can be demonstrated that required drainage to the point of discharge and away from the structure is provided at all locations on the site.

6. **Alternate setback and clearance.** The building official may approve alternate setbacks and clearances. The building official may require an investigation and recommendation of a qualified engineer to demonstrate that the intent of this section has been satisfied. Such an investigation shall include consideration of material, height of slope, slope gradient, load intensity and erosion characteristics of slope material.

(e) **Footing Design.** Except for special provisions of Section 2909 covering the design of piles, all portions of footings shall be designed in accordance with the structural provisions of this code and shall be designed to minimize differential settlement and the effects of expansive soils when present.

Slab-on-grade and mat-type footings for buildings located on expansive soils may be designed in accordance with the provisions of U.B.C. Standard No. 29-4 or such other engineering design based upon geotechnical recommendation as approved by the building official.

(f) **Foundation Plates or Sills.** Foundation plates or sills shall be bolted to the foundation or foundation wall with not less than 1/2-inch nominal diameter steel bolts embedded at least 7 inches into the concrete or masonry and spaced not more than 6 feet apart. There shall be a minimum of two bolts per piece with one bolt located within 12 inches of each end of each piece. A properly sized nut and



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washer shall be tightened on each bolt to the plate. Foundation plates and sills shall be the kind of wood specified in Section 2516 (c).

(g) **Designs Employing Lateral Bearing.** 1. **General.** Construction employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth may be used to resist both axial and lateral loads. The depth to resist lateral loads shall be determined by means of the design criteria established herein or other methods approved by the building official.

2. **Design criteria:** A. **Nonconstrained.** The following formula may be used in determining the depth of embedment required to resist lateral loads where no constraint is provided at the ground surface, such as rigid floor or rigid ground surface pavement.

$$d = \frac{A}{2}\left(1 + \sqrt{1 + \frac{4.36h}{A}}\right)$$

**WHERE:**

$A = \dfrac{2.34P}{S_1 b}$

$P$ = Applied lateral force in pounds.

$S_1$ = Allowable lateral soil-bearing pressure as set forth in Table No. 29-B based on a depth of one third the depth of embedment.

$S_3$ = Allowable lateral soil-bearing pressure as set forth in Table No. 29-B based on a depth equal to the depth of embedment.

$b$ = Diameter of round post or footing or diagonal dimension of square post or footing (feet).

$h$ = Distance in feet from ground surface to point of application of "$P$."

$d$ = Depth of embedment in earth in feet but not over 12 feet for purpose of computing lateral pressure.

B. **Constrained.** The following formula may be used to determine the depth of embedment required to resist lateral loads where constraint is provided at the ground surface, such as a rigid floor or pavement.

$$d^2 = 4.25\frac{Ph}{S_3 b}$$

C. **Vertical load.** The resistance to vertical loads is determined by the allowable soil-bearing pressure set forth in Table No. 29-B.

3. **Backfill.** The backfill in the annular space around columns not embedded in poured footings shall be by one of the following methods:

A. Backfill shall be of concrete with an ultimate strength of 2000 pounds per square inch at 28 days. The hole shall be not less than 4 inches larger than the diameter of the column at its bottom or 4 inches larger than the diagonal dimension of a square or rectangular column.

B. Backfill shall be of clean sand. The sand shall be thoroughly compacted by tamping in layers not more than 8 inches in depth.



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4. **Limitations.** The design procedure outlined in this subsection shall be subject to the following limitations:

The frictional resistance for retaining walls and slabs on silts and clays shall be limited to one half of the normal force imposed on the soil by the weight of the footing or slab.

Posts embedded in earth shall not be used to provide lateral support for structural or nonstructural materials such as plaster, masonry or concrete unless bracing is provided that develops the limited deflection required.

(h) **Grillage Footings.** When grillage footings of structural steel shapes are used on soils, they shall be completely embedded in concrete with at least 6 inches on the bottom and at least 4 inches at all other points.

(i) **Bleacher Footings.** Footings for open-air seating facilities shall comply with Chapter 29.

**EXCEPTIONS:** Temporary open-air portable bleachers as defined in Sections 3323 and 3324 may be supported upon wood sills or steel plates placed directly upon the ground surface, provided soil pressure does not exceed 1200 pounds per square foot.

## Piles—General Requirements

**Sec. 2908.** (a) **General.** Pile foundations shall be designed and installed on the basis of a foundation investigation as defined in Section 2905 where required by the building official.

The investigation and report provisions of Section 2905 shall be expanded to include but not be limited to the following:

1. Recommended pile types and installed capacities.
2. Driving criteria.
3. Installation and field inspection procedures.
4. Pile load test requirements.

The use of piles not specifically mentioned in this chapter shall be permitted, subject to the approval of the building official upon submission of acceptable test data, calculations or other information relating to the properties and load-carrying capacities of such piles.

(b) **Interconnection.** Individual pile caps and caissons of every structure subjected to seismic forces shall be interconnected by ties. Such ties shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10 percent of the larger column vertical load.

**EXCEPTION:** Other approved methods may be used where it can be demonstrated that equivalent restraint can be provided.

(c) **Determination of Allowable Loads.** The allowable axial and lateral loads on piles shall be determined by an approved formula, by load tests or by a foundation investigation.

(d) **Static Load Tests.** When the allowable axial load of a single pile is determined by a load test, one of the following methods shall be used:

**Method 1.** It shall not exceed 50 percent of the yield point under test load. The



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yield point shall be defined as that point at which an increase in load produces a disproportionate increase in settlement.

**Method 2.** It shall not exceed one half of the load which causes a net settlement, after deducting rebound, of .01 inch per ton of test load which has been applied for a period of at least 24 hours.

**Method 3.** It shall not exceed one half of that load under which, during a 40-hour period of continuous load application, no additional settlement takes place.

(e) **Column Action.** All piles standing unbraced in air, water or material not capable of lateral support, shall conform with the applicable column formula as specified in this code. Such piles driven into firm ground may be considered fixed and laterally supported at 5 feet below the ground surface and in soft material at 10 feet below the ground surface unless otherwise prescribed by the building official after a foundation investigation by an approved agency.

(f) **Group Action.** Consideration shall be given to the reduction of allowable pile load when piles are placed in groups. Where soil conditions make such load reductions advisable or necessary, the allowable axial load determined for a single pile shall be reduced by any rational method or formula approved by the building official.

(g) **Piles in Subsiding Areas.** Where piles are driven through subsiding fills or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces which may be imposed on the piles by the subsiding upper strata.

Where the influence of subsiding fills is considered as imposing loads on the pile, the allowable stresses specified in this chapter may be increased if satisfactory substantiating data are submitted.

(h) **Jetting.** Jetting shall not be used except where and as specifically permitted by the building official. When used, jetting shall be carried out in such a manner that the carrying capacity of existing piles and structures shall not be impaired. After withdrawal of the jet, piles shall be driven down until the required resistance is obtained.

(i) **Protection of Pile Materials.** Where the boring records of site conditions indicate possible deleterious action on pile materials because of soil constituents, changing water levels or other factors, such materials shall be adequately protected by methods or processes approved by the building official. The effectiveness of such methods or processes for the particular purpose shall have been thoroughly established by satisfactory service records or other evidence which demonstrates the effectiveness of such protective measures.

(j) **Allowable Loads.** The allowable loads based upon soil conditions shall be established in accordance with Section 2908.

**EXCEPTION:** Any uncased cast-in-place pile may be assumed to develop a frictional resistance equal to one sixth of the bearing value of the soil material at minimum depth as set forth in Table No. 29-B but not to exceed 500 pounds per square foot unless a greater value is allowed by the building official after a soil investigation as specified in Section 2905, is submitted. Frictional resistance and



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bearing resistance shall not be assumed to act simultaneously unless recommended after a foundation investigation as specified in Section 2905.

(k) **Use of Higher Allowable Pile Stresses.** Allowable compressive stresses greater than those specified in Section 2909 shall be permitted when substantiating data justifying such higher stresses are submitted to and approved by the building official. Such substantiating data shall include a foundation investigation including a report in accordance with Section 2908 (a) by a soil engineer defined as a civil engineer experienced and knowledgeable in the practice of soil engineering.

## Specific Pile Requirements

**Sec. 2909.** (a) **Round Wood Piles.** 1. **Material.** Except where untreated piles are permitted, wood piles shall be pressure treated in accordance with U.B.C. Standard No. 25-12. Untreated piles may be used only when it has been established that the cutoff will be below lowest groundwater level assumed to exist during the life of the structure. Every wood pile shall conform to U.B.C. Standard No. 25-14.

2. **Allowable stresses.** The allowable unit stresses for round wood piles shall not exceed those set forth in Table No. 25-E.

The allowable values listed in Table No. 25-E for compression parallel to the grain at extreme fiber in bending are based on load sharing as occurs in a pile cluster. For piles which support their own specific load, a safety factor of 1.25 shall be applied to compression parallel to the grain values and 1.30 to extreme fiber in bending values.

(b) **Uncased Cast-in-place Concrete Piles.** 1. **Material.** Concrete piles cast in place against earth in drilled or bored holes shall be made in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized shaft. The length of such pile shall be limited to not more than 30 times the average diameter. Concrete shall have an ultimate compressive strength $f'_c$ of not less than 2500 pounds per square inch.

2. **Allowable stresses.** The allowable compressive stress in the concrete shall not exceed $0.33f'_c$. The allowable compressive stress of reinforcement shall not exceed 34 percent of the yield strength of the steel nor 25,500 psi.

(c) **Metal-cased Concrete Piles.** 1. **Material.** All concrete used in metal-cased concrete piles shall have an ultimate compressive strength $f'_c$ of not less than 2500 pounds per square inch.

2. **Installation.** Every metal casing for a concrete pile shall have a sealed tip with a diameter of not less than 8 inches.

Concrete piles cast in place in metal shells shall have shells driven for their full length in contact with the surrounding soil and left permanently in place. The shells shall be sufficiently strong to resist collapse and sufficiently watertight to exclude water and foreign material during the placing of concrete.

Piles shall be driven in such order and with such spacing as to ensure against distortion of or injury to piles already in place. No pile shall be driven within four



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and one-half average pile diameters of a pile filled with concrete less than 24 hours old unless approved by the building official.

3. **Allowable stresses.** Allowable stresses shall not exceed the values specified in Section 2909 (b) 2, except that the allowable concrete stress may be increased to a maximum value of $0.40f'_c$ for that portion of the pile meeting the following conditions:

1. The thickness of the metal casing is not less than No. 14 gauge.
2. The casing is seamless or is provided with seams of equal strength and is of a configuration which will provide confinement to the cast-in-place concrete.
3. The design $f'_c$ shall not exceed 5000 pounds per square inch and the ratio of metal yield strength shall be not less than 6.
4. The pile diameter is not greater than 16 inches.

(d) **Precast Concrete Piles.** 1. **Material.** Precast concrete piles prior to driving and at 28 days after pouring shall develop an ultimate compressive strength $f'_c$ of at least 3000 pounds per square inch.

2. **Reinforcement ties.** The longitudinal reinforcement in driven precast concrete piles shall be laterally tied with steel ties or wire spirals. Ties and spirals shall be spaced not more than 3 inches apart, center to center, for a distance of 2 feet from the ends and not more than 8 inches elsewhere. The gauge of ties and spirals shall be as follows:

For piles having a diameter of 16 inches or less, wire shall be not smaller than No. 5 gauge.

For piles having a diameter of more than 16 inches and less than 20 inches, wire shall be not smaller than No. 4 gauge.

For piles having a diameter of 20 inches and larger, wire shall be not smaller than 1/4 inch round or No. 3 gauge.

3. **Allowable stresses.** Precast concrete piling shall be designed to resist stresses induced by handling and driving as well as by loads. The allowable stresses shall not exceed the values specified in Section 2909 (b) 2.

(e) **Precast Prestressed Concrete Piles (Pretensioned).** 1. **Material.** Precast prestressed concrete piles shall develop a compressive strength of not less than 4000 pounds per square inch before driving and an ultimate compressive strength $f'_c$ at 28 days after pouring of not less than 5000 pounds per square inch.

2. **Reinforcement.** The longitudinal reinforcement shall be high-tensile seven-wire strand conforming to U.B.C. Standard No. 26-7. Longitudinal reinforcement shall be laterally tied with steel ties or wire spirals.

Ties or spiral reinforcement shall be spaced not more than 3 inches apart center to center for a distance of 2 feet from the ends and not more than 8 inches elsewhere.

At each end of the pile, the first five ties or spirals shall be spaced 1 inch center to center.

For piles having a diameter of 24 inches or less, wire shall be not smaller than No. 5 gauge. For piles having a diameter greater than 24 inches but less than 36



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inches; wire shall be not smaller than No. 4 gauge. For piles having a diameter greater than 36 inches, wire shall be not smaller than 1/4 inch round or No. 3 gauge.

3. **Allowable stresses.** Precast prestressed piling shall be designed to resist stresses induced by handling and driving as well as by loads. The effective prestress in the pile shall be not less than 400 pounds per square inch for piles up to 30 feet in length, 550 pounds per square inch for piles up to 50 feet in length, and 700 pounds per square inch for piles greater than 50 feet in length.

The compressive stress in the concrete due to externally applied load shall not exceed:

$$f_c = 0.33f'_c - 0.27fp_c$$

**WHERE:**

$fp_c$ is the effective prestress stress on the gross section.

Effective prestress shall be based on an assumed loss of 30,000 pounds per square inch in the prestressing steel. The allowable stress in the prestressing steel shall not exceed the values specified in Section 2618.

(f) **Structural Steel Piles.** 1. **Material.** Structural steel piles, steel pipe piles and fully welded steel piles fabricated from plates shall conform to U.B.C. Standard No. 27-1 and be identified in accordance with Section 2701 (b).

2. **Allowable stresses.** The allowable stresses shall not exceed 0.35 of the minimum specified yield strength $F_y$, provided such yield strength shall not be assumed greater than 36,000 pounds per square inch for computational purposes.

**EXCEPTION:** When justified in accordance with Section 2908 (k), the allowable stresses may be increased to $0.50F_y$.

Combined stresses shall not exceed those in Chapter 27.

3. **Minimum dimensions.** Sections of driven H-piles shall comply with the following:

A. The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and the flange widths shall be not less than 80 percent of the depth of the section.

B. The nominal depth in the direction of the web shall be not less than 8 inches.

C. Flanges and webs shall have a minimum nominal thickness of 3/8 inch.

Sections of driven pipe piles shall have an outside diameter of not less than 10 inches and a minimum thickness of not less than 1/4 inch.

(g) **Concrete-filled Steel Pipe Piles.** 1. **Material.** Steel pipe piles shall conform to U.B.C. Standard No. 27-1 and shall be identified in accordance with Section 2701 (b). The concrete-filled steel pipe piles shall have an ultimate compressive strength $f'_c$ of not less than 2500 pounds per square inch.

2. **Allowable stresses.** The allowable stresses shall not exceed 0.35 of the minimum specified yield strength $F_y$ on the steel plus 0.33 of the ultimate compressive strength $f'_c$ of the concrete, provided $F_y$ shall not be assumed greater than 36,000 pounds per square inch for computational purposes.



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**EXCEPTION:** When justified in accordance with Section 2908 (k), the allowable stresses may be increased to $0.50F_y$.

Combined stresses shall not exceed those in Chapter 27.

3. **Minimum dimensions.** Driven piles of uniform section shall have a nominal outside diameter of not less than 8 inches.

## Foundation Construction—Seismic Zones Nos. 3 and 4

**Sec. 2910.** (a) **General.** In Seismic Zones Nos. 3 and 4 the further requirements of this section shall apply to the design and construction of foundations, foundation components and the connection of superstructure elements thereto.

(b) **Soil Capacity.** The one-third stress increase allowed by Section 2303 (d) may be exceeded for soils for combinations including earthquake when substantiated by geotechnical data. The foundation shall be capable of transmitting the design base shear and overturning forces prescribed in Section 2312 (e) from the structure into the supporting soil. The short-term dynamic nature of the loads may be taken into account in establishing the soil properties.

(c) **Superstructure-to-foundation Connection.** The connection of superstructure elements to the foundation shall be adequate to transmit to the foundation the forces for which the elements were required to be designed.

(d) **Foundation-soil Interface.** For regular buildings, the force $F_t$ may be omitted when determining the overturning moment to be resisted at the foundation-soil interface.

(e) **Special Requirements for Piles and Caissons.** Piles and caissons shall be designed for flexure whenever the tops of such members will be displaced by earthquake motions. The criteria and detailing requirements of Section 2625 (e) for concrete and Section 2722 (d) for steel shall apply for a length of such members equal to 120 percent of the flexural length.

**TABLE NO. 29-A—FOUNDATIONS FOR STUD BEARING WALLS—MINIMUM REQUIREMENTS[1] [2]**

| NUMBER OF FLOORS SUPPORTED BY THE FOUNDATION[3] | THICKNESS OF FOUNDATION WALL (Inches) | | WIDTH OF FOOTING (Inches) | THICKNESS OF FOOTING (Inches) | DEPTH BELOW UNDISTURBED GROUND SURFACE (Inches) |
|---|---|---|---|---|---|
| | CONCRETE | UNIT MASONRY | | | |
| 1 | 6 | 6 | 12 | 6 | 12 |
| 2 | 8 | 8 | 15 | 7 | 18 |
| 3 | 10 | 10 | 18 | 8 | 24 |

[1]Where unusual conditions or frost conditions are found, footings and foundations shall be as required in Section 2907 (a).

[2]The ground under the floor may be excavated to the elevation of the top of the footing.

[3]Foundations may support a roof in addition to the stipulated number of floors. Foundations supporting roofs only shall be as required for supporting one floor.



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## TABLE NO. 29-B—ALLOWABLE FOUNDATION AND LATERAL PRESSURE

| CLASS OF MATERIALS[2] | ALLOWABLE FOUNDATION PRESSURE LBS./SQ. FT.[3] | LATERAL BEARING LBS./SQ./FT./FT. OF DEPTH BELOW NATURAL GRADE[4] | LATERAL SLIDING[1] | |
|---|---|---|---|---|
| | | | COEFFICIENT[5] | RESISTANCE LBS./SQ. FT.[6] |
| 1. Massive Crystalline Bedrock | 4000 | 1200 | .70 | |
| 2. Sedimentary and Foliated Rock | 2000 | 400 | .35 | |
| 3. Sandy Gravel and/or Gravel (GW and GP) | 2000 | 200 | .35 | |
| 4. Sand, Silty Sand, Clayey Sand, Silty Gravel and Clayey Gravel (SW, SP, SM, SC, GM and GC) | 1500 | 150 | .25 | |
| 5. Clay, Sandy Clay, Silty Clay and Clayey Silt (CL, ML, MH and CH) | 1000[7] | 100 | | 130 |

[1]Lateral bearing and lateral sliding resistance may be combined.

[2]For soil classifications OL, OH and PT (i.e., organic clays and peat), a foundation investigation shall be required.

[3]All values of allowable foundation pressure are for footings having a minimum width of 12 inches and a minimum depth of 12 inches into natural grade. Except as in Footnote 7 below, increase of 20 percent allowed for each additional foot of width and/or depth to a maximum value of three times the designated value.

[4]May be increased the amount of the designated value for each additional foot of depth to a maximum of 15 times the designated value. Isolated poles for uses such as flagpoles or signs and poles used to support buildings which are not adversely affected by a 1/2-inch motion at ground surface due to short-term lateral loads may be designed using lateral bearing values equal to two times the tabulated values.

[5]Coefficient to be multiplied by the dead load.

[6]Lateral sliding resistance value to be multiplied by the contact area. In no case shall the lateral sliding resistance exceed one half the dead load.

[7]No increase for width is allowed.



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# Chapter 30

# VENEER

## Scope

**Sec. 3001.** (a) **General.** All veneer and its application shall conform to the requirements of this code. Wainscots not exceeding 4 feet in height measured above the adjacent ground elevation for exterior veneer or the finish floor elevation for interior veneer may be exempted from the provisions of this chapter if approved by the building official.

(b) **Limitations.** Exterior veneer shall not be attached to wood-frame construction at a point more than 30 feet in height above the noncombustible foundation, except the 30-foot limit may be increased when special construction is designed to provide for differential movement and when approved by the building official.

## Definitions

**Sec. 3002.** For the purpose of this chapter, certain terms are defined as follows:

**BACKING** as used in this chapter is the surface or assembly to which veneer is attached.

**VENEER** is nonstructural facing of brick, concrete, stone, tile, metal, plastic or other similar approved material attached to a backing for the purpose of ornamentation, protection or insulation.

**Adhered Veneer** is veneer secured and supported through adhesion to an approved bonding material applied over an approved backing.

**Anchored Veneer** is veneer secured to and supported by approved mechanical fasteners attached to an approved backing.

**Exterior Veneer** is veneer applied to weather-exposed surfaces as defined in Section 424.

**Interior Veneer** is veneer applied to surfaces other than weather-exposed surfaces as defined in Section 424.

## Materials

**Sec. 3003.** Materials used in the application of veneer shall conform to the applicable requirements for such materials as set forth elsewhere in this code.

For masonry units and mortar, see Chapter 24.

For precast concrete units, see Chapter 26.

For portland cement plaster, see Chapter 47.

Anchors, supports and ties shall be noncombustible and corrosion resistant.

When the terms "corrosion resistant" or "noncorrosive" are used in this chapter they shall mean having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot of surface area. When an element is required to be corrosion resistant or noncorrosive, all of its parts such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments shall be corrosion resistant.



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## Design

**Sec. 3004.** (a) **General.** The design of all veneer shall eomply with the requirements of Chapter 23 and this section.

Veneer shall support no load other than its own weight and the vertical dead load of veneer above.

Surfaces to which veneer is attached shall be designed to support the additional vertical and lateral loads imposed by the veneer.

Consideration shall be given for differential movement of supports, including that caused by temperature changes, shrinkage, creep and deflection.

(b) **Adhered Veneer.** With the exception of ceramic tile, adhered veneer and its backing shall be designed to have a bond to the supporting element sufficient to withstand a shearing stress of 50 pounds per square inch.

(c) **Anchored Veneer.** Anchored veneer and its attachments shall be designed to resist a horizontal force equal to twice the weight of the veneer.

## Adhered Veneer

**Sec. 3005.** (a) **Permitted Backing.** Backing shall be continuous and may be of any material permitted by this code. It shall have surfaces prepared to secure and support the imposed loads of veneer.

Exterior veneer, including its backing, shall provide a weatherproof covering.

For additional backing requirements, see Sections 1707 (a) and 510 (b).

(b) **Area Limitations.** The height and length of veneered areas shall be unlimited except as required to control expansion and contraction and as limited by Section 3001 (b).

(c) **Unit Size Limitations.** Veneer units shall not exceed 36 inches in the greatest dimension nor more than 720 square inches in total area and shall weigh not more than 15 pounds per square foot unless approved by the building official.

> **EXCEPTION:** Veneer units weighing less than 3 pounds per square foot shall not be limited in dimension or area.

(d) **Application.** In lieu of the design required by Sections 3004 (a) and (b) adhered veneer may be applied by one of the following application methods:

1. A paste of neat portland cement shall be brushed on the backing and the back of the veneer unit. Type S mortar then shall be applied to the backing and the veneer unit. Sufficient mortar shall be used to create a slight excess to be forced out the edges of the units. The units shall be tapped into place so as to completely fill the space between the units and the backing. The resulting thickness of mortar in back of the units shall be not less than 1/2 inch nor more than 1 1/4 inch.

2. Units of tile, masonry, stone or terra cotta, not over 1 inch in thickness shall be restricted to 81 square inches in area unless the back side of each unit is ground or box screeded to true up any deviations from plane. These units and glass mosaic units of tile not over 2 inches by 2 inches by 3/8 inch in size may be adhered by means of portland cement. Backing may be of masonry, concrete or portland cement plaster on metal lath. Metal lath shall be fastened to the supports in accordance with the requirements of Chapter 47. Mortar as described in Table No.



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30-A shall be applied to the backing as a setting bed. The setting bed shall be a minimum of 3/8 inch thick and a maximum of 3/4 inch thick. A paste of neat portland cement or half portland cement and half graded sand shall be applied to the back of the exterior veneer units and to the setting bed and the veneer pressed and tapped into place to provide complete coverage between the mortar bed and veneer unit. A portland cement grout shall be used to point the veneer.

(e) **Ceramic Tile.** Portland cement mortars for installing ceramic tile on walls, floors and ceilings shall be as set forth in Table No. 30-A.

## Anchored Veneer

**Sec. 3006.** (a) **Permitted Backing.** Backing may be of any material permitted by this code. Exterior veneer including its backing shall provide a weatherproof covering.

(b) **Height and Support Limitations.** Anchored veneers shall be supported on footings, foundations or other noncombustible support except as provided under Section 2515.

In Seismic Zones Nos. 2, 3 and 4 the weight of all anchored veneers installed on structures more than 30 feet in height above the noncombustible foundation or support shall be supported by noncombustible, corrosion-resistant structural framing. The structural framing shall have horizontal supports spaced not more than 12 feet vertically above the initial 30-foot height. The vertical spacing between horizontal supports may be increased when special design techniques, approved by the building official, are used in the construction.

Noncombustible, noncorrosive lintels and noncombustible supports shall be provided over all openings where the veneer unit is not self spanning. The deflections of all structural lintels and horizontal supports required by this subsection shall not exceed 1/600 of the span under full load of the veneer.

(c) **Area Limitations.** The area and length of anchored veneer walls shall be unlimited, except as required to control expansion and contraction and by Section 3001 (b).

(d) **Application.** In lieu of the design required by Section 3004 (a) and (c), anchored veneer may be applied in accordance with the following:

1. **Masonry and stone units (5 inches maximum in thickness).** Masonry and stone veneer not exceeding 5 inches in thickness may be anchored directly to structural masonry, concrete or studs in one of the following manners:

(i) Anchor ties shall be corrosion resistant, and if made of sheet metal, shall have a minimum size of No. 22 gauge by 1 inch or, if of wire, shall be a minimum of No. 9 gauge. Anchor ties shall be spaced so as to support not more than 2 square feet of wall area but not more than 24 inches on center horizontally. In Seismic Zones No. 3 and No. 4 anchor ties shall be provided to horizontal joint reinforcement wire of No. 9 gauge or equivalent. The joint reinforcement shall be continuous with butt splices between ties permitted.

When applied over stud construction, the studs shall be spaced a maximum of 16 inches on centers and approved paper shall first be applied over the sheathing



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or wires between studs except as otherwise provided in Section 1707, and mortar shall be slushed into the 1-inch space between facing and paper.

As an alternate, an air space of at least 1 inch may be maintained between the backing and the veneer in which case temporary spot bedding may be used away from the ties to align the veneer. Spot bedding at the ties shall be of cement mortar entirely surrounding the ties.

(ii) Veneer may be applied with 1-inch-minimum grouted backing space which is reinforced by not less than 2-inch by 2-inch No. 16 gauge galvanized wire mesh placed over waterproof paper backing and anchored directly to stud construction.

The stud spacing shall not exceed 16 inches on center. The galvanized wire mesh shall be anchored to wood studs by galvanized steel wire furring nails at 4 inches on center or by barbed galvanized nails at 6 inches on center with a 1 1/8-inch minimum penetration. The galvanized wire mesh may be attached to steel studs by equivalent wire ties. If this method is applied over solid sheathing the mesh must be furred for embedment in grout. The wire mesh must be attached at the top and bottom with not less than 8-penny common wire nails. The grout fill shall be placed to fill the space intimately around the mesh and veneer facing.

2. **Stone units (10 inches maximum in thickness).** Stone veneer units not exceeding 10 inches in thickness may be anchored directly to structural masonry, concrete or to studs:

(i) **With concrete or masonry backing.** Anchor ties shall be not less than No. 12 gauge galvanized wire, or approved equal, formed as an exposed eye and extending not less than 1/2 inch beyond the face of the backing. The legs of the loops shall be not less than 6 inches in length bent at right angles and laid in the masonry mortar joint and spaced so that the eyes or loops are 12 inches maximum on center in both directions. There shall be provided not less than a No. 12 gauge galvanized wire tie, or approved equal, threaded through the exposed loops for every 2 square feet of stone veneer. This tie shall be a loop having legs not less than 15 inches in length so bent that it will lie in the stone veneer mortar joint. The last 2 inches of each wire leg shall have a right angle bend. One inch of cement grout shall be placed between the backing and the stone veneer.

(ii) **With stud backing.** A 2-inch by 2-inch No. 16 gauge galvanized wire mesh with two layers of waterproof paper backing shall be applied directly to wood studs spaced a maximum of 16 inches on center. On studs the mesh shall be attached with 2-inch-long galvanized steel wire furring nails at 4 inches on center providing a minimum 1 1/8-inch penetration into each stud and with 8-penny common nails at 8 inches on center into top and bottom plates. The galvanized wire mesh may be attached to steel studs with equivalent wire ties. There shall be not less than a No. 12 gauge galvanized wire, or approved equal, looped through the mesh for every 2 square feet of stone veneer. This tie shall be a loop having legs not less than 15 inches in length, so bent that it will lie in the stone veneer mortar joint.

The last 2 inches of each wire leg shall have a right angle bend. One-inch minimum thickness of cement grout shall be placed between the backing and the stone veneer.



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3. **Slab-type units (2 inches maximum in thickness).** For veneer units of marble, travertine, granite or other stone units of slab form, ties of corrosion-resistant metal shall engage drilled holes of corrosion-resistant metal dowels located in the middle third of the edge of the units spaced a maximum of 24 inches apart around the periphery of each unit with not less than four ties per veneer unit. Units shall not exceed 20 square feet in area.

If the dowels are not tight fitting, the holes may be drilled not more than 1/16 inch larger in diameter than the dowel with the hole countersunk to a diameter and depth equal to twice the diameter of the dowel in order to provide a tight-fitting key of cement mortar at the dowel locations when the mortar in the joint has set.

All veneer ties shall be corrosion-resistant metal capable of resisting in tension or compression a force equal to two times the weight of the attached veneer.

If made of sheet metal, veneer ties shall be not smaller in area than No. 22 gauge by 1 inch or, if made of wire, not smaller in diameter than No. 9 gauge wire.

4. **Terra cotta or ceramic units.** Tied terra cotta or ceramic veneer units shall be not less than 1 1/4 inch in thickness with projecting dovetail webs on the back surface spaced approximately 8 inches on centers. The facing shall be tied to the backing wall with noncorrosive metal anchors of not less than No. 8 gauge wire installed at the top of each piece in horizontal bed joints not less than 12 inches nor more than 18 inches on centers; these anchors shall be secured to 1/4-inch galvanized peneil rods which pass through the vertical aligned loop anchors in the backing wall. The veneer ties shall have sufficient strength to support the full weight of the veneer in tension. The facing shall be set with not less than a 2-inch space from the backing wall and the space shall be filled solidly with portland cement grout and pea gravel. Immediately prior to setting, the backing wall and the facing shall be drenched with clean water and shall be distinctly damp when the grout is poured.

## Plastic Veneer

**Sec. 3007.** When used within a building, plastic veneer shall comply with the interior finish requirements of Chapter 42. Exterior plastic veneer shall be of approved plastics materials as defined in Chapter 4 and shall comply with the following:

1. Plastic veneer shall not be attached to any exterior wall to a height greater than 50 feet above grade.
2. Sections of plastic veneer shall not exceed 300 square feet in area and shall be separated by a minimum of 4 feet vertically.

   **EXCEPTION:** The area and separation requirements and the smoke-density limitation are not applicable to plastic veneer applied to Type V-N buildings, provided the walls are not required to have a fire-resistive rating.



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## TABLE NO. 30-A—CERAMIC TILE SETTING MORTARS

| COAT | | VOLUME TYPE 1 PORTLAND CEMENT | VOLUME TYPE S HYDRATED LIME | VOLUME U.B.C. STD. 24-21 SAND | | MAXIMUM THICKNESS OF COAT | MINIMUM INTERVAL BETWEEN COATS |
|---|---|---|---|---|---|---|---|
| | | | | Dry | Damp | | |
| 1. Walls and ceilings over 10 sq. ft. | Scratch | 1 | ½ | 4 | 5 | 3/8" | 24 hrs. |
| | | 1 | 0 | 3 | 4 | 3/8" | 24 hrs. |
| | Float or leveling | 1 | ½ | 4 | 5 | ¼" | 24 hrs. |
| | | 1 | 1 | 6 | 7 | ¼" | 24 hrs. |
| 2. Walls and ceilings 10 sq. ft. or less | Scratch and float | 1 | ½ | 2½ | 3 | ⅜" ¼" | 24 hrs. |
| 3. Floors | Setting bed | 1 | 0 | 5 | 6 | 1¼" | — |
| | | 1 | 1/10 | 5 | 6 | 1¼" | — |



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# Chapter 31
# NO REQUIREMENTS

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# Chapter 32
# ROOF CONSTRUCTION AND COVERING

## General

**Sec. 3201.** Roofs shall be as specified in this code and as otherwise required by this chapter.

Roof coverings shall be securely fastened to the supporting roof construction and shall provide weather protection for the building at the roof.

Subject to the requirements of this chapter, combustible roof coverings and roof insulation may be used in any type of construction.

Skylights shall be constructed as required in Chapter 34.

Penthouses shall be constructed as required in Chapter 36.

For use of plastics in roofs, see Chapter 52.

For solar energy collectors located above or upon a roof, see Section 1714.

## Definitions

**Sec. 3202.** For purposes of this chapter certain terms are designated as follows:

**BASE PLY** is one layer of felt secured to the deck over which a built-up roof is applied.

**BASE SHEET** is a product used as the base ply in a built-up roofing membrane.

**BUILT-UP ROOF COVERING** is two or more layers of felt cemented together and surfaced with cap sheet, mineral aggregate, smooth coating or similar surfacing material.

**CAP SHEET** is roofing made of organic or inorganic fibers, saturated and coated on both sides with a bituminous compound, surfaced with mineral granules, mica, talc, ilmenite, inorganic fibers or similar materials.

**CEMENTING** is solidly mopped application of asphalt, eold liquid asphalt compound, coal tar pitch or other approved cementing material.

**COMBINATION SHEET** is a glass fiber felt integrally attached to kraft paper.

**CORROSION-RESISTANT** is any nonferrous metal or any metal having an unbroken surfacing of nonferrous metal, or steel with not less than 10 percent chromium or with not less than 0.20 percent copper.

**EQUIVISCOUS TEMPERATURE (EVT)** is the temperature determined by the manufaeturer at which the asphalt has a viscosity of 125 centistrokes and is considered to be the proper temperature for asphalt applications.



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## TABLE NO. 30-A—CERAMIC TILE SETTING MORTARS

| COAT | | VOLUME TYPE 1 PORTLAND CEMENT | VOLUME TYPE S HYDRATED LIME | VOLUME U.B.C. STD. 24-21 SAND | | MAXIMUM THICKNESS OF COAT | MINIMUM INTERVAL BETWEEN COATS |
|---|---|---|---|---|---|---|---|
| | | | | Dry | Damp | | |
| 1. Walls and ceilings over 10 sq. ft. | Scratch | 1 | ½ | 4 | 5 | 3/8" | 24 hrs. |
| | | 1 | 0 | 3 | 4 | 3/8" | 24 hrs. |
| | Float or leveling | 1 | ½ | 4 | 5 | ¼" | 24 hrs. |
| | | 1 | 1 | 6 | 7 | ¾" | 24 hrs. |
| 2. Walls and ceilings 10 sq. ft. or less | Scratch and float | 1 | ½ | 2½ | 3 | ⅜" ¼" | 24 hrs. |
| 3. Floors | Setting bed | 1 | 0 | 5 | 6 | 1¼" | — |
| | | 1 | 1/10 | 5 | 6 | 1¼" | — |



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**FELT** is matted organic or inorganic fibers, saturated or coated with bituminous compound.

**FELT, NONBITUMINOUS SATURATED,** is a felt for special purpose roofing weighing not less than 12 pounds per 100 square feet, not less than .022 inch in thickness, containing a fire- and water-retardant binder, and reinforced with glass fibers running lengthwise of the sheet not more than 1/4 inch apart.

**INTERLAYMENT** is a layer of felt or nonbituminous saturated felt not less than 18 inches wide, shingled between each course of roof covering.

**INTERLOCKING ROOFING TILES** are individual units, typically of clay or concrete, possessing matching ribbed or interlocking vertical side joints that have been designed to restrict lateral movement and water penetration.

**METAL ROOFING** is metal shingles or sheets for application on solid roof surfaces, and corrugated or otherwise shaped metal sheets or sections for application on roof frameworks or on solid roof surfaces.

**ROOF-COVERING CLASSIFICATION** is the classification assigned to a roof-covering assembly by Section 3204 or the classification of a covering established by testing in accordance with U.B.C. Standard No. 32-7.

**ROOFING PLY** is a layer of felt in a built-up roofing membrane.

**ROOFING SQUARE** is 100 square feet of roofing surface.

**ROOFING TILES** are units, typically clay or concrete, which comply with U.B.C. Standard No. 32-12.

**SPOT CEMENTING** is discontinuous application of asphalt, cold liquid asphalt compound, coal tar pitch or other approved cementing material.

**UNDERLAYMENT** is one or more layers of felt, sheathing paper, nonbituminous saturated felt, or other approved material over which a roofing system is applied.

**VAPOR RETARDER** is a layer of material or a laminate used to appreciably reduce the flow of water vapor into the roofing system.

**WOOD SHAKES** are tapered or nontapered pieces of approved durable wood of random widths ranging from 4 inches to 14 inches and of the following four types:

1. Hand-split and resawn: tapered with one sawed and one split face; semisplit: tapered with partially sawn and split faces both sides, 15 inches, 18 inches or 24 inches in length.
2. Taper-split: tapered with both split faces, 24 inches in length.
3. Straight-split: nontapered with both split faces, either 18 inches or 24 inches in length.
4. Taper-sawn: sawn both sides, edges sawn or split. Lengths 24 inches and longer.

**Preservative-treated wood shakes** are taper-sawn pieces of southern pine wood treated in accordance with U.B.C. Standard No. 25-12 of random widths ranging from 4 inches to 8 inches and lengths of 18 inches.

**WOOD SHINGLES** are tapered pieces of approved durable wood, sawed both



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sides, of random widths ranging from 3 inches to 14 inches and in lengths of 16 inches, 18 inches or 24 inches.

## Roof Covering Requirements

**Sec. 3203.** The roof covering on any structure regulated by this code shall be as specified in Table No. 32-A and as classified in Section 3204.

The roof-covering assembly includes the roofdeck, underlayment, interlayment, insulation and covering which is assigned a roof-covering classification.

## Roof Covering Classification

**Sec. 3204.** (a) **Class A Roof Covering.** A Class A roof covering shall be one of the following roofings:

1. Any Class A roofing assembly.
2. Asbestos-cement shingles or sheets.
3. Exposed concrete slab roof.
4. Sheet ferrous or copper roof covering.
5. Slate shingles.
6. Clay or concrete roof tile.

(b) **Class B Roof Covering.** Class B roof shall be any Class B roofing assembly.

(c) **Class C Roof Covering.** Class C shall be any Class C roofing assembly.

(d) **Nonrated Roof Covering.** A nonrated roof covering shall be one of the following roofings:

1. Any mineral aggregate surface built-up roof for application to roofs having a slope of not more than 3 inches in 12 inches applied as specified in Section 3208 (b) 4, consisting of not less than the following:

   **Roofing Plies**

   Three layers of felt, and

   **Surfacing Material**

   300 pounds per roofing square of gravel or other approved surfacing material, or

   250 pounds per roofing square of crushed slag.
2. Wood shingles.
3. Wood shakes.

(e) **Special Purpose Roofs.** 1. **Wood shakes and shingles with nonbituminous saturated felt.** A. **Wood shakes.** Special purpose wood shake roofing shall conform to grading and application requirements of this chapter except that nonbituminous saturated felt is to be substituted for the asphalt felt specified in Section 3208 (b) 10. In addition, the deck shall be constructed of 19/32-inch plywood with exterior glue or 1-inch nominal tongue-and-groove boards overlaid with a layer of approved nonbituminous saturated felt lapped 2 inches on the horizontal and vertical joints. An 18-inch-wide strip of the same felt shall be



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shingled in between each course of shakes in such manner that no felt is exposed to the weather.

B. **Wood shingles.** Special purpose wood shingle roofing shall conform to grading and application requirements of this chapter. In addition, the deck, whether of spaced boards or solid, shall be overlaid with a layer of approved nonbituminous saturated felt lapped 2 inches on the horizontal and vertical joints.

2. **Wood shakes or shingles with gypsum board underlayment.** Special purpose wood shake or wood shingle roofing shall conform to the grading and application requirements of this chapter. In addition, an underlayment of 1/2-inch Type X gypsum board shall be placed under 15/32-inch plywood solid sheathing or 1-inch nominal spaced sheathing.

## Attics: Access, Draft Stops and Ventilation

**Sec. 3205.** (a) **Access.** An attic access opening shall be provided in the ceiling of the top floor of buildings with combustible ceiling or roof construction. The opening shall be located in a corridor or hallway of buildings of three or more stories in height and readily accessible in buildings of any height.

The opening shall be not less than 22 inches by 30 inches.

Thirty-inch minimum clear head room shall be provided above the access opening.

Attics with a maximum vertical clear height of less than 30 inches need not be provided with access openings.

(b) **Draft Stops.** Attics, mansards, overhangs and other concealed roof spaces formed of combustible construction shall be draft stopped as specified in Section 2516 (f).

(c) **Ventilation.** Where determined necessary by the building official due to atmospheric or climatic conditions, enclosed attics and enclosed rafter spaces formed where ceilings are applied direct to the underside of roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain and snow. The net free ventilating area shall be not less than 1/150 of the area of the space ventilated, except that the area may be 1/300, provided at least 50 percent of the required ventilating area is provided by ventilators located in the upper portion of the space to be ventilated at least 3 feet above eave or cornice vents with the balance of the required ventilation provided by eave or cornice vents. The openings shall be covered with corrosion-resistant metal mesh with mesh openings of 1/4 inch in dimension.

## Smoke and Heat Venting

**Sec. 3206.** (a) **When Required.** Smoke and heat vents complying with U.B.C. Standard No. 32-14 or fixed openings shall be installed in accordance with the provisions of this section as follows:

1. In single-story Group B, Divisions 2 and 4 Occupancies having over 50,000 square feet in undivided area.

**EXCEPTIONS:** 1. Office buildings and retail sales areas where storage does not exceed 12 feet in height.



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2. Group B, Division 4 Occupancies used for bulk frozen food storage when the building is protected by a complete automatic sprinkler system.

2. In Group H, Divisions 1, 2, 3, 4 or 5 Occupancies over 15,000 square feet in single floor area.

For requirements on smoke and heat venting in buildings with high-piled combustible stock, see the Fire Code.

(b) **Mixed Occupancies.** Venting facilities shall be installed in buildings of mixed occupancy on the basis of the individual occupancy involved.

(c) **Types of Vents.** Vents shall be fixed in the open position or vents shall be activated by temperature and shall open automatically in the event of fire.

Fixed openings may consist of skylights, or other openings which provide venting directly to exterior above the plane of the main roof in which they are located. Vents shall meet the design criteria of this subsection regarding elevation, and Subsection (e) regarding venting area, dimensions, spacing and venting ratios. The building official may require documentation of the design to assure proper performance of required venting.

Temperature activation of vents shall be at or near the highest elevation of the ceiling and in no case lower than the upper one third of the smoke curtain. Where plain glass is used, provisions shall be made to protect the occupants from glass breakage. In no case shall vents be located closer than 20 feet to an adjacent property line.

(d) **Releasing Devices.** Release devices shall be in accordance with U.B.C. Standard No. 32-14.

(e) **Size and Spacing of Vents.** 1. **Effective venting area.** The effective venting area is the minimum cross-sectional area through which the hot gases must pass en route to atmosphere. The effective venting area shall be not less than 16 square feet with no dimension less than 4 feet, excluding ribs or gutters whose total width does not exceed 6 inches.

2. **Spacing.** The maximum center-to-center spacing between vents within the building shall be:

A. In Group B Occupancies: 120 feet.

B. In Group H Occupancies: 100 feet.

3. **Venting ratios.** The following ratios of effective area of vent openings to floor areas shall be:

A. In Group B Occupancies: 1:100.

B. In Group H Occupancies: 1:50.

(f) **Curtain Boards.** 1. **General.** Curtain boards shall be provided to subdivide a vented building in accordance with the provisions of this subsection.

2. **Construction.** Curtain boards shall be sheet metal, asbestos board, lath and plaster, gypsum wallboard or other approved materials which provide equivalent performance that will resist the passage of smoke. All joints and connections shall be smoke tight.

3. **Location and depth.** Curtain boards shall extend down from the ceiling for



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a minimum depth of 6 feet but need not extend closer than 8 feet to the floor. In Group H Occupancies, the minimum depth shall be 12 feet except that it need not be closer than 8 feet to the floor, provided the curtain is not less than 6 feet in depth.

4. **Spacing.** The distance between curtain boards shall not exceed 250 feet and the curtained area shall be limited to 50,000 square feet. In Group H Occupancies, the distance between curtain boards shall not exceed 100 feet and the curtained area shall be limited to 15,000 square feet.

## Roof Drainage

**Sec. 3207.** (a) **General.** Roof systems shall be sloped a minimum of 1/4 inch in 12 inches for drainage. See Section 2305 (f).

(b) **Roof Drains.** Unless roofs are sloped to drain over roof edges, roof drains shall be installed at each low point of the roof.

Roof drains shall be sized and discharged in accordance with the Plumbing Code.

(c) **Overflow Drains and Scuppers.** Where roof drains are required, overflow drains having the same size as the roof drains shall be installed with the inlet flow line located 2 inches above the low point of the roof, or overflow scuppers having three times the size of the roof drains may be installed in adjacent parapet walls with the inlet flow line located 2 inches above the low point of the adjacent roof and having a minimum opening height of 4 inches.

Overflow drains shall be connected to drain lines independent from the roof drains.

(d) **Concealed Piping.** Roof drains and overflow drains, when concealed within the construction of the building, shall be installed in accordance with the Plumbing Code.

(e) **Over Public Property.** Roof drainage water from a building shall not be permitted to flow over public property.

**EXCEPTION:** Groups R, Division 3, and M Occupancies.

## Roof Covering Materials and Application

**Sec. 3208.** (a) **General.** Roof coverings shall be as specified in this section, and shall be provided as follows:

1. **Materials.** The quality and design of roofing materials and their fastenings shall conform to the applicable standards listed in Chapter 60.

2. **Identification.** All material shall be delivered in packages bearing the manufacturer's label or identifying mark.

Each package of asphalt shingles, mineral surfaced roll roofing, fire-retardant-treated wood shingles and shakes, and built-up roofing ply materials shall bear the label of an approved agency having a service for the inspection of material and finished products during manufacture.

Each bundle of wood shingles, slate shingles and wood shakes shall comply with U.B.C. Standards Nos. 32-8, 32-10 and 32-11, respectively, and shall bear



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the label or identification mark of an approved inspection bureau or agency showing the grade.

Asphalt shall comply with U.B.C. Standard No. 32-2 and shall be delivered in cartons indicating the name of the manufacturer, the flash point and the type of product. Bulk shipments shall be accompanied with the same information issued in the form of a certification or on the bill of lading by the manufacturer. Coal tar pitch shall comply with U.B.C. Standards Nos. 32-1 and 32-2 and bear the manufacturer's name and type. Additional information such as equiviscous temperature (EVT) may be furnished.

(b) **Application.** Application of roof-covering materials shall be in accordance with the following provisions:

1. **Asbestos-cement roofing.** Corrugated asbestos-cement roofing shall be applied in an approved manner.

2. **Asbestos-cement shingles.** Asbestos-cement shingles shall comply with U.B.C. Standard No. 32-9 and shall be installed in an approved manner.

3. **Asphalt shingles.** Asphalt shingles shall comply with U.B.C. Standard No. 32-3. Asphalt shingles shall be fastened aecording to manufacturer's instructions and Table No. 32-B-1.

4. **Built-up roofs.** Built-up roofing shall be applied in accordance with the manufacturer's instructions and Table Nos. 32-E through G.

5. **Clay or concrete tile.** Tile of clay or concrete shall comply with U.B.C. Standard No. 32-12 and shall be installed in accordance with manufacturer's instruetions and Tables Nos. 32-D-1 and 32-D-2.

6. **Metal roofing.** Metal roofing exposed to the weather shall be corrosion resistant.

Corrugated or ribbed steel shall be not less than No. 30 galvanized sheet gauge.

Flat steel sheets shall be not less than No. 30 galvanized sheet gauge. Other ferrous sections or shapes shall be not less than No. 26 galvanized sheet gauge.

Flat nonferrous sheets shall be not less than No. 28 B. & S. gauge. Other nonferrous sections or shapes shall be not less than No. 25 B. & S. gauge.

Corrugated or otherwise shaped sheets or sections shall be designed to support the required live load between supporting members.

Ferrous sheets or sections shall comply with U.B.C. Standards Nos. 27-9 and 32-4. Nonferrous sheets or sections shall comply with U.B.C. Standard No. 32-4.

7. **Metal shingles.** Metal shingles shall be applied in an approved manner. Nonferrous shingles shall be not less than No. 28 B. & S. gauge.

8. **Sheet roofing.** Sheet roofing shall comply with the provisions of U.B.C. Standard No. 32-3 and shall be installed in an approved manner.

9. **Slate shingles.** Slate shingles shall comply with U.B.C. Standard No. 32-10 and shall be installed in an approved manner.

10. **Wood shakes.** Shakes shall comply with U.B.C. Standard No. 32-8 and shall be installed in accordance with Table No. 32-B-2.



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11. **Wood shingles.** Shingles shall comply with U.B.C. Standard No. 32-11 and shall be installed in accordance with Table No. 32-B-2.

(c) **Flashing.** 1. **Valleys.** Roof valley flashings shall be as in this subsection. Shingle application shall be consistent with applicable Table No. 32-B-1, 32-B-2, 32-D-1 or 32-D-2.

A. **Asphalt shingles.** The roof valley flashing shall be provided of not less than No. 28 galvanized sheet gauge corrosion-resistant metal, and shall extend at least 8 inches from the center line each way. Sections of flashing shall have an end lap of not less than 4 inches. Alternatively, the valley shall consist of woven asphalt shingles applied in accordance with manufacturer's printed instructions.

In each case, the roof valley flashing shall have a 36-inch-wide underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to the underlayment specified in Table No. 32-B-1. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roof underlayment for slopes under 7 inches in 12 inches.

B. **Metal shingles.** The roof valley flashing shall be provided of not less than No. 28 galvanized sheet gauge corrosion-resistant metal, which shall extend at least 8 inches from the center line each way and shall have a splash diverter rib not less than 3/4 inch high at the flow line formed as part of the flashing. Sections of flashing shall have an end lap of not less than 4 inches. The metal valley flashing shall have a 36-inch-wide underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to underlayment required for metal shingles. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roofing underlayment for roof slopes under 7 inches in 12 inches.

C. **Asbestos-cement shingles, slate shingles, and clay and concrete tile.** The roof valley flashing shall be provided of not less than No. 28 galvanized sheet gauge corrosion-resistant metal, which shall extend at least 11 inches from the center line each way and shall have a splash diverter rib not less than 1 inch high at the flow line formed as part of the flashing. Sections of flashing shall have an end lap of not less than 4 inches. For roof slopes of 3 inches in 12 inches and over, the metal valley flashing shall have a 36-inch-wide underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to the underlayment specified in Tables Nos. 32-D-1 and 32-D-2. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roofing underlayment for slopes under 7 inches in 12 inches.

D. **Wood shingles and wood shakes.** The roof valley flashing shall be provided of not less than No. 28 galvanized sheet gauge corrosion-resistant metal, which shall extend at least 8 inches from the center line each way for wood shingles and 11 inches from the center line each way for wood shakes. Sections of flashing shall have an overlap of not less than 4 inches. The metal valley flashing shall have a 36-inch-wide underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to underlayment specified in Table No. 32-B-2. In severe climates, the metal valley flashing



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underlayment shall be solid cemented to the roofing underlayment for roof slopes under 7 inches in 12 inches.

**EXCEPTION:** Where local practice indicates satisfactory performance, the building official may permit valley flashing without underlayment.

2. **Other flashing.** At the juncture of the roof and vertical surfaces, flashing and counterflashing shall be provided per roofing manufacturer's instructions, and when of metal, shall be not less than No. 26 gauge corrosion-resistant metal.

(d) **Roof Insulation.** Roof insulation shall be of a rigid type suitable as a base for application of a roof covering. Foam plastic roof insulation shall conform to the requirements of Section 1712. The use of insulation in fire-resistive construction shall comply with Section 4305 (a).

The roof insulation, deck material and roof covering shall meet the fire retardancy requirements of Section 3204 and Table No. 32-A.

Insulation for built-up roofs shall be applied in accordance with Table No. 32-E. For other roofing materials such as shingles or tile, the insulation shall be covered with a suitable nailing base secured to the structure.



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## TABLE NO. 32-A—MINIMUM ROOF CLASSES

| OCCUPANCY | TYPES OF CONSTRUCTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | | | III | | IV | V | |
| | F.R. | F.R. | 1-HR | N | 1-HR | N | H.T. | 1-HR | N |
| A-1 | B | B | — | — | — | — | — | — | — |
| A) 2-2.1 | B | B | B | — | B | — | B | B | — |
| A-3 | B | B | B | B | B[3] | B[3] | B[3] | B[3] | B[3] |
| A-4 | B | B | B | B | B | B | B | B | B[3] |
| B) 1-2 | B | B | B | B | B[3] | B[3] | B[3] | B[3] | B[3] |
| B) 3-4 | B | B | B | B | B | B | B | B | B[3] |
| E | B | B | B | B | B | B | B | B | B[3] |
| H-1 | A | A | A | A | B | B | B | B | B |
| H) 2-3-4-5-6-7 | A | B | B | B | B | B | B | B | B |
| I) 1-2 | A | B | B | — | B | — | B | B | — |
| I-3 | A | B | B[1] | — | B[1] | — | — | B[2] | — |
| M | B | B | B | B | NR[4] | NR[4] | NR[4] | NR[4] | NR[4] |
| R-1 | B | B | B | B | B[2 3] | B[2 3] | B[2 3] | B[2 3] | B[2 3] |
| R-3 | B | B | B | B | NR | NR | NR | NR | NR |

[1]See Section 1002 (b)

[2]Nonrated roof coverings may be used on buildings which are not more than two stories in height and have not more than 3000 square feet of projected roof area and there is a minimum of 10 feet from the extremity of the roof to the property line on all sides except for street fronts.

[3]Buildings which are not more than two stories in height and have not more than 6000 square feet of projected roof area and there is a minimum of 10 feet from the extremity of the roof to the property line or assumed property line on all sides except for street fronts may have Class C roof coverings

A—Class A roofing
B—Class B roofing
NR—Nonrated roof coverings
N—No requirements for fire resistance
F.R.—Fire Resistive
H.T.—Heavy Timber

(Continued)





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*(Continued)*

which comply with U.B.C. Standard No. 32-7 and roofs of cedar or redwood shakes and No. 1 shingles constructed in accordance with Section 3204 (e), Special Purpose Roofs.

[4]Unless otherwise required because of location as specified in Parts IV and V of this code, Group M, Division 1 roof coverings shall consist of not less than one layer of cap sheet, or built-up roofing consisting of two layers of felt and a surfacing material as specified in Section 3204 (d) 1.

## TABLE NO. 32-B-1—ASPHALT SHINGLE APPLICATION

| | ASPHALT SHINGLES | |
|---|---|---|
| | NOT PERMITTED BELOW 2:12 | |
| ROOF SLOPE | 2:12 to less than 4:12 | 4:12 and over |
| DECK REQUIREMENT | Asphalt shingles shall be fastened to solidly sheathed roofs. Sheathing shall conform to Sections 2516 (i) and 2517 (h) 7. | |
| UNDERLAYMENT Temperate climate | Asphalt strip shingles may be installed on slopes as low as 2 inches in 12 inches, provided the shingles are approved self-sealing or are hand-sealed and are installed with an underlayment consisting of two layers of nonperforated Type 15 felt applied shingle fashion. Starting with an 18-inch-wide sheet and a 36-inch-wide sheet over it at the eaves, each subsequent sheet shall be lapped 19 inches horizontally. | One layer nonperforated Type 15 felt lapped 2 inches horizontally and 4 inches vertically to shed water. |
| Severe climate: In areas subject to wind-driven snow or roof ice buildup. | Same as for temperate climate, and additionally the two layers shall be solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 24 inches inside the exterior wall line of the building. | Same as for temperate climate, except that one layer No. 40 coated roofing or coated glass base sheet shall be applied from the eaves to a line 12 inches inside the exterior wall line with all laps cemented together. |



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| | |
|---|---|
| ATTACHMENT<br>Type of fasteners | Corrosion-resistant nails, minimum 12-gauge 3/8-inch head, or approved corrosion-resistant staples, minimum 16-gauge 15/16-inch crown width.<br>Fasteners shall comply with the requirements of U.B.C. Standard No. 25-17.<br>Fasteners shall be long enough to penetrate into the sheathing 3/4 inch or through the thickness of the sheathing, whichever is less. |
| No. of fasteners[1] | 4 per 36-40-inch strip<br>2 per 9-18-inch shingle |
| Exposure<br>Field of roof<br>Hips and ridges | Per manufacturer's instructions included with packages of shingles.<br>Hip and ridge weather exposures shall not exceed those permitted for the field of the roof. |
| Method | Per manufacturer's instructions included with packages of shingles. |
| FLASHING<br>Valleys<br>Other flashing | Per Section 3208 (c) 1 A<br>Per Section 3208 (c) 2 |

[1]Figures shown are for normal application. For special conditions such as mansard application and where roofs are in special wind regions, shingles shall be attached per manufacturer's instructions.





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## TABLE NO. 32-B-2—WOOD SHINGLE OR SHAKE APPLICATION

| | WOOD SHINGLES | WOOD SHAKES |
|---|---|---|
| | NOT PERMITTED BELOW 3:12 | NOT PERMITTED BELOW 4:12[1] |
| ROOF SLOPE | See Table No. 32-C | See Table No. 32-C |
| DECK REQUIREMENT | Shingles and shakes shall be applied to roofs with solid or spaced sheathing. Spaced sheathing for wood roofs shall be spaced not to exceed 6 inches clear nor more than the nominal width of the sheathing board. Sheathing boards shall be not less than 1 inch by 4 inches nominal dimensions. Sheathing shall conform to Sections 2516 (i) and 2517 (h)-7. | |
| UNDERLAYMENT. Temperate climate | No Requirements | One 18-inch-wide interlayment of Type 30 felt shingled between each course in such a manner that no felt is exposed to the weather below the shake butts. |
| Severe climate: In areas subject to wind-driven snow or roof ice buildup. | Two layers of nonperforated Type 15 felt applied shingle fashion shall be installed and solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 36 inches inside the exterior wall line of the building. | Sheathing shall be solid and the shakes shall be applied over a layer of nonperforated Type 15 felt applied shingle fashion. Two layers of nonperforated Type 15 felt applied shingle fashion shall be installed and solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 36 inches inside the exterior wall line of the building. |



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| | | |
|---|---|---|
| ATTACHMENT<br>Type of fasteners | Corrosion-resistant nails, minimum No. 14 1/2-gauge 7/32-inch head, or corrosion-resistant staples, when approved by the building official. | Corrosion-resistant nails, minimum No. 13-gauge 7/32-inch head, or corrosion-resistant staples, when approved by the building official. |
| | Fasteners shall comply with the requirements of U.B.C. Standard No. 25-17.<br>Fasteners shall be long enough to penetrate into the sheathing 3/4 inch or through the thickness of the sheathing, whichever is less. | |
| No. of fasteners | 2 per shingle | 2 per shake |
| Exposure<br>Field of roof<br>Hips and ridges | Weather exposures shall not exceed those set forth in Table No. 32-C.<br>Hip and ridge weather exposures shall not exceed those permitted for the field of the roof. | |
| Method | Shingles shall be laid with a side lap of not less than 1 1/2 inches between joints in adjacent courses, and not in direct alignment in alternate courses. Spaeing between shingles shall be approximately 1/4 inch. Each shingle shall be fastened with two nails only, positioned approximately 3/4 inch from each edge and approximately 1 inch above the exposure line. Starter course at the eaves shall be doubled. | Shakes shall be laid with a side lap of not less than 1 1/2 inches between joints in adjacent courses. Spacing between shakes shall be not less than 3/8 inch nor more than 5/8 inch except for preservative-treated wood shakes which shall have a spacing not less than 1/4 inch nor more than 3/8 inch.<br>Shakes shall be fastened to the sheathing with two nails only, positioned approximately 1 inch from each edge and approximately 2 inches above the exposure line. The starter course at the eaves shall be doubled. The bottom or first layer may be either shakes or shingles. Fifteen-inch or 18-inch shakes may be used for the starter course at the eaves and final course at the ridge. |
| FLASHING<br>Valleys<br>Other flashing | Per Section 3208 (c) 1 D<br>Per Section 3208 (c) 2 | |

[1]When approved by the building official, wood shakes may be installed on a slope of not less than 3 inches in 12 inches when an underlayment of not less than nonperforated Type 15 felt in installed.





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## TABLE NO. 32-C—MAXIMUM WEATHER EXPOSURE

| GRADE LENGTH | 3" TO LESS THAN 4" IN 12" Inches | 4" IN 12" AND STEEPER: Inches |
|---|---|---|
| **WOOD SHINGLES** | | |
| No. 1 16-inch | 3 3/4 | 5 |
| No. 2[1] 16-inch | 3 1/2 | 4 |
| No. 3[1] 16-inch | 3 | 3 1/2 |
| No. 1 18-inch | 4 1/4 | 5 1/2 |
| No. 2[1] 18-inch | 4 | 4 1/2 |
| No. 3[1] 18-inch | 3 1/2 | 4 |
| No. 1 24-inch | 5 3/4 | 7 1/2 |
| No. 2[1] 24-inch | 5 1/2 | 6 1/2 |
| No. 3[1] 24-inch | 5 | 5 1/2 |
| **WOOD SHAKES[2]** | | |
| 18-inch | 7 1/2 | 7 1/2 |
| 24-inch | 10 | 10 |

[1]To be used only when specifically permitted by the building official.

[2]Exposure of 24-inch by 3/8-inch resawn handsplit shakes shall not exceed 5 inches regardless of the roof slope.



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## TABLE NO. 32-D-1—ROOFING TILE APPLICATION[1] FOR ALL TILES

| ROOF SLOPE | 2½:12 to less than 3:12 | 3:12 and over |
|---|---|---|
| DECK REQUIREMENTS | Solid sheathing per Sections 2516 (i) and 2517 (h) 7 | |
| UNDERLAYMENT<br>In climate areas subject to wind-driven snow, roof ice damming or special wind regions as shown in Figure No. 1 of Chapter 23. | Built-up roofing membrane, three plies minimum, applied per Section 3208 (b) 4. Surfacing not required. | Same as for other climate areas, except that extending from the eaves up the roof to a line 24 inches inside the exterior wall line of the building, two layers of underlayment shall be applied shingle fashion and solidly cemented together with an approved cementing material. |
| Other climate areas | | One layer heavy-duty felt or Type 30 felt side lapped 2 inches and end lapped 6 inches. |
| ATTACHMENT[2]<br>Type of fasteners | Corrosion-resistant nails not less than No. 11 gauge, 5/16-inch head. Fasteners shall comply with the requirements of U.B.C. Standard No. 25-17. Fasteners shall be long enough to penetrate into the sheathing ¾ inch or through the thickness of the sheathing, whichever is less. Attaching wire for clay or concrete tile shall not be smaller than No. 14-gauge, and shall comply with U.B.C. Standards Nos. 32-6 and 32-13. | |
| No. of fasteners[2,3] | One fastener per tile. Flat tile without vertical laps, two fasteners per tile. | Two fasteners per tile. Only one fastener on slopes of 7:12 and less for tiles with installed weight exceeding 7.5 pounds per square foot having a width no greater than 16 inches.[4] |
| Tile headlap | 3 inches minimum | |
| FLASHING | Per Sections 3208 (c) 1 C and 3208 (c) 2 | |

[1]In snow areas a minimum of two fasteners per tile are required.

[2]In areas designated by the building official as being subject to repeated wind velocities to excess of 80 mph or where the roof height exceeds 40 feet above grade, all tiles shall be attached as follows:

(a) The heads of all tiles shall be nailed.

*(Continued)*





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## FOOTNOTES FOR TABLE NO. 32-D-1—(Continued)

(b) The noses of all eave course tiles shall be fastened with approved clips.
(c) All rake tiles shall be nailed with two nails.
(d) The noses of all ridge, hip and rake tiles shall be set in a bead of approved roofer's mastic.

[3]In snow areas a minimum of two fasteners per tile are required, or battens and one fastener.

[4]On slopes over 24:12, the nose end of all tiles shall be securely fastened.

## TABLE NO. 32-D-2—CLAY OR CONCRETE ROOFING TILE APPLICATION INTERLOCKING TILE WITH PROJECTING ANCHOR LUGS

| ROOF SLOPE | 4:12 and over |
|---|---|
| DECK REQUIREMENTS | Spaced structural sheathing boards or solid roof sheathing. |
| UNDERLAYMENT<br>In climate areas subject to wind-driven snow, roof ice or special wind regions as shown in Figure No. 1 of Chapter 23. | Solid sheathing one layer of Type 30 felt lapped 2 inches horizontally and 6 inches vertically, except that extending from the eaves up the roof to line 24 inches inside the exterior wall line of the building, two layers of the underlayment shall be applied shingle fashion and solid cemented together with approved cementing material. |
| Other climates | For spaced sheathing, approved reinforced membrane. For solid sheathing; one layer heavy-duty felt or Type 30 felt lapped 2 inches horizontally and 6 inches vertically. |
| ATTACHMENT[1]<br>Type of fasteners | Corrosion-resistant nails not less than No. 11 gauge, 5/16-inch head.<br>Fasteners shall comply with the requirements of U.B.C. Standard No. 25-17.<br>Fasteners shall be long enough to penetrate into the battens[2] or sheathing 3/4 inch or through the thickness of the sheathing, whichever is less. Attaching wire for clay or concrete tile shall not be smaller than 14 gauge and shall comply with U.B.C. Standards Nos. 32-6 and 32-13. Horizontal battens are required on solid sheathing for slopes 7:12 and over.[1]<br>Horizontal battens are required for slopes over 7:12.[2] |



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| | |
|---|---|
| No. of fasteners[3] | Below 5:12, fasteners not required. 5:12 to less than 12:12, one fastener every other row. 12:12 to 24:12, one fastener every tile.[4] All perimeter tiles require one fastener.[5] Solid sheathing without battens, one fastener per tile required. Tiles with installed weight less than 9 pounds per square foot require a minimum of one fastener per tile.[3] |
| With battens | |
| Without battens | One fastener every tile. |
| Tile headlap | 3-inch minimum |
| FLASHING | Per Section 3208 (c) 1 C and 3208 (c) 2 |

[1]In areas designated by the building official as being subject to repeated wind velocities to excess of 80 mph, or where the roof height exceeds 40 feet above grade, all tiles shall be attached as set forth below:

(a) The heads of all tiles shall be nailed.

(b) The noses of all eave course tiles shall be fastened with a special clip.

(c) All rake tiles shall be nailed with two nails.

(d) The noses of all ridge, hip and rake tiles shall be set in a bead of approved roofer's mastic.

[2]Battens shall be not less than 1-inch by 2-inch nominal. Provisions shall be made for drainage beneath battens by a minimum of 1/8-inch risers at each nail or by 4-foot long battens with at least 1/2-inch separation between battens. Battens shall be fastened with approved fasteners spaced at not more than 24 inches on center.

[3]In snow areas a minimum of two fasteners per tile are required, or battens and one fastener.

[4]Slopes over 24:12, nose ends of all tiles must be securely fastened.

[5]Perimeter fastening areas include three tile courses but not less than 36 inches from either side of hips or ridges and edges of eaves and gable rakes.





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## TABLE NO. 32-E—BUILT-UP ROOF COVERING APPLICATION

| | MECHANICALLY FASTENED SYSTEMS | ADHESIVELY FASTENED SYSTEMS |
|---|---|---|
| DECK CONDITIONS | Decks shall be firm, broom-clean, smooth and dry. Insulated decks shall have wood insulation stops at all edges of the deck, unless an alternative suitable curbing is provided. Insulated decks with slopes greater than 2:12 shall have wood insulation stops at not more than 8-feet face-to-face. Wood nailers shall be provided where nailing is required for roofing plies. | |
| | Solid wood sheathing shall conform to Sections 2516 (i) and 2517 (h) 7. | Provide wood nailers where nailing is required for roofing plies (see below). |
| UNDERLAYMENT | One layer of sheathing paper, Type 15 felt or other approved underlayment nailed sufficiently to hold in place, is required over board decks where openings between boards would allow bitumen to drip through. No underlayment requirements for plywood decks. Underlayment on other decks shall be in accordance with deck manufacturer's recommendations. | Not required |
| BASE PLY REQUIREMENTS Over non-insulated decks | Over approved decks, the base ply shall be nailed using not less than one fastener for each 1 1/3 square feet. | Decks shall be primed in accordance with the roofing manufacturer's instructions. The base ply shall be solidly cemented or spot mopped as required by the type of deck material using adhesive application rates shown in Table No. 32-F. |
| MECHANICAL FASTENERS | Fasteners shall be long enough to penetrate 3/4 inch into the sheathing or through the thickness of the sheathing, whichever is less. Built-up roofing nails for wood board decks shall be minimum No. 12 gauge 7/16-inch head driven through tin caps or approved nails with integral caps. For plywood, No. 11 gauge ring-shank nails driven through tin caps or approved nails with integral caps shall be used. For gypsum, insulating concrete, cementitious wood-fiber and other decks, fasteners recommended by the manufacturer shall be used. | When mechanical fasteners are required for attachment of roofing plies to wood nailers or insulation stops, (see below), they shall be as required for wood board decks. |



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| | | |
|---|---|---|
| VAPOR RETARDER<br>Over insulated decks | A vapor retarder shall be installed where the average January temperature is below 45°F., or where excessive moisture conditions are anticipated within the building. It shall be applied as for a base ply. | |
| INSULATION | When no vapor retarder is required, roof insulation shall be fastened in an approved manner. When a vapor retarder is required, roof insulation is to be solidly mopped to the vapor retarder using the adhesive application rate specified in Table No. 32-F. See manufacturer's instructions for the attachment of insulation over steel decks. | When no vapor retarder is required, roof insulation shall be solid mopped to the deck using the adhesive application rate specified in Table No. 32-F. When a vapor retarder is required, roof insulation is to be solidly mopped to the vapor retarder, using the adhesive application rate specified in Table No. 32-F. See manufacturer's installation instructions for attachment of insulation over steel decks. |
| ROOFING PLIES | Successive layers shall be solidly cemented together and to the base ply or the insulation using the adhesive rates shown in Table No. 32-F. On slopes greater than 1:12 for aggregate-surfaced, or 2:12 for smooth-surfaced or cap sheet surfaced roofs, mechanical fasteners are required. Roofing plies shall be blind-nailed to the deck, wood nailers or wood insulation stops in accordance with the roofing manufacturer's recommendations. On slopes exceeding 3:12, plies shall be laid parallel to the slope of the deck (strapping method). | |
| CEMENTING MATERIALS | See Table No. 32-G | |
| CURBS AND WALLS | Suitable cant strips shall be used at all vertical intersections. Adequate attachment shall be provided for both base flashing and counterflashing on all vertical surfaces. Reglets shall be provided in wall or parapets receiving metal counterflashing. | |
| SURFACING | Mineral aggregate surfaced roofs shall comply with the requirements of U.B.C. Standard No. 32-5 and Table No. 32-F. Cap sheets shall be cemented to the roofing plies as set forth in Table No. 32-F. | |





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## TABLE NO. 32-F—BUILT-UP ROOFING
## CEMENTING ADHESIVE AND SURFACING APPLICATION RATES

| | MINIMUM APPLICATION RATE, MATERIAL/100 FT.² ROOF AREA | | |
|---|---|---|---|
| MATERIAL TO BE ADHERED | HOT ASPHALT (Lbs.) | HOT COAL-TAR (Lbs.) | COLD-PROCESS CEMENT (Gal.) |
| Base Ply or Vapor Retarder | | | |
| 1. Spot mopping | 15 | 15 | 1 |
| 2. Solid cementing | 20 | 20 | 1 1/2 |
| Insulation | | | |
| 1. Solid cementing | 20 | 20 | 1 1/2 |
| Roofing Plies (and between layers of vapor retarder) | | | |
| 1. Felts | 20 | 20 | not permitted |
| 2. Coated felts | 20 | 20 | 1 1/2 |
| Cap Sheets | | | |
| 1. Solid cementing | 20 | not permitted | 1 1/2 |
| Mineral Aggregate[1] [2] | | | |
| 1. Fire-retardant roof coverings | | | |
| (a) Gravel, 400 lb./sq. | 50 | 60 | not permitted |
| (b) Slag, 300 lb./sq. | 50 | 60 | not permitted |
| 2. Nonrated roof coverings | | | |
| (a) Gravel, 300 lb./sq. | 40 | 50 | not permitted |
| (b) Slag, 250 lb./sq. | 40 | 50 | not permitted |

[1]Mineral aggregate shall not be used for built-up roofing membranes at roof slopes greater than 3 inches in 12 inches.

[2]A minimum of 50 percent of the required aggregate shall be embedded in the pour coat.



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## TABLE NO. 32-G—APPLICATION OF CEMENTING MATERIALS

| APPLICATION | MAXIMUM SLOPE, INCHES PER 12 INCHES | | | | |
|---|---|---|---|---|---|
| | ASPHALT TYPE | | | | COAL-TAR PITCH |
| | TYPE I | TYPE II | TYPE III | TYPE IV | |
| Insulation to deck | — | — | All | All | — |
| Felt or vapor retarder to deck | — | 1/2 or less | 3 or less | All | 1/2 or less |
| Felt to felt | — | 1/2 or less | 1/2-3 | All | 1/2 or less |
| Cap sheet to felt | — | — | 3 or less | All | — |
| Gravel to felts | 1/2 or less | 1/2 or less | 1/2-3 | N.P. | 1/2 or less |
| Heating of Cementing Mat'l.,[1] °F. | | | | | |
| Temperature at kettle[2] (maximum) | 475 | 525 | 525 | 525 | 425 |
| Application temperature,[3] °F. | 375-425 | 375-425 | 375-425 | 400-450 | 350-400 |

N.P. = Not permitted

[1]Bulk tanker temperatures shall be reduced to 320-350°F. at night or during periods when no roofing will occur.

[2]Cementing material shall not be heated above a temperature which is 25°F. below its flash point.

[3]Asphalt which is identified with the equiviscous temperature (EVT) shall be applied at the EVT ± 25°F.





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# Chapter 33
# EXITS

## General

**Sec. 3301.** (a) **General.** Every building or portion thereof shall be provided with exits as required by this chapter.

(b) **Definitions.** For the purpose of this chapter, certain terms are defined as follows:

**BALCONY, EXTERIOR EXIT,** is a landing or porch projecting from the wall of a building, and which serves as a required exit. The long side shall be at least 50 percent open, and the open area above the guardrail shall be so distributed as to prevent the accumulation of smoke or toxic gases.

**CONTINENTAL SEATING** is the configuration of fixed seating where the number of seats per row exceeds 14 and required exits from the seating area are side exits.

**EXIT** is a continuous and unobstructed means of egress to a public way and shall include intervening aisles, doors, doorways, corridors, exterior exit balconies, ramps, stairways, smokeproof enclosures, horizontal exits, exit passageways, exit courts and yards.

**EXIT COURT** is a yard or court providing access to a public way for one or more required exits.

**EXIT PASSAGEWAY** is an enclosed exit connecting a required exit or exit court with a public way.

**HORIZONTAL EXIT** is an exit from one building into another building on approximately the same level, or through or around a wall constructed as required for a two-hour occupancy separation and which completely divides a floor into two or more separate areas so as to establish an area of refuge affording safety from fire or smoke coming from the area from which escape is made.

**PANIC HARDWARE** is a door-latching assembly incorporating an unlatching device, the activating portion of which extends across at least one half the width of the door leaf on which it is installed.

**PRIVATE STAIRWAY** is a stairway serving one tenant only.

**PUBLIC WAY** is any street, alley or similar parcel of land essentially unobstructed from the ground to the sky which is deeded, dedicated or otherwise permanently appropriated to the public for public use and having a clear width of not less than 10 feet.

**SPIRAL STAIRWAY** is a stairway having a closed circular form in its plan view with uniform section shaped treads attached to and radiating about a minimum diameter supporting column. The effective tread is delineated by the nosing radius line, the exterior arc (center line of railing) and the overlap radius line (nosing radius line of tread above). Effective tread dimensions are taken along a line perpendicular to the center line of the tread.

(c) **Exit Obstruction.** Obstructions shall not be placed in the required width of an exit except projections permitted by this chapter.



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(d) **Changes in Elevation.** Within a building, changes in elevation of less than 12 inches along any exit serving an occupant load of 10 or more shall be by ramps.

**EXCEPTION:** Group R, Division 3 Occupancies and along aisles adjoining seating areas.

(e) **Building Accessibility.** Portions of buildings shall be accessible to the physically handicapped as required by Table No. 33-A, and at least one primary entrance to a building which is required to be accessible shall be usable by the physically handicapped and be on a level that would provide accessibility to the elevators where provided.

## Occupant Load

**Sec. 3302.** (a) **Determination of Occupant Load.** In determining the occupant load, all portions of a building shall be presumed to be occupied at the same time.

**EXCEPTION:** Accessory use areas which ordinarily are used only by persons who occupy the main areas of an occupancy shall be provided with exits as though they are completely occupied, but their occupant load need not be included in computing the total occupant load of the building.

The occupant load for a building shall be determined in accordance with the following:

1. **General.** For areas without fixed seats, the occupant load shall be not less than the number determined by dividing the floor area assigned to that use by the occupant load factor set forth in Table No. 33-A. Where an intended use is not listed in Table No. 33-A the building official shall establish an occupant load factor based on a listed use which most nearly resembles the intended use.

For a building or portion thereof which has more than one use, the occupant load shall be determined by the use which gives the largest number of persons.

The occupant load for buildings or areas containing two or more occupancies shall be determined by adding the occupant loads of the various use areas as computed in accordance with the applicable provisions of this section.

2. **Fixed seating.** For areas having fixed seat and aisles, the occupant load shall be determined by the number of fixed seats installed therein. The required width of aisles serving fixed seats shall not be used for any other purpose.

For areas having fixed benches or pews, the occupant load shall be not less than the number of seats based on one person for each 18 inches of length of pew or bench.

Where booths are used in dining areas, the occupant load shall be based on one person for each 24 inches of booth length or major portion thereof.

3. **Reviewing stands, grandstands and bleachers.** The occupant load for reviewing stands, grandstands and bleachers shall be calculated in accordance with this section and the specific requirements contained in Sections 3323 and 3324.

(b) **Maximum Occupant Load.** The maximum occupant load for other than an assembly use shall not exceed the capacity of exits as determined in accordance with this chapter.



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The maximum occupant load for an assembly use shall not exceed the occupant load as determined in accordance with Section 3302 (a).

**EXCEPTION:** The occupant load for an assembly building or portion thereof may be increased, when approved by the building official, if all the requirements of this code are met for such increased number of persons. The building official may require an approved aisle, seating or fixed equipment diagram to substantiate such an increase, and may require that such diagram be posted.

(c) **Posting of Room Capacity.** Any room having an occupant load of 50 or more where fixed seats are not installed, and which is used for classroom, assembly or similar purpose, shall have the capacity of the room posted in a conspicuous place on an approved sign near the main exit from the room. Such signs shall be maintained legible by the owner or his authorized agent and shall indicate the number of occupants permitted for each room use.

(d) **Revised Occupant Load.** After a building is occupied, any change in use or increase in occupant load shall comply with this chapter. See Section 502.

## Exits Required

**Sec. 3303.** (a) **Number of Exits.** Every building or usable portion thereof shall have at least one exit, not less than two exits where required by Table No. 33-A and additional exits as required by this subsection.

For purposes of this section, basements and occupied roofs shall be provided with exits as required for stories.

**EXCEPTIONS:** Occupied roofs on Group R, Division 3 Occupancies may have one exit if such occupied areas are less than 500 square feet and are located no higher than immediately above the second story.

Floors complying with the provisions for mezzanines as specified in Section 1716 shall be provided with exits as specified therein.

The second story shall be provided with not less than two exits when the occupant load is ten or more. Occupants on floors above the seeond story and in basements shall have access to not less than two separate exits from the floor or basement.

**EXCEPTIONS:** 1. Two or more dwelling units on the second story or in a basement may have access to only one common exit when the total occupant load served by that exit does not exceed ten.

2. Except as provided in Table No. 33-A, only one exit need be provided from the second floor or a basement within an individual dwelling unit. Refer to Section 1204 for emergency escape or rescue requirements from sleeping rooms.

3. When the third floor within an individual dwelling unit does not exceed 500 square feet, only one exit need be provided from that floor.

4. Floors and basements used exclusively for service of the building may have one exit. For the purposes of this exception, storage rooms, laundry rooms, maintenance offices and similar uses shall not be considered as providing service to the building.

5. Storage rooms, laundry rooms and maintenance offices not exceeding 300 square feet in floor area may be provided with only one exit.

For special requirements see the following sections: Group A, Sections 3317



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and 3318; Group E, Section 3319; Group H, Section 3320; Group I, Section 3321; Rooms Containing Fuel-fired Equipment and Cellulose Nitrate Handling Rooms, Section 3322; Reviewing Stands, Grandstands and Bleachers, Sections 3323 and 3324; Laboratories, Sections 702 (b) and 802 (d); and Open Parking Garages, Section 709 (g). For stage exits, see Section 3903 (f).

Every story or portion thereof having an occupant load of 501 to 1000 shall have not less than three exits.

Every story or portion thereof having an occupant load of 1001 or more shall have not less than four exits.

The number of exits required from any story of a building shall be determined by using the occupant load of that story plus the percentages of the occupant loads of floors which exit into the level under consideration as follows:

1. Fifty percent of the occupant load in the first adjacent story above and the first adjacent story below, when a story below exits through the level under consideration.

2. Twenty-five percent of the occupant load in the story immediately beyond the first adjacent story.

The maximum number of exits required for any story shall be maintained until egress is provided from the structure. (See Section 3311.)

(b) **Width.** The total width of exits in feet shall be not less than the total occupant load served divided by 50. Such width of exits shall be divided approximately equally among the separate exits. The total exit width required from any story of a building shall be determined by using the occupant load of that story plus the percentages of the occupant loads of floors which exit through the level under consideration as follows:

1. Fifty percent of the occupant load in the first adjacent story above and the first adjacent story below, when a story below exits through the level under consideration.

2. Twenty-five percent of the occupant load in the story immediately beyond the first adjacent story.

The maximum exit width required from any story of a building shall be maintained.

(c) **Arrangement of Exits.** If only two exits are required, they shall be placed a distance apart equal to not less than one half of the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line between exits.

**EXCEPTION:** When exit enclosures are provided as a portion of the required exit and are interconnected by a corridor conforming to the requirements of Section 3305 (g); exit separations may be measured along a direct line of travel within the exit corridor. Enclosure walls shall be not less than 30 feet apart at any point in a direct line of measurement.

Where three or more exits are required, at least two exits shall be placed a distance apart equal to not less than one half of the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line



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between the exits, and the additional exits shall be arranged a reasonable distance apart so that if one becomes blocked the others will be available.

(d) **Distance to Exits.** The maximum distance of travel from any point to an exterior exit door, horizontal exit, exit passageway or an enclosed stairway in a building not equipped with an automatic sprinkler system throughout shall not exceed 150 feet, or 200 feet in a building equipped with an automatic sprinkler system throughout. These distances may be increased 100 feet when the last 150 feet is within a corridor, complying with Section 3305. See Section 3319 for Group E Occupancy and Section 3320 for Group H Occupancy travel distances.

In a one-story Group B, Division 4 Occupancy classified as a factory or warehouse and in one-story airplane hangars, the exit travel distance may be increased to 400 feet if the building is equipped with an automatic sprinkler system throughout and provided with smoke and heat ventilation as specified in Section 3206.

In an open parking garage as defined in Section 709, the exit travel distance may be increased to 250 feet which may be measured to open stairways which are permitted in accordance with Section 3309 (a).

(e) **Exits Through Adjoining Rooms.** Rooms may have one exit through an adjoining or intervening room which provides a direct, obvious and unobstructed means of travel to an exit corridor, exit enclosure or until egress is provided from the building, provided the total distance of travel does not exeeed that permitted by other provisions of this code: In other than dwelling units, exits shall not pass through kitchens, store rooms, rest rooms, closets or spaces used for similar purposes.

**EXCEPTIONS:** 1. Rooms within dwelling units may exit through more than one intervening room.

2. Rooms with a cumulative occupant load of 10 or less may exit through more than one intervening room.

Foyers, lobbies and reception rooms constructed as required for corridors shall not be construed as intervening rooms.

## Doors

**Sec. 3304.** (a) **General.** This section shall apply to every exit door serving an area having an occupant load of 10 or more, or serving hazardous rooms or areas, except that Subsections (c), (i), (j) and (k) shall apply to all exit doors regardless of occupant load. Buildings or structures used for human occupancy shall have at least one exterior exit door that meets the requirements of Subsection (f).

(b) **Swing and Opening Force.** Exit doors shall be of the pivoted or side-hinged swinging type. Exit doors shall swing in the direction of exit travel when serving any hazardous area or when serving an occupant load of 50 or more. The door latch shall release when subjected to a 15-pound force, and the door shall be set in motion when subjected to a 30-pound force. The door shall swing to full-open position when subjected to 15-pound force. Forces shall be applied to the latch side. See Section 4507 for doors swinging over public property.



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**EXCEPTIONS:** 1. Group I, Division 3 Occupancy used as a place of detention.
2. Doors within or serving an individual dwelling unit.
3. Special door conforming with Subsection (h).

Double-acting doors shall not be used as exits when any of the following conditions exist:

1. The occupant load served by the door is 100 or more.
2. The door is part of a fire assembly.
3. The door is part of a smoke- and draft-control assembly.
4. Panic hardware is required or provided on the door.

A double-acting door shall be provided with a view panel of not less than 200 square inches.

(c) **Type of Lock or Latch.** Exit doors shall be openable from the inside without the use of a key or any special knowledge or effort.

**EXCEPTIONS:** 1. In Group B Occupancies, key-locking hardware may be used on the main exit when the main exit consists of a single door or pair of doors if there is a readily visible, durable sign on or adjacent to the door stating THIS DOOR TO REMAIN UNLOCKED DURING BUSINESS HOURS. The sign shall be in letters not less than 1 inch high on a contrasting background. When unlocked, the single door or both leaves of a pair of doors must be free to swing without operation of any latching device. The use of this exception may be revoked by the building official for due cause.

2. Exit doors from individual dwelling units and guest rooms of Group R Occupancies having an occupant load of 10 or less may be provided with a night latch, dead bolt or security chain, provided such devices are openable from the inside without the use of a key or tool and mounted at a height not to exceed 48 inches above the finished floor.

Manually operated edge- or surface-mounted flush bolts and surface bolts are prohibited. When exit doors are used in pairs and approved automatic flush bolts are used, the door leaf having the automatic flush bolts shall have no door knob or surface-mounted hardware. The unlatching of any leaf shall not require more than one operation.

**EXCEPTIONS:** 1. Group R, Division 3 Occupancies.
2. When a pair of doors serving a room not normally occupied are needed for the movement of equipment, manually operated edge or surface bolts may be used and a door closer need not be provided on the inactive leaf.

(d) **Panic Hardware.** Panic hardware, when installed, shall comply with the requirements of U.B.C. Standard No. 33-4. The activating member shall be mounted at a height of not less than 30 inches nor more than 44 inches above the floor. The unlatching force shall not exceed 15 pounds when applied in the direction of exit travel.

When balanced doors are used and panic hardware is required, panic hardware shall be of the push-pad type and the pad shall not extend across more than one half of the width of the door measured from the latch side.

(e) **Special Egress-control Devices.** When approved by the building official, exit doors in Group B, Division 2 Occupancies may be equipped with approved



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listed special egress-control devices of the time-delay type, provided the building is protected throughout by an approved automatic sprinkler system and an approved automatic smoke-detection system. Such devices shall conform to all of the following:

1. Automatically deactivate the egress-control device upon activation of either the sprinkler system or the detection system.
2. Automatically deactivate the egress-control device upon loss of electrical power to any one of the following:
   A. The egress-control device.
   B. The smoke-detection system.
   C. Exit illumination as required by Section 3313.
3. Be capable of being deactivated by a signal from a switch located in an approved location.
4. Initiate an irreversible process which will deactivate the egress-control device whenever a manual force of not more than 15 pounds is applied for two seconds to the panic bar or other door-latching hardware. The egress-control device shall deactivate within an approved time period not to exceed a total of 15 seconds. The time-delay established for each egress-control device shall not be field adjustable.
5. Actuation of the panic bar or other door-latching hardware shall activate an audible signal at the door.
6. The unlatching shall not require more than one operation.

A sign shall be provided on the door located above and within 12 inches of the panic bar or other door-latching hardware reading:

KEEP PUSHING. THIS DOOR WILL OPEN IN _____ SECONDS. ALARM WILL SOUND.

Sign letter shall be at least 1 inch in height and shall have a stroke of not less than 1/8 inch.

Regardless of the means of deactivation, relocking of the egress-control device shall be by manual means only at the door.

(f) **Width and Height.** Every required exit doorway shall be of a size as to permit the installation of a door not less than 3 feet in width and not less than 6 feet 8 inches in height. When installed, exit doors shall be capable of opening so that the clear width of the exit is not less than 32 inches. In computing the exit width required by Section 3303 (b), the net dimension of the exitway shall be used.

(g) **Door Leaf Width.** A single leaf of an exit door shall not exceed 4 feet in width.

(h) **Special Doors.** Revolving, sliding and overhead doors shall not be used as required exits.

Power-operated doors complying with U.B.C. Standard No. 33-1 may be used for exit purposes. Such doors when swinging shall have two guide rails installed on the swing side projecting out from the face of the door jambs for a distance not less than the widest door leaf. Guide rails shall be not less than 30 inches in height



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with solid or mesh panels to prevent penetration into door swing and shall be capable of resisting a horizontal load at top of rail of not less than 50 pounds per lineal foot.

**EXCEPTIONS:** 1. Walls or other type separators may be used in lieu of the above guide rail, provided all the criteria are met.

2. Guide rails in industrial or commercial occupancies not accessible to the public may conform with Exception 4 to the provision of Section 1711.

3. Doors swinging toward flow of traffic shall not be permitted for use by untrained pedestrian traffic unless actuating devices start to function at least 8 feet 11 inches beyond door in open position and guide rails extend 6 feet 5 inches beyond door in open position.

Clearances for guide rails shall be as follows:

1. Six inches maximum between rails and leading edge of door at the closest point in its are of travel.

2. Six inches maximum between rails and the door in open position.

3. Two inches minimum between rail at hinge side and door in open position.

4. Two inches maximum between freestanding rails and jamb or other adjacent surface.

(i) **Floor Level at Doors.** Regardless of the occupant load, there shall be a floor or landing on each side of a door. When access for the physically handicapped is required by Section 3301 (e), the floor or landing shall be not more than 1/2 inch lower than the threshold of the doorway. When such access is not required, such dimension shall not exceed 1 inch. Landings shall be level except for exterior landings, which may have a slope not to exceed 1/4 inch per foot.

**EXCEPTIONS:** 1. In Groups R, Division 3, and M Occupancies and within individual units of Group R, Division 1 Occupancies:

A. A door may open at the top step of an interior flight of stairs, provided the door does not swing over the top step.

B. A door may open at a landing that is not more than 7 1/2 inches lower than the floor level, provided the door does not swing over the landing.

C. Screen doors and storm doors may swing over stairs, steps or landings.

2. Doors serving building equipment rooms which are not normally occupied.

(j) **Landings at Doors.** Landings shall have a width not less than the width of the stairway or the width of the door, whichever is the greater. Doors in the fully open position shall not reduce a required dimension by more than 7 inches. When a landing serves an occupant load of 50 or more, doors in any position shall not reduce the landing dimension to less than one half its required width. Landings shall have a length measured in the direction of travel of not less than 44 inches.

**EXCEPTION:** In Groups R, Division 3, and M Occupancies and within individual units of Group R, Division 1 Occupancies, such length need not exceed 36 inches.

A landing which has no adjoining door shall comply with Section 3306 (g).

(k) **Door Identification.** Glass doors shall conform to the requirements specified in Section 5406.



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Exit doors shall be so marked that they are readily distinguishable from the adjacent construction.

(l) **Additional Doors.** When additional doors are provided for egress purposes, they shall conform to all provisions of this chapter.

**EXCEPTION:** Approved revolving doors having leaves which will collapse under opposing pressures may be used in exit situations, provided:

1. Such doors have a minimum width of 6 feet 6 inches.
2. At least one conforming exit door is located adjacent to each revolving door.
3. The revolving door shall not be considered to provide any exit width.

## Corridors and Exterior Exit Balconies

**Sec. 3305.** (a) **General.** This section shall apply to every corridor serving as a required exit for an occupant load of 10 or more except that Subsection (b) shall apply to all corridors. For the purposes of the section, the term "corridor" shall include "exterior exit balconies" and any covered or enclosed exit passageway, including walkways, tunnels and malls. Partitions, rails, counters and similar space dividers not over 5 feet 9 inches in height above the floor shall not be construed to form corridors.

Exit corridors shall not be interrupted by intervening rooms.

**EXCEPTION:** Foyers, lobbies or reception rooms constructed as required for corridors shall not be construed as intervening rooms.

For Group I Occupancies see Section 3321 (c).

(b) **Width.** Every corridor serving an occupant load of 10 or more shall be not less than 44 inches in width. Corridors serving an occupant load of less than 10 shall not be less than 36 inches in width. For special requirements for Groups E and I Occupancies, see Sections 3319 and 3321.

(c) **Height.** Corridors and exterior exit balconies shall have a clear height of not less than 7 feet measured to the lowest projection from the ceiling.

(d) **Projections.** The required width of corridors shall be unobstructed.

**EXCEPTION:** Handrails and doors, when fully opened, shall not reduce the required width by more than 7 inches. Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width 11/2 inches on each side.

(e) **Access to Exits.** When more than one exit is required, they shall be so arranged that it is possible to go in either direction from any point in a corridor to a separate exit, except for dead ends not exceeding 20 feet in length.

(f) **Changes in Elevation.** When a corridor or exterior exit balcony is accessible to the handicapped, changes in elevation of the floor shall be made by means of a ramp, except as provided for doors by Section 3304 (i).

(g) **Construction.** Walls of corridors serving a Group R, Division 1 or Group I Occupancy having an occupant load of 10 or more and walls of corridors serving other occupancies having an occupant load of 30 or more shall be of not less than



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one-hour fire-resistive construction and the ceilings shall be not less than that required for a one-hour fire-resistive floor or roof system.

**EXCEPTIONS:** 1. One-story buildings housing Group B, Division 4 Occupancies.

2. Corridors more than 30 feet in width where occupancies served by such corridors have at least one exit independent from the corridor. (See Chapter 56 for covered malls.)

3. Exterior sides of exterior exit balconies.

4. In Group I, Division 3 Occupancies such as jails, prisons, reformatories and similar buildings with open-barred cells forming corridor walls, the corridors and cell doors need not be fire resistive.

5. Corridor walls and ceilings need not be of fire-resistive construction within office spaces having an occupant load of 100 or less when the entire story in which the space is located is equipped with an automatic sprinkler system throughout and smoke detectors are installed within the corridor in accordance with their listing.

6. In other than Type I or II construction, exterior exit balcony roof assemblies may be of heavy timber construction without concealed spaces.

When the ceiling of the entire story is an element of a one-hour fire-resistive floor or roof system, the corridor walls may terminate at the ceiling. When the room-side fire-resistive membrane of the corridor wall is carried through to the underside of a fire-resistive floor or roof above, the corridor side of the ceiling may be protected by the use of ceiling materials as required for one-hour floor or roof system construction or the corridor ceiling may be of the same construction as the corridor walls.

Ceilings of noncombustible construction may be suspended below the fire-resistive ceiling.

For wall and ceiling finish requirements, see Table No. 42-B.

(h) **Openings.** 1. **Doors.** When corridor walls are required to be of one-hour fire-resistive construction by Section 3305 (g), every door opening shall be protected by a tight-fitting smoke- and draft-control assembly having a fire-protection rating of not less than 20 minutes when tested in accordance with U.B.C. Standard No. 43-2. Said doors shall not have louvers. The door and frame shall bear an approved label or other identification showing the rating thereof, the name of the manufacturer and the identification of the service conducting the inspection of materials and workmanship at the factory during fabrication and assembly. Doors shall be maintained self-closing or shall be automatic-closing by actuation of a smoke detector in accordance with Section 4306 (b). Smoke- and draft-control door assemblies shall be provided with a gasket so installed as to provide a seal where the door meets the stop on both sides and across the top.

**EXCEPTIONS:** 1. Viewports may be installed if they require a hole not larger than 1 inch in diameter through the door, have at least a 1/4-inch-thick glass disc and the holder is of metal which will not melt out when subject to temperatures of 1700°F.

2. Protection of openings in the interior walls of exterior exit balconies is not required.

In fully sprinklered office buildings, corridors may lead through enclosed elevator lobbies if all areas of the building have access to at least one required exit without passing through the elevator lobby.



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2. **Openings other than doors.** Where corridor walls are required to be of one-hour fire-resistive construction by Section 3305(g), interior openings for other than doors or ducts shall be protected by fixed, approved 1/4-inch-thick wired glass installed in steel frames. The total area of all openings, other than doors, in any portion of an interior corridor shall not exceed 25 percent of the area of the corridor wall of the room which it is separating from the corridor. For duct openings, see Section 4306.

**EXCEPTION:** Protection of openings in the interior walls of exterior exit balconies is not required.

(i) **Location on Property.** Exterior exit balconies shall not be located in areas where openings are not permitted or where openings are required to be protected due to location on the property.

## Stairways

**Sec. 3306.** (a) **General.** Every stairway having two or more risers serving any building or portion thereof shall conform to the requirements of this section.

**EXCEPTION:** Stairs or ladders used only to attend equipment are exempt from the requirements of this section.

(b) **Width.** Stairways serving an occupant load of 50 or more shall be not less than 44 inches in width. Stairways serving an occupant load of 49 or less shall be not less than 36 inches in width.

Handrails may project into the required width a distance of 3 1/2 inches from each side of a stairway. Stringers and other projections such as trim and similar decorative features may project into the required width 1 1/2 inches on each side.

(c) **Rise and Run.** The rise of every step in a stairway shall be not less than 4 inches nor greater than 7 inches. Except as permitted in Subsections (d) and (f), the run shall be not less than 11 inches as measured horizontally between the vertical planes of the furthermost projection of adjacent treads. Except as permitted in Subsections (d), (e) and (f), the largest tread run within any flight of stairs shall not exceed the smallest by more than 3/8 inch. The greatest riser height within any flight of stairs shall not exceed the smallest by more than 3/8 inch.

**EXCEPTIONS:** 1. Private stairways serving an occupant load of less than 10 and stairways to unoccupied roofs may be constructed with an 8-inch maximum rise and 9-inch minimum run.

2. Where the bottom or top riser adjoins a sloping public way, walk or driveway having an established grade and serving as a landing, the bottom or top riser may be reduced along the slope to less than 4 inches in height with the variation in height of the bottom or top riser not to exceed 3 inches in every 3 feet of stairway width.

(d) **Winding Stairways.** In Group R, Division 3 Occupancies and in private stairways in Group R, Division 1 Occupancies, winders may be used if the required width of run is provided at a point not more than 12 inches from the side of the stairway where the treads are the narrower, but in no case shall any width of run be less than 6 inches at any point.

(e) **Circular Stairways.** Circular stairways may be used as an exit, provided the minimum width of run is not less than 10 inches and the smaller radius is not



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less than twice the width of the stairway. The largest tread width or riser height within any flight of stairs shall not exceed the smallest by more than 3/8 inch.

(f) **Spiral Stairways.** In Group R, Division 3 Occupancies and in private stairways within individual units of Group R, Division 1 Occupancies, spiral stairways may be installed. Such stairways may be used for required exits when the area served is limited to 400 square feet.

The tread must provide a clear walking area measuring at least 26 inches from the outer edge of the supporting column to the inner edge of the handrail. A run of at least 7 1/2 inches is to be provided at a point 12 inches from where the tread is the narrowest. The rise must be sufficient to provide 6-foot 6-inch headroom. The rise shall not exceed 9 1/2 inches.

(g) **Landings.** Every landing shall have a dimension measured in the direction of travel not less than the width of the stairway. Such dimension need not exceed 44 inches when the stair has a straight run. For landings with adjoining doors, see Section 3304 (j).

**EXCEPTION:** Stairs serving an unoccupied roof are exempt from these provisions.

(h) **Basement Stairways.** When a basement stairway and a stairway to an upper story terminate in the same exit enclosure, an approved barrier shall be provided to prevent persons from continuing on into the basement. Directional exit signs shall be provided as specified in Section 3314.

(i) **Distance Between Landings.** There shall be not more than 12 feet vertically between landings.

(j) **Handrails.** Stairways shall have handrails on each side, and every stairway required to be more than 88 inches in width shall be provided with not less than one intermediate handrail for each 88 inches of required width. Intermediate handrails shall be spaced approximately equally across with the entire width of the stairway.

**EXCEPTIONS:** 1. Stairways less than 44 inches in width or stairways serving one individual dwelling unit in Group R, Division 1 or 3 Occupancies may have one handrail.

2. Private stairways 30 inches or less in height may have handrails on one side only.

3. Stairways having less than four risers and serving one individual dwelling unit in Group R, Division 1 or 3, or serving Group M Occupancies need not have handrails.

The top of handrails shall be placed not less than 34 inches nor more than 38 inches above the nosing of treads. They shall be continuous the full length of the stairs and except for private stairways at least one handrail shall extend not less than 6 inches beyond the top and bottom risers. Ends shall be returned or shall terminate in newel posts or safety terminals.

The handgrip portion of handrails shall be not less than 1 1/2 inches nor more than 2 inches in cross-sectional dimension or the shape shall provide an equivalent gripping surface. The handgrip portion of handrails shall have a smooth surface with no sharp corners.



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Handrails projecting from a wall shall have a space of not less than 1 1/2 inches between the wall and the handrail.

(k) **Guardrails.** Stairways open on one or both sides shall have guardrails as required by Section 1711.

(l) **Exterior Stairway Protection.** Except in Group R, Division 3 Occupancies, all openings in the exterior wall below and within 10 feet, measured horizontally, of an exterior exit stairway serving a building over two stories in height or a floor level having such openings in two or more floors below shall be protected by self-closing fire assembly having a three-fourths-hour fire-protection rating. Exterior stairways enclosed on three or more sides shall comply with the flame-spread requirements for interior stairways.

**EXCEPTION:** Openings may be unprotected when two separated exterior stairways serve an exterior exit balcony.

(m) **Interior Stairway Construction.** Interior stairways shall be constructed as specified in Part IV of this code.

Except when enclosed usable space under stairs is prohibited by Section 3309 (f), the walls and soffits of the enclosed space shall be protected on the enclosed side as required for one-hour fire-resistive construction.

All required interior stairways which extend to the top floor in any building four or more stories in height shall have, at the highest point of the stair shaft, an approved hatch openable to the exterior not less than 16 square feet in area with a minimum dimension of 2 feet.

**EXCEPTION:** The hatch need not be provided on smokeproof enclosures or on stairways that extend to the roof with an opening onto that roof.

(n) **Exterior Stairway Construction.** Exterior stairways shall be constructed as specified in Part IV of this code.

Exterior stairways shall not project into yards where openings are not permitted or protection of openings is required.

Enclosed usable space under stairs shall have the walls and soffits protected on the enclosed side as required for one-hour fire-resistive construction.

(o) **Stairway to Roof.** In every building four or more stories in height, one stairway shall extend to the roof surface, unless the roof has a slope greater than 4 in 12. See Subsection 3306 (m) for roof hatch requirements.

(p) **Headroom.** Every stairway shall have a headroom clearance of not less than 6 feet 8 inches. Such clearances shall be measured vertically from a plane parallel and tangent to the stairway tread nosings to the soffit above at all points.

(q) **Stairway Identification.** Approved stairway identification signs shall be located at each floor level in all enclosed stairways in buildings four or more stories in height. The sign shall identify the stairway, indicate whether there is roof access, the floor level, and the upper and lower terminus of the stairway. The sign shall be located approximately 5 feet above the floor landing in a position which is readily visible when the door is in the open or closed position. Signs shall comply with requirements of U.B.C. Standard No. 33-2.



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## Ramps

**Sec. 3307.** (a) **General.** Ramps used as exits shall conform to the provisions of this section.

(b) **Width.** The width of ramps shall be as required for stairways.

(c) **Slope.** The slope of ramps required by Table No. 33-A shall be not steeper than 1 vertical to 12 horizontal. The slope of other ramps shall not be steeper than 1 vertical to 8 horizontal.

When provided with fixed seating, the main floor of the assembly room of a Group A, Division 1, 2, 2.1 or 3 Occupancy may have a slope not steeper than 1 vertical to 5 horizontal.

(d) **Landings.** Ramps having slopes steeper than 1 vertical to 15 horizontal shall have landings at the top and bottom, and at least one intermediate landing shall be provided for each 5 feet of rise. Top landings and intermediate landings shall have a dimension measured in the direction of ramp run of not less than 5 feet. Landings at the bottom of ramps shall have a dimension in the direction of ramp run of not less than 6 feet.

Doors in any position shall not reduce the minimum dimension of the landing to less than 42 inches and shall not reduce the required width by more than 3 1/2 inches when fully open.

When ramp access is provided in accordance with Table No. 33-A and a door swings over a landing, the landing shall extend at least 24 inches beyond the latch edge of the door, measured parallel to the door in the closed position, and shall have a length parallel to the direction of travel through the doorway of not less than 5 feet.

(e) **Handrails.** Ramps having slopes steeper than 1 vertical to 15 horizontal shall have handrails as required for stairways, except that intermediate handrails shall not be required. Ramped aisles need not have handrails on sides serving fixed seating.

(f) **Construction.** Ramps shall be constructed as required for stairways.

(g) **Surface.** The surface of ramps shall be roughened or shall be of slip-resistant materials.

(h) **Guardrails.** See Section 1711.

## Horizontal Exit

**Sec. 3308.** (a) **Used as a Required Exit.** A horizontal exit may be considered as a required exit when conforming to the provisions of this chapter. A horizontal exit shall not serve as the only exit from a portion of a building, and when two or more exits are required, not more than one half of the total number of exits or total exit width may be horizontal exits.

(b) **Openings.** All openings in the two-hour fire-resistive wall which provide a horizontal exit shall be protected by a fire assembly having a fire-protection rating of not less than one and one-half hours.

(c) **Discharge Areas.** A horizontal exit shall lead into a floor area having capacity for an occupant load not less than the occupant load served by such exit.



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The capacity shall be determined by allowing 3 square feet of net clear floor area for each occupant to be accommodated therein, not including areas of stairs, elevators and other shafts or courts. In Group I, Division 1 Occupancies the capacity shall be determined by allowing 15 square feet of net clear floor area per ambulatory occupant and 30 square feet per nonambulatory occupant. The area into which a horizontal exit leads shall be provided with exits adequate to meet the requirements of this chapter but need not include the added capacity imposed by persons entering it through horizontal exits.

## Stairway, Ramp and Escalator Enclosures

**Sec. 3309.** (a) **General.** Every interior stairway, ramp or escalator shall be enclosed as specified in this section.

**EXCEPTIONS:** 1. In other than Groups H and I Occupancies, an enclosure need not be provided for a stairway, ramp or escalator serving only one adjacent floor and not connected with corridors or stairways serving other floors. For enclosure of escalators serving Group B Occupancies, see Chapter 17.

2. Stairs in Group R, Division 3 Occupancies and stairs within individual dwelling units in Group R, Division 1 Occupancies need not be enclosed.

3. Stairs in open parking garages, as defined in Section 709, need not be enclosed.

(b) **Enclosure Construction.** Enclosure walls shall be of not less than two-hour fire-resistive construction in buildings more than four stories in height or of Types I and II fire-resistive construction and shall be of not less than one-hour fire-resistive construction elsewhere.

**EXCEPTION:** In sprinkler-protected parking garages restricted to the storage of private pleasure-type motor vehicles, stairway enclosures may be enclosed with glazing meeting the requirements of Section 4306 (g), (h) and (i).

(c) **Openings into Enclosures.** Openings into exit enclosures other than permitted exterior openings shall be limited to those necessary for exiting from a normally occupied space into the enclosure and exiting from the enclosure. Other penetrations into and opening through exit enclosure are prohibited except for ductwork and equipment necessary for independent stair pressurization, sprinkler piping, standpipes and electrical conduit serving the stairway and terminating in a listed box not exceeding 16 square inches in area. Penetrations and communicating openings between adjacent exit enclosures are not permitted regardless of whether the opening is protected.

All exit doors in an exit enclosure shall be protected by a fire assembly having a fire-protection rating of not less than one hour where one-hour shaft construction is permitted and one and one-half hours where two-hour shaft construction is required. Doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector as provided for in Section 4306 (b). The maximum transmitted temperature end point shall not exceed 450°F. above ambient at the end of 30 minutes of the fire exposure specified in U.B.C. Standard No. 43-2.

(d) **Extent of Enclosure.** Stairway and ramp enclosures shall include landings and parts of floors connecting stairway flights and shall also include a corridor on the ground floor leading from the stairway to the exterior of the building.



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Enclosed corridors or passageways are not required from unenclosed stairways. Every opening into the corridor shall comply with the requirements of Section 3309 (c).

**EXCEPTION:** In office buildings classed as a Group B, Division 2 Occupancy, a maximum of 50 percent of the exits may discharge through a street-floor lobby, provided the required exit width is free and unobstructed and the entire street floor is protected with an automatic sprinkler system.

(e) **Barrier.** A stairway in an exit enclosure shall not continue below the grade level exit unless an approved barrier is provided at the ground-floor level to prevent persons from accidentally continuing into the basement.

(f) **Use of Space Under Stair and Ramp.** There shall be no enclosed usable space under stairways or ramps in an exit enclosure, nor shall the open space under such stairways be used for any purpose.

## Smokeproof Enclosures

**Sec. 3310.** (a) **General.** A smokeproof enclosure shall consist of a vestibule and continuous stairway enclosed from the highest point to the lowest point by walls of two-hour fire-resistive construction. There shall be no openings into the stairway portion of the smokeproof enclosure other than those permitted by the first paragraph of Section 3309 (c). The supporting frame shall be protected as set forth in Table No. 17-A.

In buildings with air-conditioning systems or pressure air supply serving more than one story, an approved smoke detector shall be placed in the return-air duct or plenum prior to exhausting from the building or being diluted by outside air. Upon activation, the detector shall cause the return air to exhaust completely from the building without any recirculation through the building. Such devices may be installed in each room or space served by a return-air duct.

(b) **When Required.** In a building having a floor used for human occupancy which is located more than 75 feet above the lowest level of fire department vehicle access, all of the required exits shall be smokeproof enclosures.

**EXCEPTIONS:** 1. For buildings equipped with an automatic sprinkler system throughout in accordance with Section 1807 (c), smoke-proof enclosures may be omitted, provided all enclosed exit stairways are equipped with a barometric dampered relief opening at the top and the stairway supplied mechanically with sufficient air to discharge a minimum of 2500 cubic feet per minute through the relief opening while maintaining a minimum positive pressure of 0.15-inch water column in the shaft relative to atmospheric pressure with all doors closed. Activation of the mechanical equipment shall be in accordance with Section 3310 (g) 6.

2. Enclosures need not be provided in open parking garages as defined in Section 709.

(c) **Outlet.** A smokeproof enclosure shall exit into a public way or into an exit passageway leading to a public way. The exit passageway shall be without other openings and shall have walls, floors and ceiling of two-hour fire-resistive construction.

(d) **Barrier.** A stairway in a smokeproof enclosure shall not continue below the



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grade level unless an approved barrier is provided at the ground level to prevent persons from accidentally continuing into the basement.

(e) **Access.** Access to stairways in smokeproof enclosures shall be by way of a vestibule or open exterior exit balcony construction of noncombustible materials.

(f) **Smokeproof Enclosure by Natural Ventilation** 1. **Doors.** When a vestibule is provided, the door assembly into the vestibule shall have a one and one-half-hour fire-protection rating, and the door assembly from the vestibule to the stairs shall be a smoke- and draft-control assembly having not less than a 20-minute fire-protection rating. Doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector.

When access to the stairway is by means of an open exterior exit balcony, the door assembly to the stairway shall have a one and one-half-hour fire-protection rating and shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector.

2. **Open-air vestibule.** The vestibule shall have a minimum dimension of 44 inches in width and 72 inches in direction of exit travel. The vestibule shall have a minimum of 16 square feet of opening in a wall facing an exterior court, yard or public way at least 20 feet in width.

(g) **Smokeproof Enclosures by Mechanical Ventilation.** 1. **Doors.** The door assembly from the building into the vestibule shall have a one and one-half-hour fire-protection rating, and the door assembly from the vestibule to the stairway shall be a smoke- and draft-control assembly having not less than a 20-minute fire-protection rating. The door to the stairways shall be provided with a drop sill or other provision to minimize the air leakage. Doors shall be maintained self-closing or shall be automatic-closing by activation of a smoke detector or in the event of a power failure.

2. **Vestibule size.** Vestibules shall have a minimum dimension of 44 inches in width and 72 inches in direction of exit travel.

3. **Vestibule ventilation.** The vestibule shall be provided with not less than one air change per minute, and the exhaust shall be 150 percent of the supply. Supply air shall enter and exhaust air shall discharge from the vestibule through separate tightly constructed ducts used only for that purpose. Supply air shall enter the vestibule within 6 inches of the floor level. The top of the exhaust register shall be down from the top of the smoke trap and shall be entirely within the smoke trap area. Doors, when in the open position, shall not obstruct duct openings. Duct openings may be provided with controlling dampers if needed to meet the design requirements but are not otherwise required.

4. **Smoke trap.** The vestibule ceiling shall be at least 20 inches higher than the door opening into the vestibule to serve as a smoke and heat trap and to provide an upward-moving air column. The height may be decreased when justified by engineering design and field testing.

5. **Stair shaft air movement system.** The stair shaft shall be provided with a dampered relief opening at the top and supplied mechanically with sufficient air to discharge a minimum of 2500 cubic feet per minute through the relief opening



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while maintaining a minimum positive pressure of 0.05 inch of water column in the shaft relative to atmosphere with all doors closed and a minimum of 0.10-inch water column difference between the stair shaft and the vestibule.

6. **Operation of ventilating equipment.** The activation of the ventilating equipment shall be initiated by a smokc deteetor installed outside the vestibule door in an approved loeation. The activation of the closing device on any door shall activate the closing deviees on all doors of the smokeproof enclosure at all levels. When the closing device for the stair shaft and vestibule doors is activated by a smoke deteetor or power failure, the mechanical equipment shall operate at the levels specified in Items Nos. 3 and 5.

7. **Standby power.** Standby power for meehanical ventilation equipment shall be provided by an approved self-contained generator set to operate whenever there is a loss of power in the normal house current. The generator shall be in a separate room having a minimum one-hour fire-resistive oecupancy separation and shall have a minimum fuel supply adequate to operate the equipment for two hours. See Section 1807 (i) for standby power requirements for high-rise Group B, Division 2 offices and Group R, Division 1 Oeeupancies.

8. **Aeceptance testing.** Before the mechanieal equipment is accepted by the building official, it shall be tested to confirm that the mechanical equipment is operating in compliance with these requirements.

9. **Emergency lighting.** The stair shaft and vestibule shall be provided with emergency lighting. A standby generator which is installed for the smokeproof enclosure mechanieal ventilation equipment may be used for such stair shaft and vestibule power supply. See Section 1807 (i) for emergency lighting requirements for high-rise Group B, Division 2 offices and Group R, Division 1 Occupancies.

## Exit Courts

**Sec. 3311.** (a) **General.** Every exit court shall discharge into a public way or exit passageway.

(b) **Width.** Exit eourt minimum widths shall be determined in accordance with provisions of Section 3303 based on the occupant load and such required width shall be unobstructed to a height of 7 feet, except for projections permitted in corridors by Seetion 3305. The minimum exit court width shall be not less than 44 inches.

When the width is reduced from any cause, the reduction shall be affeeted gradually by a guardrail at least 3 feet in height and making an angle of not more than 30 degrees with the axis of the exit eourt.

(c) **Number of Exits.** Every exit court shall be provided with exits as determined by Section 3303.

(d) **Construction and Openings.** When an exit court serving a building or portion thereof having an occupant load of 10 or more is less than 10 feet in width, the exit court walls shall be a minimum of one-hour fire-resistive construction for a distance of 10 feet above the floor of the court, and all openings therein shall be protected by fire assemblies having a fire-protection rating of not less than three-fourths hour.



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## Exit Passageways

**Sec. 3312.** (a) **Construction and Openings.** The walls of exit passageways shall be without openings other than required exits and shall have walls, floors and ceilings of the same period of fire resistance as required for the walls, floors and ceilings of the building served with a minimum of one-hour fire-resistive construction. Exit openings through the enclosing walls of exit passageways shall be protected by fire assemblies having a three-fourths-hour fire-protection rating.

(b) **Detailed Requirements.** Except for construction and opening protection as specified in Subsection (a) above, exit passageways shall comply with the requirements for corridors as specified in Section 3305.

## Exit Illumination

**Sec. 3313.** (a) **General.** Except within individual dwelling units, guest rooms and sleeping rooms, exits shall be illuminated at any time the building is occupied with light having intensity of not less than 1 footcandle at floor level.

**EXCEPTION:** In auditoriums, theaters, concert or opera halls and similar assembly uses, the illumination at floor level may be reduced during performances to not less than 0.2 footcandle.

Fixtures required for exit illumination shall be supplied from separate sources of power where required by Subsection (b).

(b) **Separate sources of power.** The power supply for exit illumination shall normally be provided by the premises' wiring system. In the event of its failure, illumination shall be automatically provided from an emergency system for Group I, Division 1 Occupancies and for all other occupancies where the exiting system serves an occupant load of 100 or more.

For high-rise buildings, see Section 1807. For smokeproof enclosures, see Section 3310 (g) 9.

Emergency systems shall be supplied from storage batteries or an on-site generator set and the system shall be installed in accordance with the requirements of the Electrical Code.

## Exit Signs

**Sec. 3314.** (a) **Where Required.** Exit signs shall be installed at required exit doorways and where otherwise necessary to clearly indicate the direction of egress when the exit serves an occupant load of 50 or more.

**EXCEPTION:** Main exterior exit doors which obviously and clearly are identifiable as exits need not be signed when approved by the building official.

(b) **Graphics.** The color and design of lettering, arrows and other symbols on exit signs shall be in high contrast with their background. Words on the sign shall be in block letters 6 inches in height with a stroke of not less than 3/4 inch.

(c) **Illumination.** Signs shall be internally or externally illuminated by two electric lamps or shall be of an approved self-luminous type. When the luminance on the face of an exit sign is from an external source, it shall have an intensity of not less than 5.0 footcandles from either lamp. Internally illuminated signs shall provide equivalent luminance.



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(d) **Power Supply.** Current supply to one of the lamps for exit signs shall be provided by the premises' wiring system. Power to the other lamp shall be from storage batteries or an on-site generator set and the system shall be installed in accordance with the Electrical Code. For high-rise buildings, see Section 1807.

## Aisles

**Sec. 3315.** (a) **General.** Aisles leading to required exits shall be provided from all portions of buildings.

(b) **Width.** Aisle widths shall be provided in accordance with the following:

1. In areas serving employees only, the minimum aisle width may be 24 inches but not less than the width required by the number of employees served.
2. In public areas of Group B, Division 2 Occupancies, and in assembly occupancies without fixed seats, the minimum clear aisle width shall be 36 inches where tables, counters, furnishings, merchandise or other similar obstructions are placed on one side of the aisle only and 44 inches when such obstructions are placed on both sides of the aisle.
3. In assembly occupancies with fixed seats.
   A. With standard seating, every aisle shall be not less than 3 feet when serving seats on only one side and not less than 42 inches wide when serving seats on both sides. Such minimum width shall be measured from the point furthest from the exit, cross aisle or foyer and such minimum width shall be increased by 1 1/2 inches for each 5 feet of length toward the exit, cross aisle or foyer.
   B. With continental seating as specified in Section 3316, side aisles shall be provided and be not less than 44 inches in width.

(c) **Distances to Nearest Exit.** In areas occupied by seats and in Group A Occupancies without seats, the line of travel to an exit door by an aisle shall be not more than 150 feet. Such travel distance may be increased to 200 feet if the building is provided with an approved automatic sprinkler system.

(d) **Aisle Spacing.** With standard seating, aisles shall be so located that there will be not more than six intervening seats between any seat and the nearest aisle.

With continental seating, the number of intervening seats may be increased, provided the seating configuration conforms with the requirements specified in Section 3316.

When benches or pews are used, the number of seats shall be based on one person for each 18 inches of length of pew or bench.

(e) **Cross Aisles.** Aisles shall terminate in a cross aisle, foyer or exit. The width of the cross aisle shall be not less than the sum of the required width of the widest aisle plus 50 percent of the total required width of the remaining aisles leading thereto. In Groups A and E Occupancies, aisles shall not have a dead end greater than 20 feet in length.

(f) **Vomitories.** Vomitories connecting the foyer or main exit with the cross aisles shall have a total width not less than the sum of the required width of the



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widest aisle leading thereto plus 50 pereent of the total required width of the remaining aisles leading thereto.

(g) **Slope.** The slope portion of aisles shall be not steeper than 1 vertical in 8 horizontal, except as permitted in Section 3307 (c).

(h) **Steps.** Steps shall not be used in an aisle when the change in elevation is less than 1 vertical in 8 horizontal. A single step or riser shall not be used in any aisle. Steps in aisles shall extend across the full width of the aisle and shall be illuminated. Treads and risers in such steps shall comply with Section 3306 (c).

## Seat Spacing

**Sec. 3316.** (a) **Standard Seating.** With standard seating, the spacing of chairs shall provide a space of not less than 12 inches from the back of one chair to the front of the most forward projection of the chair immediately behind. The rows of chairs shall be spaced not less than 33 inches back-to-back. Horizontal measurements shall be made between vertical planes. When all chairs in a row have automatic- or self-rising seats, the measurement may be made with the seats in the up position. When any chair in the row does not have an automatic- or self-rising seat, then the measurement shall be made with the seat in the down position.

(b) **Continental Seating.** The number of seats per row of seats for continental seating may be increased subject to all of the following conditions:

1. The spacing of unoccupied seats shall provide a clear width between rows of seats measured horizontally as follows (automatic- or self-rising seats shall be measured in the seat-up position, other seats shall be measured in the seat-down position):
   18 inches between rows for 1 to 18 seats
   20 inches between rows for 19 to 35 seats
   21 inches between rows for 36 to 45 seats
   22 inches between rows for 46 to 59 seats
   24 inches between rows for 60 seats or more
2. Exit doors shall be provided along each side aisle of the row of seats at the rate of one pair of doors for each five rows of seats.
3. Each pair of exit doors shall provide a minimum clear width of 66 inches discharging into a foyer, lobby, approved stairway, exit passageway leading to a public way, or the exterior of the building.
4. There shall be not more than five seat rows between pairs of doors.

## Group A, Division 1 Occupancies

**Sec. 3317.** (a) **Main Exit.** Every Group A, Division 1 Occupancy shall be provided with a main exit.

The main exit shall be of sufficient width to accommodate one half of the total occupant load but shall be not less than the total required width of all aisles, exit passageways and stairways leading thereto and shall connect to a continuous and unobstructed means of egress to a public way.

(b) **Side Exits.** Every auditorium of a Group A, Division 1 Occupancy shall be provided with exits on each side. The exits on each side of the auditorium shall be



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of sufficient width to accommodate one third of the total occupant load served. Side exits shall open directly to a public way or into an exit court, approved stairway, exterior stairway or exit passageway leading to a public way. Side exits shall be accessible from a cross aisle.

(e) **Balcony Exits.** Every balcony having an occupant load of 11 or more shall be provided with a minimum of two exits. Balcony exits shall open directly to an exterior stairway or other approved stairway or ramp. When there is more than one balcony, exits shall open into an exterior or enclosed stairway or ramp. Balcony exits shall be accessible from a cross aisle. The number and distribution of exits shall be as otherwise specified in this chapter.

(d) **Panic Hardware.** An exit door from a Group A, Division 1 Occupancy having an occupant load of 50 or more shall not be provided with a latch or lock unless it is panic hardware.

## Group A, Divisions 2, 2.1, 3 and 4 Occupancies

**Sec. 3318.** (a) **Group A, Divisions 2, 2.1 and 3.** Group A, Divisions 2 and 2.1 Occupancies shall have exits as required by Section 3317. In Group A, Division 3 Occupancies having an occupant load of 50 or more, exit doors shall not be provided with a latch or lock unless it is panic hardware.

**EXCEPTION:** In Group A, Division 3 Occupancies and in all churches, panic hardware may be omitted from the main exit when the main exit consists of a single door or pair of doors. A key-locking device may be used in place of the panic hardware, provided there is a readily visible durable sign adjacent to the doorway stating THIS DOOR MUST REMAIN UNLOCKED DURING BUSINESS HOURS. The sign shall be in letters not less than 1 inch high on a contrasting background. When unlocked, the single door or both leaves of a pair of doors must be free to swing without operation of any latching device. When a pair of doors is installed, one leaf shall have no locking devices whatsoever, and the second leaf shall be arranged to latch or lock into the frame and into the first leaf in such a manner that a single unlocking action will unlock both leaves simultaneously. Flush, edge or surface bolts or any other type of device that may be used to close or restrain the door other than by operation of the locking device are prohibited. The use of this exception may be revoked by the building official for due cause.

(b) **Group A, Division 4.** In Group A, Division 4 Occupancies having an occupant load of 50 or more, exit doors shall not be provided with a latch or lock unless it is panic hardware.

Panic hardware may be waived on gates surrounding stadiums when the gates are under constant immediate supervision while the public is present, and provided safe dispersal areas based on 3 square feet per occupant are located between the stadium and the fence. The required dispersal area shall be located not less than 50 feet from the stadium.

## Group E Occupancies

**Sec. 3319.** (a) **Definitions.** For the purpose of this section, the following definitions apply:

**INTERIOR ROOM** is a room whose only exit is through an adjoining or intervening room which is not an exit corridor.



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**ROOM** is a space or area bounded by any obstructions to exit passage which at any time enelose more than 80 percent of the perimeter of the area. In computing the unobstructed perimeter, openings less than 3 feet in clear width and less than 6 feet 8 inches high shall not be considered.

**SEPARATE EXIT SYSTEM** is a path of exit travel separated in such a manner from other required exits as to provide an atmospheric separation which precludes contamination of both paths by the same fire.

(b) **Separate Exit Systems Required.** Every room with an occupant load of more than 300 shall have one of its exits into a separate exit system. When three or more exits are required from a room, no more than two required exits shall enter into the same exit system.

(c) **Distance to Exits.** 1. The distance from any point in a room shall be not more than 75 feet from an exit corridor, an enclosed stairway or the exterior of the building.

**EXCEPTIONS:** 1. In buildings not more than two stories in height and proteeted throughout with smoke detectors, the distance may be increased to 90 feet.

2. In buildings protected throughout by an automatic sprinkler system, the distance may be increased to 110 feet.

2. All portions of unsprinklered building shall be not more than 150 feet from either an exterior exit door, a horizontal exit, an exit passageway or an enclosed stairway measured along the line of travel. In a building protected throughout with an automatic sprinkler system such distance may be increased to 225 feet. In buildings not more than two stories in height protected throughout with smoke detectors, the distance may be increased to 175 feet.

(d) **Exits Through Adjoining Rooms.** Interior rooms may exit through adjoining or intervening rooms, provided the total distance of travel through such rooms to an exit corridor does not exceed that specified in Subsection (c) 1 above and is a direct, obvious and unobstructed path of travel. Such paths of exit travel shall not pass through kitchens, storerooms, rest rooms, closets, laboratories using hazardous materials, industrial shops or other similar places.

Foyers and lobbies constructed as required for exit corridors shall not be construed as adjoining or intervening rooms.

When the only means of exit from a room is through an adjoining or intervening room, smoke detectors shall be installed throughout the area of the common atmosphere through which the exit must pass. The detectors shall actuate alarms audible in the interior room and shall be connected to the school fire alarm system.

**EXCEPTIONS:** 1. When the aggregate occupant load of the interior room or rooms is 10 or less.

2. When the enclosures forming interior rooms are less than two thirds of the floor-to-ceiling height and do not exceed 8 feet.

3. Rooms used exclusively for mechanical and public utility service to the buildings.

(e) **Corridors and Exterior Exit Balconies.** Corridor walls and ceilings shall be of not less than one-hour fire-resistive construction with openings protected as required in Section 3305 (h).



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**EXCEPTION:** When each room used for instruction has at least one exit door directly to the exterior at ground level and when rooms used for assembly purposes have at least one half of the required exits directly to the exterior ground level, one-hour fire-resistive construction of corridor walls and ceilings is not required.

Any change in elevation of less than 2 feet in a corridor or exterior exit balcony shall be by means of ramps.

The width of a corridor in a Group E, Division 1 Occupancy shall be the width required by Section 3303, plus 2 feet, but not less than 6 feet.

**EXCEPTION:** When the number of occupants served is 100 or less, the corridor may be 44 inches wide.

(f) **Exit Serving Auditoriums in Group E, Division 1 Occupancy.** An exit serving an auditorium and other rooms need provide only for the capacity of whichever requires the greater width if the auditorium is not to be used simultaneously with the other rooms.

(g) **Stairs.** Each floor above or below the ground floor level shall have not less than two exit stairs and the required exit width shall be equally divided between such stairs, provided that stairs serving an occupant load of 100 or more shall be not less than 5 feet in clear width.

**EXCEPTION:** This subsection does not apply to rooms used for maintenance, storage and similar purposes.

(h) **Doors.** The width of exit doors shall be sufficient to accommodate the occupant load served.

(i) **Basement Rooms.** Exit stairways from a basement shall open directly to the exterior of the building without entering the first floor corridor.

(j) **Panic Hardware.** Exit doors from rooms having an occupant load of 50 or more and from corridors shall not be provided with a latch or lock unless it is panic hardware.

(k) **Fences and Gates.** School grounds may be fenced and gates therein equipped with locks, provided safe dispersal areas are located not less than 50 feet from the buildings. Dispersal areas shall be sized to provide an area of not less than 3 square feet per occupant. Gates shall not be installed across corridors or passageways leading to such dispersal areas unless they comply with exit requirements. See Section 3323 for exits from dispersal areas.

## Group H Occupancies

**Sec. 3320.** Every portion of a Group H Occupancy having a floor area of 200 square feet or more shall be served by at least two separate exits.

**EXCEPTION:** Group H, Division 4 Occupancies having a floor area of less than 1000 square feet may have one exit.

Within Group H, Divisions 1, 2 and 3 Occupancies, all portions of any room shall be within 75 feet of an exit.

Doors leading to a corridor of fire-resistive construction shall have a minimum three-fourths-hour fire-protection rating; shall have not more than 100 square inches of wired glass set in steel frames; shall be maintained self-closing or shall



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be automatic closing as defined in Section 4306 (b); and shall open in the direction of exit travel.

Within Group H, Division 7 and within fabrication areas of Group H, Division 6 Occupancies, the distance of travel to an exterior exit door, exit corridor, horizontal exit, exit passageway or an enclosed stairway shall not exceed 100 feet.

## Group I Occupancies

**Sec. 3321.** (a) **Exterior Doors.** All required exterior exit doors shall open in the direction of exit travel.

(b) **Minimum Size of Exits.** The clear width of exits serving areas occupied or used by bed or litter patients shall be such that it will allow ready passage of such equipment, but shall not be less than 44 inches. Other exits shall have a clear width of not less than 32 inches. There shall be no projections into the clear width.

(c) **Corridors.** The minimum clear width of a corridor shall be 44 inches, except that corridors serving any area housing one or more nonambulatory persons shall be not less than 8 feet in width. Any change in elevation of the floor in a corridor serving nonambulatory persons shall be made by means of a ramp.

Corridors shall comply with Section 3305 except that in hospitals and nursing homes classified as Group I, Division 1 Occupancies the following exceptions apply:

1. Nurses' stations including space for doctors' and nurses' charting and communications constructed as required for corridors need not be separated from corridors.
2. Waiting areas and similar spaces constructed as required for corridors need not be separated from corridors, provided:
   (i) Each space is located to permit direct visual supervision by the facility staff, and
   (ii) The space and corridors into which the space opens are in the same smoke compartment and the space is protected by an approved electrically supervised automatic smoke-detection system.
3. Door closers need not be installed on doors to sleeping rooms.
4. Fixed fully-tempered or laminated glass in wood or metal frames may be used in corridor walls, provided the glazed area does not exceed 25 percent of the area of the corridor wall of the room.
5. The total area of glass in corridor walls is not limited when the glazing is fixed 1/4-inch-thick wired glass in steel frames and the size of individual glazed panel does not exceed 1296 square inches.

(d) **Basement Exits.** One exit accessible to every room below grade shall lead directly to the exterior at grade level.

(e) **Ramps.** Group I, Division 1 Occupancies housing nonambulatory patients shall have access to a ramp leading from the first story to the exterior of the building at the ground floor level.

(f) **Hardware.** Exit doors serving an area having an occupant load of 50 or



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more shall not be provided with a latch or lock unless it is panic hardware. Patient room doors shall be readily openable from either side without the use of keys.

**EXCEPTIONS:** 1. In Group I, Division 1 hospitals and nursing homes, locking devices, when approved, may be installed on patient sleeping rooms, provided such devices are readily openable from the patient room side and are readily operable by the facility staff on the other side. When key locks are used on patient room doors, keys shall be located on the floor involved at a prominent location accessible to the staff.

2. No requirements of this chapter shall be construed as to prohibit the construction of cell blocks in jails or prevent the use of any locks or safety devices where it is necessary to forcibly restrain the inmates.

## Special Hazards

**Sec. 3322.** (a) **Rooms Containing Fuel-fired Equipment or Cellulose Nitrate.** Except in Group R, Division 3 Occupancies, any room containing a boiler, furnace, incinerator or other fuel-fired equipment shall be provided with two exits when both of the following conditions exist:

1. The area of the room exceeds 500 square feet, and
2. The largest piece of fuel-fired equipment exceeds 400,000 Btu per hour input capacity.

If two exits are required, one may be a fixed ladder. Exits shall be separated by a horizontal distance not less than half the greatest horizontal dimension of the room. Interior openings between a Group H Occupancy and an incinerator room are prohibited.

(b) **Cellulose Nitrate Handling.** When cellulose nitrate is handled in film laboratories, projection rooms and film processing rooms, two exits shall be provided. Doors shall be self-closing and have a fire-protection rating of not less than one hour.

## Reviewing Stands, Grandstands and Bleachers

**Sec. 3323.** (a) **Scope.** The provisions of this section apply to reviewing stands, grandstands and bleachers: (See Section 3324 for folding and telescoping seating.)

(b) **Definitions.** For the purpose of this section certain terms are defined as follows:

**BLEACHERS** are tiered or stepped seating facilities without backrests in which an area of 3 square feet or less is assigned per person for computing the occupant load.

**DISPERSAL AREA, SAFE,** is an area which will accommodate a number of persons equal to the total capacity of the stand and building which it serves such that a person within the area will not be closer than 50 feet from the stand or building. Dispersal area capacity shall be determined by allowing 3 square feet of net clear area per person.

**FOOTBOARDS** are that part of a raised seating facility other than an aisle or cross aisle upon which the occupant walks to reach a seat.



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**GRANDSTANDS** are tiered or stepped seating facilities wherein an area of more than 3 square feet is provided for each person.

**OPEN-AIR GRANDSTANDS AND BLEACHERS** are seating facilities which are located so that the side toward which the audience faces is unroofed and without an enclosing wall.

**PERMANENT STANDS** are those seating facilities which remain at a location for more than 90 days.

**REVIEWING STANDS** are elevated platforms accommodating not more than 50 persons. Seating facilities, if provided, are normally in the nature of loose chairs. Reviewing stands accommodating more than 50 persons shall be regulated as grandstands.

**TEMPORARY SEATING FACILITIES** are those which are intended for use at a location for not more than 90 days.

(c) **Height of Grandstands and Bleachers.** See Section 602 (a).

(d) **Design Requirements.** See Chapter 23 and Section 2907 (i).

(e) **General Requirements.** 1. **Row spacing.** There shall be a clear space of not less than 12 inches measured horizontally between the back or backrest of each seat and the front of the seat immediately behind it. The minimum spacing of rows of seats measured from back to back shall be:

A. Twenty-two inches for seats without backrests.

B. Thirty inches for seats with backrests.

C. Thirty-three inches for chair seating.

2. **Rise between rows.** The maximum rise from one row of seats to the next shall not exceed 16 inches unless the seat spacing from back to back measured horizontally is 40 inches or more.

> **EXCEPTION:** When automatic- or self-rising seats are installed, the rise between rows may be increased to 24 inches with the horizontal spacing back to back of 33 inches.

3. **Seating capacity determination.** When bench-type seating is used, the number of seats shall be based on one person for each 18 inches of length of the bench.

4. **Aisles.** A. **Aisles required.** Aisles shall be provided in all seating facilities except that aisles may be omitted when all of the following conditions exist:

(i) Seats are without backrests.

(ii) The rise from row to row does not exceed 12 inches per row.

(iii) The number of rows does not exceed 11 in height.

(iv) The top seating board is not over 10 feet above grade.

(v) The first seating board is not more than 20 inches above grade.

B. **Obstructions.** No obstruction shall be placed in the required width of any aisle or exitway.

C. **Width.** Aisles serving seats on both sides shall have a minimum width of 42



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inches. When serving seats on only one side, the aisle shall have a minimum width of 36 inches.

5. **Cross aisles and vomitories.** Cross aisles and vomitories shall be not less than 54 inches in clear width and shall extend to an exit, enclosed stairway or exterior perimeter ramp.

6. **Stairs and ramps.** All stairs and ramps shall have a maximum rise and run as provided in Section 3306 (c) and Section 3307, except those within the seating area which serve as aisles at right angles to the rows of seats where the rise shall not exceed 8 inches. When an aisle terminates at an elevation more than 8 inches above grade, the aisle shall be provided with a stairway or ramp whose width is not less than the width of the aisle.

7. **Guardrails.** Perimeter guardrails or enclosing walls or fencing shall be provided for all portions of elevated seating facilities which are more than 30 inches above grade or floor. Construction of guardrails shall comply with Section 1711 and Table No. 23-B. Guardrails shall be 42 inches above the rear of a seat board or 42 inches above the rear of the steps in an aisle when the guardrail is parallel and adjacent to the aisle.

**EXCEPTION:** Guardrails at the front of the front row of seats, which are not located at the end of an aisle and where there is no cross aisle, may have a height of 26 inches and need not meet the 6-inch maximum spacing specified in Section 1711; however, a midrail shall be installed.

The open vertical space between footboards and seats shall not exceed 9 inches when footboards are more than 30 inches above grade.

8. **Toeboards.** A 4-inch-high vertical barrier shall be installed along the edge of walking platforms whenever guardrails are required.

**EXCEPTION:** Toeboards shall not be required at the ends of footboards.

9. **Footboards.** Footboards shall be provided for all rows of seats above the third row or beginning at such a point where the seating plank is more than 2 feet above grade. When the same platform is used for both seating and footrests, footrests are not required, provided each level or platform is not less than 24 inches wide. Footboards in bleachers at a level below the seat board it serves are not to be considered as walking platforms but shall be not less than a structural grade of 2-inch by 8-inch lumber or equivalent. When aisles are required by Section 3323 (e) 4, footboards not less than 18 inches in width shall be installed between each row of seats.

(f) **Grandstands and Bleachers Within Buildings.** Except as otherwise provided in this section, grandstands and bleachers within a building shall comply with the other applicable sections of this chapter.

**EXCEPTIONS:** 1. When seats are without backrests, there may be nine seats between any seat and an aisle.

2. When seats are without backrests, dead ends in vertical aisles shall not exceed a depth of 16 rows.

(g) **Open-air Grandstands and Bleachers.** Except as otherwise provided in Items Nos. 1 through 9 below, open-air grandstands and bleachers shall comply with the other applicable sections of this chapter.



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1. **Number of seats between aisles.** The number of seats between any seat and an aisle shall be not greater than 20 when the seats are without backrests and nine if the seats have backrests.

2. **Dead ends.** Dead ends in vertical aisles shall not exceed a depth of 16 rows for permanent grandstands and 26 rows for temporary grandstands.

3. **Distance to exit.** The line of travel from any seat to a safe dispersal area exit ramp, enclosed stairway or vomitory shall be not more than 200 feet. When the seats have no backrests, the distance may be a direct line measurement.

4. **Safe dispersal area.** Each safe dispersal area shall have a minimum of two exits. If more than 6000 persons are to be accommodated within a dispersal area, there shall be a minimum of three exits and for more than 9000 persons there shall be at least four exits. The aggregate clear width of exits from a safe dispersal area shall be determined on the basis of not less than one exit unit of 22 inches for each 500 persons to be accommodated and no exit shall be less than 44 inches in width.

5. **Two exits required.** Two exits shall be provided from every stand which accommodates more than 300 persons.

6. **Three exits required.** Three exits shall be required when a grandstand or section thereof accommodates more than 1000 persons.

7. **Four exits required.** Four exits shall be required when a grandstand or section thereof accommodates more than 3000 persons.

8. **Determination of exit width.** The total width of exits in feet shall be not less than the total occupant load served divided by 150 when exiting by stairs and divided by 200 when exiting by ramps, corridors, tunnels or vomitories.

9. **Minimum exit width.** No exit shall be less than 42 inches in width.

## Folding and Telescoping Seating

**Sec. 3324.** (a) **Scope.** Folding and telescoping seating facilities shall conform to the provisions of this section.

(b) **Definition.** For the purpose of this section:

**FOLDING AND TELESCOPING SEATING** is a structure that is used for tiered seating of persons, and whose overall shape and size may be reduced, without being dismantled, for purposes of moving or storing.

(c) **Design Requirements.** See Chapter 23 and Section 2907 (i).

(d) **General Requirements.** 1. **Aisles.** Aisles shall be required when any of the following conditions exist:

A. Backrest-type seating is used.

B. Rise from row to row exceeds 12 inches per row.

C. Exiting from seating is restricted by railings or other obstacles.

D. Row spacing exceeds 28 inches unless seat boards and footboards are at the same elevation.



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E. Seat boards are of other than continuous flat surfaces.

F. The number of rows exceeds 11 in height.

2. **Number of seats between aisles.** When aisles are provided, aisles shall be arranged so that the number of seats between any seat and the nearest aisle shall not exceed:

A. For seating within a building, the number of seats between any seat and an aisle shall not exceed nine when seats are without backrests and six if seats have backrests.

B. For seating not within a building, the number of seats between any seat and an aisle shall not exceed 20 when seats are without backrests and 11 if seats have backrests.

3. **Aisle width.** Aisles shall be not less than 34 inches in clear width. When an aisle is divided by a portal, column or other obstruction, a minimum aisle clear width of 22 inches shall be provided on each side of such obstructions.

4. **Aisle steps.** Intermediate aisle steps are not required when the rise per row is 12 inches or less. When the rise per row exceeds 12 inches, an intermediate aisle step shall be provided; this step shall divide the rise into two or more equal parts of not more than 12 inches each and have a minimum tread width of 10 inches. When the seat board and footboard are not on the same elevation in a bleacher installation requiring intermediate aisle steps, the rear corner of each seat board adjacent to the aisle shall be chamfered to a maximum of 4½ inches by 45 degrees to provide a minimum of 6 inches of ankle clearance between aisle step and seat board.

5. **Seating.** The horizontal distance back to back shall be not less than 22 inches for seats without backrests. There shall be a space of not less than 12 inches between the back of each seat and the front of each seat immediately behind it. If seats are of the chair type, the 12-inch dimension shall be measured to the front edge of the rear seat in its normal unoccupied position. All measurements shall be taken between plumb lines.

The width of footboards and seat boards shall be not less than 9 inches. When the same level is not used for both seat boards and footboards, footboards independent of seats shall be provided.

6. **Guardrails.** Perimeter guardrails or enclosing walls or fencing shall be provided for all portions of elevated seating facilities which are more than 30 inches above grade or floor. Construction of guardrails shall comply with Section 1711 and Table No. 23-B. Guardrails shall be 42 inches above the rear of a seat board or 42 inches above the rear of the steps in an aisle when the guardrail is parallel and adjacent to the aisle.

**EXCEPTIONS:** 1. Guardrails at the front of the front row of seats, which are not located at the end of an aisle and where there is no cross aisle, may have a height of 26 inches and need not meet the 6-inch maximum spacing specified in Section 1711; however, a midrail shall be installed.

2. When seating is adjacent to a wall or fence within 6 inches of the seating and of sufficient height and strength to afford the intended protection, guardrails may be omitted.



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Cross aisles located within the seating area shall be provided with guardrails not less than 26 inches high along the front edge of the aisle.

**EXCEPTION:** When the backs of the seats in front of the cross aisle project 24 inches or more above the surface of the cross aisle, guardrails may be omitted.

**TABLE NO. 33-A—MINIMUM EGRESS AND ACCESS REQUIREMENTS**

| USE[1] | MINIMUM OF TWO EXITS OTHER THAN ELEVATORS ARE REQUIRED WHERE NUMBER OF OCCUPANTS IS AT LEAST | OCCUPANT LOAD FACTOR[2] (Sq. Ft.) | ACCESS BY MEANS OF A RAMP OR AN ELEVATOR MUST BE PROVIDED FOR THE PHYSICALLY HANDICAPPED AS INDICATED[3] |
|---|---|---|---|
| 1. Aircraft Hangars (no repair) | 10 | 500 | Yes |
| 2. Auction Rooms | 30 | 7 | Yes |
| 3. Assembly Areas, Concentrated Use (without fixed seats)<br>Auditoriums<br>Churches and Chapels<br>Dance Floors<br>Lobby Accessory to Assembly Occupancy<br>Lodge Rooms<br>Reviewing Stands<br>Stadiums | 50 | 7 | Yes[4,5] |
| Waiting Area | 50 | 3 | Yes[4,5] |
| 4. Assembly Areas, Less-concentrated Use<br>Conference Rooms<br>Dining Rooms<br>Drinking Establishments<br>Exhibit Rooms<br>Gymnasiums<br>Lounges<br>Stages | 50 | 15 | Yes[4,5,6] |
| 5. Bowling Alley (assume no occupant load for bowling lanes) | 50 | [12] | Yes |
| 6. Children's Homes and Homes for the Aged | 6 | 80 | Yes[7] |
| 7. Classrooms | 50 | 20 | Yes[8] |
| 8. Courtrooms | 50 | 40 | Yes |
| 9. Dormitories | 10 | 50 | Yes[7] |
| 10. Dwellings | 10 | 300 | No |

*(Continued)*



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| USE[1] | MINIMUM OF TWO EXITS OTHER THAN ELEVATORS ARE REQUIRED WHERE NUMBER OF OCCUPANTS IS AT LEAST | OCCUPANT LOAD FACTOR[2] (Sq. Ft.) | ACCESS BY MEANS OF A RAMP OR AN ELEVATOR MUST BE PROVIDED FOR THE PHYSICALLY HANDICAPPED AS INDICATED[3] |
|---|---|---|---|
| 11. Exercising Rooms | 50 | 50 | Yes |
| 12. Garage, Parking | 30 | 200 | Yes[9] |
| 13. Hospitals and Sanitariums—Nursing Homes | 6 | 80 | Yes |
| 14. Hotels and Apartments | 10 | 200 | Yes[10] |
| 15. Kitchen—Commercial | 30 | 200 | No |
| 16. Library Reading Room | 50 | 50 | Yes[4] |
| 17. Locker Rooms | 30 | 50 | Yes |
| 18. Malls (see Chapter 56) | — | — | — |
| 19. Manufacturing Areas | 30 | 200 | Yes[7] |
| 20. Mechanical Equipment Room | 30 | 300 | No |
| 21. Nurseries for Children (Day care) | 7 | 35 | Yes |
| 22. Offices | 30 | 100 | Yes[7] |
| 23. School Shops and Vocational Rooms | 50 | 50 | Yes |
| 24. Skating Rinks | 50 | 50 on the skating area; 15 on the deck | Yes[4] |
| 25. Storage and Stock Rooms | 30 | 300 | No |
| 26. Stores—Retail Sales Rooms | | | |
| Basement | [11] | 30 | Yes |
| Ground Floor | 50 | 30 | Yes |
| Upper Floors | 10 | 60 | Yes |
| 27. Swimming Pools | 50 | 50 for the pool area; 15 on the deck | Yes[4] |
| 28. Warehouses | 30 | 500 | No |
| 29. All others | 50 | 100 | |

*(Footnotes appear on page 666.)*



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## FOOTNOTES FOR TABLE NO. 33-A

[1]For additional provisions on number of exits from Group H and I Occupancies and from rooms containing fuel-fired equipment or cellulose nitrate, see Sections 3320, 3321 and 3322, respectively.

[2]This table shall not be used to determine working space requirements per person.

[3]Elevators shall not be construed as providing a required exit.

[4]Access to secondary areas on balconies or mezzanines may be by stairs only, except when such secondary areas contain the only available toilet facilities.

[5]Reviewing stands, grandstands, bleachers, and folding and telescopic bleachers need not comply.

[6]Access requirements for conference rooms, dining rooms, lounges and exhibit rooms that are part of an office use shall be the same as required for the office use.

[7]Access to floors other than that closest to grade may be by stairs only, except when the only available toilet facilities are on other levels.

[8]When the floor closest to the grade offers the same programs and activities available on other floors, access to the other floors may be by stairs only, except when the only available toilet facilities are on other levels.

[9]Access to floors other than that closest to grade and to garages used in connection with apartment houses may be by stairs only.

[10]See Section 1214 for access to buildings and facilities in hotels and apartments.

[11]See Section 3303 for basement exit requirements.

[12]Occupant load based upon five persons for each alley, including 15 feet of runway.



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# Chapter 34
# SLOPED GLAZING AND SKYLIGHTS

**NOTE: This chapter has been revised in its entirety.**

## Scope

**Sec. 3401.** This chapter applies to the installation of glass or other transparent, translucent or opaque glazing material installed at a slope of 15 degrees or more from the vertical plane including glazing materials in skylights, roofs and sloped walls.

## Allowable Glazing Materials

**Sec. 3402.** Sloped glazing shall be of any of the following materials, subject to the limitations specified in Section 3403.

For single-layer glazing systems, the glazing material of the single light or layer shall be laminated glass with a minimum 30 mil polyvinyl butyral (or equivalent) interlayer, wired glass, approved plastic materials meeting the requirements of Section 5207, heat-strengthened glass or fully-tempered glass.

For multiple-layer glazing systems, each light or layer shall consist of any of the glazing materials specified above.

Annealed glass may be used as specified within Exceptions 2 and 3 of Section 3403.

## Screening

**Sec. 3403.** Heat-strengthened glass and fully-tempered glass when used in single-layer glazing systems shall have screens installed below glazing. The screens shall be capable of supporting the weight of the glass and shall be substantially supported below and installed within 4 inches of the glass. They shall be constructed of a noncombustible material not thinner than 0.08 inch with a mesh not larger than 1 inch by 1 inch. In a corrosive atmosphere, structurally equivalent noncorrosive screening materials shall be used. Heat-strengthened glass, fully-tempered glass and wired glass, when used in multiple-layer glazing systems as the bottom glass layer over the walking surface, shall be equipped with screening which complies with the requirements for monolithic glazing systems.

**EXCEPTIONS:** 1. Fully-tempered glass may be installed without required protective screens when located between intervening floors at a slope of 30 degrees or less from the vertical plane if the highest point of the glass is 10 feet or less above the walking surface.

2. Allowable glazing material, including annealed glass, may be installed without required screens if the walking surface or any other accessible area below the glazing material is permanently protected from falling glass for a minimum horizontal distance equal to twice the height.

3. Allowable glazing material, including annealed glass, may be installed without screens in the sloped glazing systems of commercial or detached greenhouses used exclusively for growing plants and not intended for use by the public, provided the height of the greenhouse at the ridge does not exceed 20 feet above grade.



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## Framing

**Sec. 3404.** In Types I and II construction, skylight frames shall be constructed of noncombustible materials.

**EXCEPTION:** In foundries or buildings where acid fumes deleterious to metal are incidental to the use of the buildings, approved pressure-treated woods or other approved noncorrosive materials may be used for sash and frames.

Skylights set at an angle of less than 45 degrees from the horizontal plane shall be mounted at least 4 inches above the plane of the roof on a curb constructed of materials as required for the frame. Skylights may be installed in the plane of the roof when the roof slope is 45 degrees or greater from horizontal.

## Design Loads

**Sec. 3405.** Sloped glazing and skylights shall be designed to withstand the tributary loads specified in Section 2305. Sizing limitations specified within Graph No. 54-1 and Table No. 54-A may be utilized for glazing materials set forth in Section 3402, provided the design loads are increased by a factor of 2.67.

## Floors and Sidewalks

**Sec. 3406.** Glass used for the transmission of light, if placed in floors or sidewalks, shall be supported by metal or reinforced concrete frames, and such glass shall be not less than 1/2 inch in thickness. Any such glass over 16 square inches in area shall have wire mesh embedded in the same or shall be provided a wire screen underneath, as specified for skylights in this section. All portions of the floor lights or sidewalk lights shall be of the same strength as is required by this code for floor or sidewalk construction, except in cases where the floor is surrounded by a railing not less than 3 feet 6 inches in height, in which case the construction shall be calculated for not less than roof loads.

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# Chapter 35
# SOUND TRANSMISSION CONTROL

For Sound Transmission Control, see Appendix Chapter 35.



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# Chapter 36
# PENTHOUSES AND ROOF STRUCTURES

## Penthouses and Roof Structures

**Sec. 3601.** (a) **Height.** No penthouse or other projection above the roof in structures of other than Type I construction shall exceed 28 feet in height above the roof when used as an enclosure for tanks or for elevators which run to the roof and in all other cases shall not extend more than 12 feet in height above the roof.

(b) **Area.** The aggregate area of all penthouses and other roof structures shall not exceed 33⅓ percent of the area of the supporting roof.

(c) **Prohibited Uses.** No penthouse, bulkhead or any other similar projection above the roof shall be used for purposes other than shelter of mechanical equipment or shelter of vertical shaft openings in the roof. Penthouses or bulkheads used for purposes other than permitted by this section shall conform to the requirements of this code for an additional story.

(d) **Construction.** Roof structures shall be constructed with walls, floors and roof as required for the main portion of the building.

**EXCEPTIONS:** 1. On Types I and II-F.R. buildings, the exterior walls and roofs of penthouses which are 5 feet or more from an adjacent property line may be of one-hour fire-resistive noncombustible construction.

2. On Types III and IV buildings, walls not less than 5 feet from an adjacent property line may be of one-hour fire-resistive noncombustible construction.

3. Enclosures housing only mechanical equipment and located at least 20 feet from adjacent property lines may be of unprotected noncombustible construction.

4. On one-story buildings, unroofed mechanical equipment screens, fences or similar enclosures may be of combustible construction when located at least 20 feet from adjacent property lines and when not exceeding 4 feet in height above the roof surface.

The restrictions of this subsection shall not prohibit the placing of wood flagpoles or similar structures on the roof of any building.

## Towers and Spires

**Sec. 3602.** Towers or spires when enclosed shall have exterior walls as required for the building to which they are attached. Towers not enclosed and which extend more than 75 feet above grade shall have their framework constructed of iron, steel or reinforced concrete. No tower or spire shall occupy more than one fourth of the street frontage of any building to which it is attached and in no case shall the base area exceed 1600 square feet unless it conforms entirely to the type of construction requirements of the building to which it is attached and is limited in height as a main part of the building. If the area of the tower or spire exceeds 100 square feet at any horizontal cross section, its supporting frame shall extend directly to the ground. The roof covering of spires shall be as required for the main roof of the rest of the structure.

Skeleton towers used as radio masts and placed on the roof of any building shall be constructed entirely of noncombustible materials when more than 25 feet in height and shall be directly supported on a noncombustible framework to the ground. They shall be designed to withstand a wind load from any direction as specified in Section 2311 in addition to any other loads.



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# Chapter 37
# CHIMNEYS, FIREPLACES AND BARBECUES

## Scope

**Sec. 3701.** Chimneys, flues, fireplaces and barbecues, and their connections, carrying products of combustion shall conform to the requirements of this chapter.

## Definitions

**Sec. 3702. BARBECUE** is a stationary open hearth or brazier, either fuel fired or electric, used for food preparation.

**CHIMNEY** is a hollow shaft containing one or more passageways, vertical or nearly so, for conveying products of combustion to the outside atmosphere.

**CHIMNEY, FACTORY-BUILT,** is a chimney manufactured at a location other than the building site and composed of listed factory-built components assembled in accordance with the terms of the listing to form the completed chimney.

**MASONRY CHIMNEY** is a chimney of masonry units, bricks, stones or listed masonry chimney units lined with approved flue liners. For the purpose of this chapter, masonry chimneys shall include reinforced concrete chimneys.

**CHIMNEY CLASSIFICATIONS:**

**Chimney, Residential Appliance-type,** is a factory-built or masonry chimney suitable for removing products of combustion from residential-type appliances producing combustion gases not in excess of 1000°F measured at the appliance flue outlet.

**Chimney, Low-heat Industrial Appliance-type,** is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning low-heat appliances producing combustion gases not in excess of 1000°F under normal operating conditions but capable of producing combustion gases of 1400°F during intermittent forced firing for periods up to one hour. All temperatures are measured at the appliance flue outlet.

**Chimney, Medium-heat Industrial Appliance-type,** is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning medium-heat appliances producing combustion gases not in excess of 2000°F measured at the appliance flue outlet.

**Chimney, High-heat Industrial Appliance-type,** is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning high-heat appliances producing combustion gases in excess of 2000°F measured at the appliance flue outlet.

**CHIMNEY CONNECTOR** is the pipe or breeching which connects a fuel-burning appliance to a chimney. (See Chapter 9, Mechanical Code.)

**CHIMNEY LINER** is a lining material of fireclay or other approved material that meets the requirements of U.B.C. Standard No. 37-1.



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**FIREBRICK** is a refractory brick which meets the requirements of U.B.C. Standard No. 37-1.

**FIREPLACE** is a hearth and fire chamber or similar prepared place in which a fire may be made and which is built in conjunction with a chimney.

**Factory-built Fireplace** is a listed assembly of a fire chamber, its chimney and related factory-made parts designed for unit assembly without requiring field construction. Factory-built fireplaces are not dependent upon mortar-filled joints for continued safe use.

**Masonry Fireplace** is a hearth and fire chamber of solid masonry units such as bricks, stones, masonry units, or reinforced concrete provided with a suitable chimney.

## Chimneys, General

**Sec. 3703.** (a) **Chimney Support.** Chimneys shall be designed, anchored, supported and reinforced as required in this chapter and applicable provisions of Chapters 23, 24, 26, 27 and 29 of this code. A chimney shall not support any structural load other than its own weight unless designed as a supporting member.

(b) **Construction.** Each chimney shall be so constructed as to safely convey flue gases not exceeding the maximum temperatures for the type of construction as set forth in Table No. 37-B and shall be capable of producing a draft at the appliance not less than that required for safe operation.

(c) **Clearance.** Clearance to combustible material shall be as required by Table No. 37-B.

(d) **Lining.** When required by Table No. 37-B, chimneys shall be lined with fireclay flue tile, firebrick, molded refractory units or other approved lining not less than 5/8 inch thick as set forth in Table No. 37-B. Chimney liners shall be carefully bedded in approved mortar with close-fitting joints left smooth on the inside.

(e) **Area.** Chimney passageways shall be not smaller in area than the vent connection on the appliance attached thereto nor less than that set forth in Table No. 37-A, unless engineering methods approved by the building official have been used to design the system.

(f) **Height and Termination.** Every chimney shall extend above the roof and the highest elevation of any part of a building as shown in Table No. 37-B. For altitudes over 2000 feet, the building official shall be consulted in determining the height of the chimney.

All incinerator chimneys shall terminate in a substantially constructed spark arrester having a mesh not exceeding 1/2 inch.

(g) **Cleanouts.** Cleanout openings shall be provided at the base of every masonry chimney.

## Masonry Chimneys

**Sec. 3704.** (a) **Design.** Masonry chimneys shall be designed and constructed to comply with Section 3703 (b) and Section 3704 (b).



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(b) **Walls.** Walls of masonry chimneys shall be constructed as set forth in Table No. 37-B.

(c) **Reinforcing and Seismic Anchorage.** Unless a specific design is provided, every masonry or concrete chimney in Seismic Zones No. 2, No. 3 and No. 4 shall be reinforced with not less than four No. 4 steel reinforcing bars conforming to the provisions of Chapter 24 or 26 of this code. The bars shall extend the full height of the chimney and shall be spliced in accordance with the applicable requirements of Chapters 24 and 26. The bars shall be tied horizontally at 18-inch intervals with not less than 1/4-inch-diameter steel ties. Two ties shall also be placed at each bend in vertical bars. Where the width of the chimney exceeds 40 inches, two additional No. 4 vertical bars shall be provided for each additional flue incorporated in the chimney or for each additional 40 inches in width or fraction thereof.

In Seismic Zones No. 2, No. 3 and No. 4, all masonry and concrete chimneys shall be anchored at each floor or ceiling line more than 6 feet above grade, except when constructed completely within the exterior walls of the building. Anchorage shall consist of two 3/16-inch by 1-inch steel straps cast at least 12 inches into the chimney with a 180-degree bend with a 6-inch extension around the vertical reinforcing bars in the outer face of the chimney.

Each strap shall be fastened to the structural framework of the building with two 1/2-inch bolts per strap. Where the joists do not head into the chimney the anchor straps shall be connected to 2-inch by 4-inch ties crossing a minimum of four joists. The ties shall be connected to each joist with two 16d nails. Metal chimneys shall be anchored at each roof and ceiling with two 1 1/2-inch by 1/8-inch metal straps looped around the outside of the chimney insulation and nailed with six 8d nails per strap to the roof or ceiling framing.

(d) **Chimney Offset.** Masonry chimneys may be offset at a slope of not more than 4 inches in 24 inches but not more than one third of the dimension of the chimney in the direction of the offset. Where lined, the lining shall be cut to fit.

(e) **Change in Size or Shape.** Changes in the size or shape of a masonry chimney, where the chimney passes through the roof, shall not be made within a distance of 6 inches above or below the roof joists or rafters.

(f) **Separation of Masonry Chimney Passageways.** Two or more flues in a chimney shall be separated by masonry not less than 4 inches thick bonded into the masonry wall of the chimney.

(g) **Inlets.** Every inlet to any masonry chimney shall enter the side thereof and shall be of not less than 1/8-inch-thick metal or 5/8-inch-thick refractory material.

## Factory-built Chimneys and Fireplaces

**Sec. 3705.** (a) **General.** Factory-built chimneys and factory-built fireplaces shall be listed and shall be installed in accordance with the terms of their listings and the manufacturer's instructions as specified in the Mechanical Code.

(b) **Hearth Extensions.** Hearth extensions of listed factory-built fireplaces shall conform to the conditions of listing and the manufacturer's installation instructions.



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(c) **Multiple Venting in Vertical Shafts.** Factory-built chimneys utilized with listed factory-built fireplaces may be used in a common vertical shaft having the required fire-resistanee rating.

## Metal Chimneys

**Sec. 3706.** Metal chimneys shall be constructed and installed to meet the requirements of the Mechanical Code.

## Masonry and Concrete Fireplaces and Barbecues

**Sec. 3707.** (a) **General.** Masonry fireplaces, barbecues, smoke chambers and fireplaee chimneys shall be of masonry or reinforced eoncrete and shall conform to the requirements of this section.

(b) **Support.** Masonry fireplaees shall be supported on foundations designed as specified in Chapters 23, 24 and 29.

When an approved design is not provided, foundations for masonry and concrete fireplaces shall be not less than 12 inches thick, extend not less than 6 inches outside the fireplace wall and project below the natural ground surface in accordance with the depth of foundations set forth in Table No. 29-A.

(c) **Fireplace Walls.** Masonry walls of fireplaces shall be not less than 8 inches in thickness. Walls of fireboxes shall be not less than 10 inches in thickness, except that where a lining of firebrick is used such walls shall be not less than a total of 8 inches in thickness. The firebox shall be not less than 20 inches in depth. Joints in firebrick shall not exceed 1/4 inch.

(d) **Hoods.** Metal hoods used as part of a fireplace or barbecue shall be not less than No. 19 gauge copper, galvanized steel or other equivalent corrosion-resistant ferrous metal with all seams and connections of smokeproof unsoldered constructions. The hoods shall be sloped at an angle of 45 degrees or less from the vertical and shall extend horizontally at least 6 inches beyond the limits of the firebox. Metal hoods shall be kept a minimum of 18 inches from combustible materials unless approved for reduced clearances.

(e) **Metal Heat Circulators.** Approved metal heat circulators may be installed in fireplaces.

(f) **Smoke Chamber.** Front and side walls shall be not less than 8 inches in thickness. Smoke chamber back walls shall be not less than 6 inches in thickness.

(g) **Chimneys.** Chimneys for fireplaces shall be constructed as specified in Sections 3703, 3704 and 3705 for residential-type appliances.

(h) **Clearance to Combustible Material.** Combustible materials shall not be placed within 2 inches of fireplace, smoke chamber or chimney walls. Combustible material shall not be placed within 6 inches of the fireplace opening. No such combustible material within 12 inches of the fireplace opening shall project more than 1/8 inch for each 1-inch clearance from such opening.

No part of metal hoods used as part of a fireplace or barbecue shall be less than 18 inches from combustible material. This clearance may be reduced to the minimum requirements specified in the Mechanical Code.



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(i) **Areas of Flues, Throats and Dampers.** The net cross-sectional area of the flue and of the throat between the firebox and the smoke chamber of a fireplace shall be not less than as set forth in Table No. 37-A. Metal dampers equivalent to not less than No. 12 gauge steel shall be installed. When fully opened, damper openings shall be not less than 90 percent of the required flue area.

(j) **Lintel.** Masonry over the fireplace opening shall be supported by a noncombustible lintel.

(k) **Hearth.** Masonry fireplaces shall be provided with a brick, concrete, stone or other approved noncombustible hearth slab. This slab shall be not less than 4 inches thick and shall be supported by noncombustible materials or reinforced to carry its own weight and all imposed loads. Combustible forms and centering shall be removed.

(l) **Hearth Extensions.** Hearths shall extend at least 16 inches from the front of, and at least 8 inches beyond each side of, the fireplace opening. Where the fireplace opening is 6 square feet or larger, the hearth extension shall extend at least 20 inches in front of, and at least 12 inches beyond each side of, the fireplace opening.

Except for fireplaces which open to the exterior of the building, the hearth slab shall be readily distinguishable from the surrounding or adjacent floor.

(m) **Firestopping.** Firestopping between chimneys and wooden construction shall meet the requirements specified in Section 2516.

(n) **Nonconforming Fireplaces.** Imitation and other fireplaces not conforming to the other requirements of this section shall not exceed 6 inches in depth. Gas-burning appliances may be installed in such nonconforming fireplaces, provided that compliance is made in accordance with the requirements of the Mechanical Code.



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## TABLE NO. 37-A—MINIMUM PASSAGEWAY AREAS FOR MASONRY CHIMNEYS[1]

| TYPE OF MASONRY CHIMNEY | MINIMUM CROSS-SECTIONAL AREA | | |
|---|---|---|---|
| | TILE LINED | | LINED WITH FIREBRICK OR UNLINED |
| | ROUND | SQUARE OR RECTANGLE | |
| 1. Residential | 50 sq. in. | 50 sq. in. | 85 sq. in. |
| 2. Fireplace[2] | 1/12 of opening Minimum 50 sq. in. | 1/10 of opening Minimum 64 sq. in. | 1/8 of opening Minimum 100 sq. in. |
| 3. Low heat | 50 sq. in. | 57 sq. in. | 135 sq. in. |
| 4. Incinerator | | | |
| Apartment type | | | |
| 1 opening | 196 sq. in. | | |
| 2 to 6 openings | 324 sq. in. | | |
| 7 to 14 openings | 484 sq. in. | | Not applicable |
| 15 or more openings | 484 sq. in. plus 10 sq. in. for each additional opening | | |

[1]Areas for medium- and high-heat chimneys shall be determined using accepted engineering methods and as approved by the building official.

[2]Where fireplaces open on more than one side, the fireplace opening shall be measured along the greatest dimension.

**Note:** For altitudes over 2000 feet above sea level, the building official shall be consulted in determining the area of the passageway.



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## TABLE NO. 37-B—CONSTRUCTION, CLEARANCE AND TERMINATION REQUIREMENTS FOR MASONRY AND CONCRETE CHIMNEYS

| Chimneys Serving | Thickness (Min. Inches) | | Height Above Roof Opening (Feet) | Height Above any Part of Building within (Feet) | | | Clearance to Combustible Construction (Inches) | |
|---|---|---|---|---|---|---|---|---|
| | Walls | Lining | | 10 | 25 | 50 | Int. Inst. | Ext. Inst. |
| 1. RESIDENTIAL-TYPE APPLIANCES[1] [2] (Low Btu Input) | | | | | | | | |
| Clay, Shale or Concrete Brick | 4[3] | 5/8 fire-clay tile or 2 fire-brick | 2 | 2 | | | 2 | 1 or ½ gypsum[4] |
| Reinforced Concrete | 4[3] | | | | | | | |
| Hollow Masonry Units | 4[8] | | | | | | | |
| Stone | 12 | | | | | | | |
| Unburned Clay Units | 8 | 4½ fire-brick | | | | | | |
| 2. BUILDING HEATING AND INDUSTRIAL-TYPE LOW-HEAT APPLIANCES[1] [2] (1000°F. operating temp.—1400°F. Maximum) | | | | | | | | |
| Clay, Shale or Concrete Brick | 8 | 5/8 fire-clay tile or 2 fire-brick | 3 | 2 | | | 2 | 2 |
| Hollow Masonry Units | 8[8] | | | | | | | |
| Reinforced Concrete | 8 | | | | | | | |
| Stone | 12 | | | | | | | |



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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **3. MEDIUM-HEAT INDUSTRIAL-TYPE APPLIANCES[1, 5]** (2000°F. Maximum) | | | | | | | | |
| Clay, Shale or Concrete Brick | 8 | 4½ Medium duty fire-brick | 10 | | 10 | | 4 | 4 |
| Hollow Masonry Units (Grouted Solid) | 8 | | | | | | | |
| Reinforced Concrete | 8 | | | | | | | |
| Stone | 12 | | | | | | | |
| **4. HIGH-HEAT INDUSTRIAL-TYPE APPLIANCES[1, 2]** (Over 2000°F.) | | | | | | | | |
| Clay, Shale or Concrete Brick | 16[6] | 4½ High duty fire-brick | 20 | | | 20 | [7] | [7] |
| Hollow Masonry Units (Grouted Solid) | 16[6] | | | | | | | |
| Reinforced Concrete | 16[6] | | | | | | | |
| **5. RESIDENTIAL TYPE INCINERATORS** | Same as for Residential-Type Appliances as shown above | | | | | | | |
| **6. CHUTE-FED AND FLUE-FED INCINERATORS WITH COMBINED HEARTH AND GRATE AREA 7 SQ. FT. OR LESS** | | | | | | | | |
| Clay, Shale or Concrete Brick or Hollow Units | | 4½ Medium duty fire-brick | 3 | 2 | | | 2 | 2 |
| Portion extending to 10 ft. above combustion chamber roof | 4 | 5/8 fire-clay tile liner | | | | | | |
| Portion more than 10 ft. above combustion chamber roof | 8 | | | | | | | |

(Continued)





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## TABLE NO. 37-B—CONSTRUCTION, CLEARANCE AND TERMINATION REQUIREMENTS FOR MASONRY AND CONCRETE CHIMNEYS—(Continued)



| Chimneys Serving | Thickness (Min. Inches) | | Height Above Roof Opening (Feet) | Height Above any Part of Building within (Feet) | | | Clearance to Combustible Construction (Inches) | |
|---|---|---|---|---|---|---|---|---|
| | Walls | Lining | | 10 | 25 | 50 | Int. Inst. | Ext. Inst. |
| **7. CHUTE-FED AND FLUE-FED INCINERATORS — COMBINED HEARTH AND GRATE AREAS LARGER THAN 7 SQ. FT.** | | | | | | | | |
| Clay, Shale or Concrete Brick or Hollow Units Grouted Solid or Reinforced Concrete | | 4½ Medium duty fire-brick | | | | | | |
| Portion extending to 40 ft. above combustion chamber roof | 4 | 5/8 fire-clay tile liner | | 10 | | | 2 | 2 |
| Portion more than 40 ft. above combustion chamber roof | 8 | 4½ Medium | | | | | | |
| Reinforced Concrete | 8 | duty fire-brick laid in medium duty refract mortar | | | | | | |
| **8. COMMERCIAL OR INDUSTRIAL – TYPE INCINERATORS[2]** | | | | | | | | |
| Clay or Shale Solid Brick | 8 | 4½ Medium | | | | | | |
| Reinforced Concrete | 8 | duty fire-brick laid in medium duty refract mortar | | 10 | | | 4 | 4 |



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[1]See Table No. 9-A of the Mechanical Code for types of appliances to be used with each type of chimney.
[2]Lining shall extend from bottom to top of chimney.
[3]Chimneys having walls 8 inches or more in thickness may be unlined.
[4]Chimneys for residential-type appliances installed entirely on the exterior of the building. For fireplace and barbecue chimneys, see Section 3707 (h).
[5]Lining to extend from 24 inches below connector to 25 feet above.
[6]Two 8-inch walls with 2-inch air space between walls. Outer and inner walls may be of solid masonry units or reinforced concrete or any combination thereof.
[7]Clearance shall be approved by the building official and shall be such that the temperature of combustible materials will not exceed 160°F.
[8]Equivalent thickness including grouted cells when grouted solid. The equivalent thickness may also include the grout thickness between the liner and masonry unit.





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# Chapter 38
# FIRE-EXTINGUISHING SYSTEMS

## Scope

**Sec. 3801.** (a) **General.** All fire-extinguishing systems required in this code shall be installed in accordance with the requirements of this chapter.

Fire hose threads used in connection with fire-extinguishing systems shall be National Standard hose thread or as approved by the fire department.

In buildings used for high-piled combustible storage, fire protection shall be in accordance with the Fire Code.

(b) **Approvals.** All fire-extinguishing systems including automatic sprinkler systems, Classes I, II and III standpipe systems, combined systems, special automatic extinguishing systems and basement pipe inlets shall be approved and shall be subject to such periodic tests as may be required. The location of all fire department hose connections shall be approved by the fire department.

(c) **Definitions.** For the purpose of this chapter, certain terms are defined as follows:

**AUTOMATIC FIRE-EXTINGUISHING SYSTEM** is an approved system of devices and equipment which automatically detects a fire and discharges an approved fire-extinguishing agent onto or in the area of a fire.

**COMBINED SYSTEM** is a system of water piping which serves 2 1/2-inch hose outlets for use by the fire department and also supplies water to fire sprinklers.

**FIRE DEPARTMENT INLET CONNECTION** is a connection through which the fire department can pump water into a standpipe system, or sprinkler system.

**STANDPIPE SYSTEM** is a wet or dry system of piping, valves, outlets and related equipment designed to provide water at specified pressures and installed exclusively for the fighting of fires, including the following:

**Class I** is a standpipe system equipped with 2 1/2-inch outlets.

**Class II** is a standpipe system directly connected to a water supply and equipped with 1 1/2-inch outlets and hose.

**Class III** is a standpipe system directly connected to a water supply and equipped with 2 1/2-inch outlets or 2 1/2-inch and 1 1/2-inch outlets when a 1 1/2-inch hose is required. Hose connections for Class III systems may be made through 2 1/2-inch hose valves with easily removable 2 1/2-inch by 1 1/2-inch reducers.

(d) **Standards.** Fire-extinguishing systems shall comply with U.B.C. Standards Nos. 38-1 and 38-2.

**EXCEPTIONS:** 1. Automatic fire-extinguishing systems not covered by U.B.C. Standard No. 38-1 or 38-2 shall be approved and installed in accordance with the Fire Code.

2. Automatic sprinkler systems may be connected to the domestic water-supply main when approved by the building official, provided the domestic water supply is of adequate pressure, capacity and sizing for the combined domestic and sprinkler



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requirements. In such case, the sprinkler system connection shall be made between the public water main or meter and the building shutoff valve, and there shall not be intervening valves or connections. The fire department connection may be omitted when approved by the fire department.

## Automatic Fire-extinguishing Systems

**Sec. 3802.** (a) **Where Required.** An automatic fire-extinguishing system shall be installed in the occupancies and locations as set forth in this section.

For special provisions on hazardous chemicals and magnesium, and calcium carbide, see the Fire Code.

(b) **All Occupancies Except Group R, Division 3 and Group M.** Except for Group R, Division 3 and Group M Occupancies, an automatic sprinkler system shall be installed:

1. In every story or basement of all buildings when the floor area exceeds 1500 square feet and there is not provided at least 20 square feet of opening entirely above the adjoining ground level in each 50 lineal feet or fraction thereof of exterior wall in the story or basement on at least one side of the building. Openings shall have a minimum dimension of not less than 30 inches. Such openings shall be accessible to the fire department from the exterior and shall not be obstructed in a manner that fire fighting or rescue cannot be accomplished from the exterior.

   When openings in a story are provided on only one side and the opposite wall of such story is more than 75 feet from such openings, the story shall be provided with an approved automatic sprinkler system, or openings as specified above shall be provided on at least two sides of an exterior wall of the story.

   If any portion of a basement is located more than 75 feet from openings required in this section, the basement shall be provided with an approved automatic sprinkler system.
2. At the top of rubbish and linen chutes and in their terminal rooms. Chutes extending through three or more floors shall have additional sprinkler heads installed within such chutes at alternate floors. Sprinkler heads shall be accessible for servicing.
3. In rooms where nitrate film is stored or handled.
4. In protected combustible fiber storage vaults as defined in the Fire Code.

(c) **Group A Occupancies.** 1. **Drinking establishments.** An automatic sprinkler system shall be installed in rooms used by the occupants for the consumption of alcoholic beverages and unseparated accessory uses where the total area of such unseparated rooms and assembly uses exceeds 5000 square feet. For uses to be considered as separated, the separation shall not be less than as required for a one-hour occupancy separation. The area of other uses shall be included unless separated by at least a one-hour occupancy separation.

2. **Basements.** An automatic sprinkler system shall be installed in basements classified as a Group A Occupancy when the basement is larger than 1500 square feet in floor area.



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3. **Exhibition and display rooms.** An automatic sprinkler system shall be installed in Group A Occupancies which have more than 12,000 square feet of floor area which can be used for exhibition or display purposes.

4. **Stairs.** An automatic sprinkler system shall be installed in enclosed usable space below or over a stairway in Group A, Divisions 2, 2.1, 3 and 4 Occupancies. See Section 3309 (f).

5. **Other areas.** An automatic sprinkler system shall be installed under the roof and gridiron, in the tie and fly galleries and in all places behind the proscenium wall of stages; over and within permanent platforms in excess of 500 square feet in area; and in dressing rooms, workshops and storerooms accessory to such stages or permanent platforms.

**EXCEPTIONS:** 1. Stages or platforms open to the auditorium room on three or more sides.

2. Altars, pulpits or similar platforms and their accessory rooms.

3. Stage gridirons when side-wall sprinklers with 135°F. rated heads with heat-baffle plates are installed around the entire perimeter of the stage except for the proscenium opening at points not more than 30 inches below the gridiron nor more than 6 inches below the baffle plate.

4. Under stage or under platform areas less than 4 feet in clear height used exclusively for chair or table storage and lined on the inside with materials approved for one-hour fire-resistive construction.

(d) **Group B, Division 2 Occupancies.** An automatic sprinkler system shall be installed in retail sales rooms classed as Group B, Division 2 Occupancies where the floor area exceeds 12,000 square feet on any floor or 24,000 square feet on all floors or in Group B, Division 2 retail sales occupancies more than three stories in height. The area of mezzanines shall be included in determining the areas where sprinklers are required.

(e) **Group E Occupancies.** 1. **Basements.** An automatic sprinkler system shall be installed in basements classified as a Group E Occupancy when the basement is larger than 1500 square feet in floor area.

2. **Stairs.** An automatic sprinkler system shall be installed in enclosed usable space below or over a stairway in Group E Occupancies. See Section 3309 (f).

(f) **Group H Occupancies.** 1. **General.** An automatic fire-extinguishing system shall be installed in Group H, Divisions 1, 2, 3 and 7 Occupancies.

2. **Division 4.** An automatic fire-extinguishing system shall be installed in Group H, Division 4 Occupancies having a floor area of more than 3000 square feet.

3. **Division 6.** An automatic fire-extinguishing system shall be installed throughout buildings containing Group H, Division 6 Occupancies. The design of the sprinkler system shall be not less than that required under U.B.C. Standard No. 38-1 for the occupancy hazard classifications as follows:



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| LOCATION | OCCUPANCY HAZARD CLASSIFICATION |
|---|---|
| Fabrication areas | Ordinary Hazard Group 3 |
| Service corridors | Ordinary Hazard Group 3 |
| Storage rooms without dispensing | Ordinary Hazard Group 3 |
| Storage rooms with dispensing | Extra Hazard Group 2 |
| Exit corridors | Ordinary Hazard Group 3[1] |

[1]When the design area of the sprinkler system consists of a corridor protected by one row of sprinklers, the maximum number of sprinklers that need be calculated is 13.

(g) **Group I Occupancies.** An automatic sprinkler system shall be installed in Group I Occupancies.

**EXCEPTION:** In jails, prisons and reformatories, the piping system may be dry, provided a manually operated valve is installed at a continuously monitored location. Opening of the valve will cause the piping system to be charged. Sprinkler heads in such systems shall be equipped with fusible elements or the system shall be designed as required for deluge systems in U.B.C. Standard No. 38-1.

(h) **Group R, Division 1 Occupancies.** An automatic sprinkler system shall be installed throughout every apartment house three or more stories in height or containing more than 15 dwelling units, and every hotel three or more stories in height or containing 20 or more guest rooms. Residential or quick-response standard sprinkler heads shall be used in the dwelling unit and guest room portions of the building.

## Sprinkler System Supervision Alarms

**Sec. 3803.** Automatic sprinkler systems shall be supervised by an approved central, proprietary or remote station service or a local alarm which will give an audible signal at a constantly attended location when the number of sprinklers is:

1. 20 or more in Group 1, Division 1 Occupancies.
2. 100 or more in other occupancies.

## Permissible Sprinkler Omissions

**Sec. 3804.** Subject to the approval of the building official and with the concurrence of the chief of the fire department, sprinklers may be omitted in rooms or areas as follows:

1. When sprinklers are considered undesirable because of the nature of the contents or in rooms or areas which are of noncombustible construction with wholly noncombustible contents and which are not exposed by other areas. Sprinklers shall not be omitted from any room merely because it is damp or of fire-resistive construction.

2. Sprinklers shall not be installed when the application of water or flame and water to the contents may constitute a serious life or fire hazard, as in the manufacture or storage of quantities of aluminum powder, calcium carbide, calcium phosphide, metallic sodium and potassium, quicklime, magnesium powder and sodium peroxide.



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3. Safe deposit or other vaults of fire-resistive construction, when used for the storage of records, files and other documents, when stored in metal cabinets.

4. Communication equipment areas under the exclusive control of a public communication utility agency, provided:

A. The equipment areas are separated from the remainder of the building by one-hour fire-resistive occupancy separation; and

B. Such areas are used exclusively for such equipment; and

C. An approved automatic smoke detection system is installed in such areas and is supervised by an approved central, proprietary or remote station service or a local alarm which will give an audible signal at a constantly attended location; and

D. Other approved fire-protection equipment such as portable fire extinguishers or Class II standpipes are installed in such areas.

5. Other approved automatic fire-extinguishing systems may be installed to protect special hazards or occupancies in lieu of automatic sprinklers.

## Standpipes

**Sec. 3805.** (a) **General.** Standpipes shall comply with the requirements of this section and U.B.C. Standard No. 38-2.

(b) **Where Required.** Standpipe systems shall be provided as set forth in Table No. 38-A.

(c) **Location of Class I Standpipes.** There shall be a Class I standpipe outlet connection at every floor-level landing of every required stairway above or below grade and on each side of the wall adjacent to the exit opening of a horizontal exit. Outlets at stairways shall be located within the exit enclosure or, in the case of smokeproof enclosures, within the vestibule or exterior balcony, giving access to the stairway.

Risers and laterals of Class I standpipe systems not located within an enclosed stairway or smokeproof enclosure shall be protected by a degree of fire resistance equal to that required for vertical enclosures in the building in which they are located.

**EXCEPTION:** In buildings equipped with an approved automatic sprinkler system, risers and laterals which are not located within an enclosed stairway or smokeproof enclosure need not be enclosed within fire-resistive construction.

There shall be at least one outlet above the roof line when the roof has a slope of less than 4 inches in 12 inches.

In buildings where more than one standpipe is provided, the standpipes shall be interconnected at the bottom.

(d) **Location of Class II Standpipes.** Class II standpipe outlets shall be accessible and shall be located so that all portions of the building are within 30 feet of a nozzle attached to 100 feet of hose.

In Group A, Divisions 1, 2 and 2.1 Occupancies, with occupant loads of more than 1000, outlets shall be located on each side of any stage, on each side of the rear of the auditorium and on each side of the balcony.



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Fire-resistant protection of risers and laterals of Class II standpipe systems is not required.

(e) **Location of Class III Standpipes.** Class III standpipe systems shall have outlets located as required for Class I standpipes in Section 3805 (c) and shall have Class II outlets as required in Section 3805 (d).

Risers and laterals of Class III standpipe systems shall be protected as required for Class I systems.

**EXCEPTIONS:** 1. In buildings equipped with an approved automatic sprinkler system, risers and laterals which are not located within an enclosed stairway or smokeproof enclosure need not be enclosed within fire-resistive construction.

2. Laterals for Class II outlets on Class III systems need not be protected.

In buildings where more than one Class III standpipe is provided, the standpipes shall be interconnected at the bottom.

## Buildings Under Construction

**Sec. 3806.** (a) **General.** During the construction of a building and until the permanent fire-extinguishing system has been installed and is in service, fire protection shall be provided in accordance with this section.

(b) **Where Required.** Every building six stories or more in height shall be provided with not less than one standpipe for use during construction. Such standpipes shall be installed when the progress of construction is not more than 50 feet in height above grade. Such standpipe shall be provided with fire department hose connections at accessible locations adjacent to usable stairs and the standpipe outlets shall be located adjacent to such usable stairs. Such standpipe systems shall be extended as construction progresses to within one floor of the highest point of construction having secured decking or flooring.

In each floor there shall be provided a 2½-inch valve outlet for fire department use. Where construction height requires installation of a Class III standpipe, fire pumps and water main connections shall be provided to serve the standpipe.

(c) **Temporary Standpipes.** Temporary standpipes may be provided in place of permanent systems if they are designed to furnish 75 gallons of water per minute at 50 pounds per square inch pressure with a standpipe size of not less than 4 inches. All outlets shall be not less than 2½ inches. Pumping equipment sufficient to provide this pressure and volume shall be available at all times when a Class III standpipe system is required.

(d) **Detailed Requirements.** Standpipe systems for buildings under construction shall be installed as required for permanent standpipe systems.

## Basement Pipe Inlets

**Sec. 3807.** For basement pipe inlet requirements, see Appendix Section 3807.



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## TABLE NO. 38-A—STANDPIPE REQUIREMENTS

| OCCUPANCY | NONSPRINKLERED BUILDING[1] | | SPRINKLERED BUILDING[2,3] | |
|---|---|---|---|---|
| | Standpipe Class | Hose Requirement | Standpipe Class | Hose Requirement |
| 1. Occupancies exceeding 150 ft. in height and more than one story | III | Yes | I | No |
| 2. Occupancies 4 stories or more but less than 150 ft. in height, except Group R, Div. 3 | [I and II[4]] (or III) | Yes[5] | I | No |
| 3. Group A Occupancies with occupant load exceeding 1000[6] | II | Yes | No requirement | No |
| 4. Group A, Div. 2.1 Occupancies over 5000 square feet in area used for exhibition | II | Yes | II | Yes |
| 5. Groups I, H, B, Div. 1, 2 or 3 Occupancies less than 4 stories in height but greater than 20,000 square feet per floor | II[4] | Yes | No requirement | No |

[1]Except as otherwise specified in Item No. 4 of this table, Class II standpipes need not be provided in basements having an automatic fire-extinguishing system throughout.

[2]Combined systems with their related water supplies may be used in sprinklered buildings.

[3]Portions of otherwise sprinklered buildings which are not protected by automatic sprinklers shall have Class II standpipes installed as required for the unsprinklered portions.

[4]In open structures where Class II standpipes may be damaged by freezing, the building official may authorize the use of Class I standpipes which are located as required for Class II standpipes.

[5]Hose is required for Class II standpipes only.

[6]Class II standpipes need not be provided in assembly areas used solely for worship.



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# Chapter 39
# STAGES AND PLATFORMS

## Scope

**Sec. 3901.** (a) **General.** Platforms and stages shall conform with the requirements of this chapter.

(b) **Definitions.** For the purpose of this chapter, certain terms are defined as follows:

**BATTEN** is a flown metal pipe or shape on which lights or scenery are fastened.

**DROP** is a large piece of scenic canvas or cloth which hangs vertically, usually across the stage area.

**FLY** is the space over the stage of a theater where scenery and equipment can be hung out of view. Also called lofts and rigging lofts.

**FLY GALLERY** is a narrow raised platform at the side of legitimate stage from which the lines for flying scenery are manipulated.

**GRIDIRON** is the arrangement of beams over a legitimate stage supporting the machinery for flying scenery and hanging battens from which lighting is hung.

**LEG DROP** is a long narrow strip of fabric used for masking. When used on either or both sides of the acting area, it is provided to designate an entry onto the stage by the actors. It is also used to mask the side stage area. They may also be called "wings."

**PINRAIL** is a beam at one side of a legitimate stage through which wooden or metal pins are driven and to which lines from the flies are fastened.

**PLATFORM** is that raised area within a building used for the presentation of music, plays or other entertainment; the head table for special guests, the raised area for lectures and speakers; boxing and wrestling rings; theater in the round; and similar purposes wherein there are not overhead hanging curtains, drops, scenery or stage effects other than lighting.

**PLATFORM, PERMANENT,** is a platform used within an area for more than 30 days.

**PLATFORM, TEMPORARY,** is a platform used within an area for not more than 30 days.

**PROSCENIUM WALL** is the wall that separates the stage from the auditorium or house.

**STAGE** is a partially enclosed area within a building used for the purpose of entertainment and shall be classified as either:

**Stage, Legitimate,** is a stage wherein curtains, drops, leg drops, scenery, lighting devices or other stage effects are retractable horizontally or suspended overhead.

**Stage, Regular,** is a stage wherein curtains, fixed leg drops, valances, scenery and other stage effects are hung and are not usually retractable.



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**Stage, Thrust,** is a platform extending beyond the proscenium arch and into the audience.

**THEATER-IN-THE-ROUND** is an acting area in the middle of a room with the audience sitting all around it.

(c) **Materials and Design.** Materials used in the construction of platforms and stages shall conform to the applicable materials and design requirements as set forth in this code.

## Platforms

**Sec. 3902.** Temporary platforms may be constructed of any materials. The space between the floor and the platform above shall not be used for any purpose other than electrical wiring to platform equipment.

Permanent platforms shall be constructed of materials as required for the type of construction of the building in which the permanent platform is located. When the space beneath the permanent platform is used for storage or any purpose other than equipment wiring or plumbing, the floor construction shall be not less than one-hour fire-resistive construction. When the space beneath the permanent platform is not used for any purpose other than equipment wiring or plumbing, the underside of the permanent platform need not be protected.

## Stages

**Sec. 3903.** (a) **Construction.** Regular stages and thrust stages shall be constructed of materials as required for the type of construction of the building in which it is located. In all cases the finish floor may be of wood.

Legitimate stages shall be constructed of materials as required for a Type I or II F.R. building. Legitimate stage floors may be constructed with a wood floor of not less than 2 inches in nominal thickness on a resilient mounting upon a concrete or masonry floor.

Openings through stage floors (traps) shall be equipped with tight-fitting trap doors of wood having a nominal thickness of not less than 2 inches with approved safety locks.

(b) **Accessory Rooms.** Dressing rooms, workshops and store rooms accessory to stages shall be separated from each other and from the stage by not less than one-hour fire-resistive construction, and openings within such separations shall be protected as required for corridors.

**EXCEPTION:** A separation is not required for stages having a floor area not exceeding 500 square feet.

(c) **Vents.** Stages exceeding 500 square feet in floor area shall be provided with one or more vents constructed of noncombustible material. Vents shall be located near the center and above the highest part of any stage. They shall be raised above the stage roof and shall have a total vent area equal to at least 5 percent of the floor area of the stage.

The vents shall open by spring action or force of gravity sufficient to overcome the effects of neglect, rust, dirt, frost, snow or expansion by heat or warping of the framework. Glass, if used in vents, must be protected against falling onto the



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stage. A wire screen, if used under the glass, must be so placed that, if clogged, it cannot reduce the required venting area or interfere with the operating mechanism or obstruct the distribution of water from an automatic sprinkler. Vents shall be arranged to open automatically by the use of fusible links. The fusible links and operating cable shall hold each door closed against the minimum 30-pound counterforce which may be exerted by springs or counterweights. This minimum counterforce shall be exerted on each door through its entire arc of travel and for a minimum of 155 degrees. A manual control shall be provided.

Springs, when employed to actuate vent doors, shall be capable of maintaining full required tension. Springs shall not be stressed more than 50 percent of their rated capacity and shall not be located directly in the airstream nor exposed to the outside.

A fusible link shall be placed in the cable control system on the underside of the vent at or above the roof line or as approved by the building official and shall be so located as not to be affected by the operation of an automatic sprinkler system. Remote, manual or electrical controls shall provide for both opening and closing of the vent doors for periodic testing and shall be located at a point on the stage designated by the building official. When remote control vents are electrical, power failure shall not affect its instant operation in the event of fire. Hand winches may be employed to facilitate operation of manually controlled vents.

Curbs for vents shall be as required for skylights.

(d) **Proscenium Walls.** Legitimate stages shall be completely separated from the seating area by a proscenium wall of not less than two-hour fire-resistive noncombustible construction. The proscenium wall shall extend at least 4 feet above the roof of the auditorium.

Proscenium walls may have, in addition to the main proscenium opening, one opening at the orchestra pit level and not more than two openings into the auditorium at the stage floor level. Each of the latter two openings shall be not more than 25 square feet in area.

All openings in the proscenium wall of a legitimate stage shall be protected by a fire assembly having a one- and one-half-hour fire-resistive rating. Closing devices on such assemblies shall be located where the vents or ducts pass through the proscenium walls and shall be operated by fusible links located on both sides of the proscenium wall and both inside of and outside of the vent or duct. The main proscenium opening used for viewing performances shall be provided with an automatic-closing fire-resistive curtain as provided in U.B.C. Standard No. 6-1. In lieu of such fire-resistive curtain, a woven high-temperature coated fiberglass fabric weighing a minimum of 2 3/8 pounds per square yard with a minimum warp and fill tensile strength of 400 pounds per inch reinforced with noncorrosive wire may be used. Such curtain materials shall conform to the following conditions:

1. The construction materials used for the curtain shall be noncombustible and noncorrosive.
2. The curtain shall be tested in accordance with U.B.C. Standard No. 17-3. The time period for testing shall be not less than 30 minutes, and the unexposed portion of the test sample shall not show any evidence of through



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penetrations, flaming nor excessive smoking (only the vapors escaping as a result of baking the sample).

3. The curtain shall be listed by an approved agency with a permanent marking giving the manufacturer's name, the approved agency's name or insignia, the rating achieved, and a statement that the curtain shall be installed in accordance with U.B.C. Standard No. 6-1.
4. Curtain materials shall have a smoke density no greater than 10 when tested in accordance with U.B.C. Standard No. 42-1.

(e) **Gridirons, Fly Galleries and Pinrails.** Gridirons, fly galleries and pinrails shall be constructed of noncombustible material.

(f) **Special Exiting.** Each side of a legitimate stage shall be provided with at least one well-marked exit providing not less than 32 inches clear width. Such exit shall open directly to a street, exit court or exit passageway leading to a street.

Fly galleries shall be provided with an exit stair not less than 30 inches in width. Each tier of dressing rooms shall be provided with two exits meeting the requirements of Chapter 33.

Stairways required by this subsection need not be enclosed.



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# Chapter 40
# MOTION PICTURE PROJECTION ROOMS

## General

**Sec. 4001.** (a) **Scope.** The provisions of this chapter shall apply where ribbon-type cellulose acetate or other safety film is used in conjunction with electric arc, Xenon or other light-source projection equipment which develops hazardous gases, dust or radiation. Where cellulose nitrate film is used, projection rooms shall comply with the Fire Code.

(b) **Projection Room Required.** Every motion picture machine projecting film as mentioned within the scope of this chapter shall be enclosed in a projection room. Appurtenant electrical equipment, such as rheostats, transformers and generators, may be within the projection room or in an adjacent room of equivalent construction.

There shall be posted on the outside of each projection room door and within the projection room itself a conspicuous sign with 1-inch block letters stating: SAFETY FILM ONLY PERMITTED IN THIS ROOM.

## Construction

**Sec. 4002.** Every projection room shall be of permanent construction consistent with the construction requirements for the type of building in which the projection room is located. Openings need not be protected.

The room shall have a floor area of not less than 80 square feet for a single machine and at least 40 square feet for each additional machine. Each motion picture projector, floodlight, spotlight or similar piece of equipment shall not be used unless approved and shall have a clear working space not less than 30 inches by 30 inches on each side and at the rear thereof, but only one such space shall be required between two adjacent projectors.

The projection room and the rooms appurtenant thereto shall have a ceiling height of not less than 7 feet 6 inches.

## Exits

**Sec. 4003.** Exits shall be provided as required in Chapter 33. Motion picture projections rooms used for projection of safety film only are required to have only one exit.

## Projection Ports and Openings

**Sec. 4004.** The aggregate of openings for projection equipment shall not exceed 25 percent of the area of the wall between the projection room and the auditorium.

All openings shall be provided with glass or other approved material so as to completely close the opening.

## Ventilation

**Sec. 4005.** (a) **General.** Ventilation shall be provided in accordance with the provisions of this section.



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(b) **Projection Booth.** 1. **Supply air.** Each projection room shall be provided with adequate air-supply inlets so arranged as to provide well-distributed air throughout the room. Air-inlet ducts shall provide an amount of air equivalent to the amount of air being exhausted by projection equipment. Air may be taken from the outside; from adjaeent spaces within the building, provided the volume and infiltration rate is suffieient; or from the building air-conditioning system, provided it is so arranged as to provide sufficient air when other systems are not in operation.

2. **Exhaust air.** Projection booths may be exhausted through the lamp exhaust system. The lamp exhaust system shall be positively interconneeted with the lamp so that the lamp will not operate unless there is the air flow required for the lamp. Exhaust air ducts shall terminate at the exterior of the building in sueh a location that the exhaust air cannot be readily recireulated into any air-supply system. The projection room ventilation system may also serve appurtenant rooms such as the generator room and the rewind room.

Each projection machine shall be provided with an exhaust duct that will draw air from each lamp and exhaust it directly to the outside of the building. The lamp exhaust may serve to exhaust air from the projection room to provide room air circulation. Such ducts shall be of rigid materials, except for a flexible connector approved for the purpose. The projection lamp or projection room exhaust system or both may be combined but shall not be interconnected with any other exhaust or return system, or both, within the building.

(c) **Projection Equipment Ventilation.** Each projection machine shall be provided with an exhaust duct which will draw air from each lamp and exhaust it directly to the outside of the building in such a fashion that it will not be picked up by supply inlets. Such a duct shall be of rigid materials, except for a continuous flexible connector approved for the purpose. The lamp exhaust system shall not be interconnected with any other system.

1. **Electric arc projection equipment.** The exhaust capacity shall be 200 cubic feet per minute for eaeh lamp connected to the lamp exhaust system, or as recommended by the equipment manufacturer. Auxiliary air may be introduced into the system through a screened opening to stabilize the arc.

2. **Xenon projection equipment.** The lamp exhaust system shall exhaust not less than 300 cubie feet per minute per lamp nor less than that exhaust volume required or recommended by the equipment manufacturer, whichever is the greater. The external temperature of the lamp housing shall not exceed 130°F when operating.

## Miscellaneous Equipment

**Sec. 4006.** Each projection room shall be provided with rewind and film storage facilities.

A maximum of four containers for flammable liquids not greater than 16-ounce capacity and of a nonbreakable type may be permitted in each projection booth.

## Sanitary Facilities

**Sec. 4007.** Every projection room shall be provided with a lavatory. Every



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projection room serving an assembly occupancy shall be provided with a water closet.

**EXCEPTION:** A water closet shall not be required in a projection room where completely automated projection equipment is installed which does not require a projectionist in attendance for projection or rewinding film.

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# Chapter 41
# (SEE UNIFORM BUILDING SECURITY CODE™)



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# *Part VII*

# FIRE-RESISTIVE STANDARDS FOR FIRE PROTECTION

## Chapter 42
## INTERIOR WALL AND CEILING FINISH

### General

**Sec. 4201.** Interior wall and ceiling finish shall mean interior wainscoting, paneling or other finish applied structurally or for decoration, acoustical correction, surface insulation or similar purposes. Requirements for finishes in this chapter shall not apply to trim defined as picture molds, chair rails, baseboards and handrails; to doors and windows or their frames, nor to materials which are less than 1/28 inch in thickness cemented to the surface of walls or ceilings, if these materials have surface-burning characteristics no greater than paper of this thickness cemented to a noncombustible backing.

Foam plastics shall not be used as interior finish except as provided in Section 1712. For foam plastic trim, see Section 1705 (e).

### Testing and Classification of Materials

**Sec. 4202.** (a) **Testing.** Tests shall be made by an approved testing agency to establish surface-burning characteristics and to show that materials when cemented or otherwise fastened in place will not readily become detached when subjected to room temperatures of 300°F. for 25 minutes. Surface-burning characteristics shall be determined by one of the following methods:

1. The surface-burning characteristics as set forth in U.B.C. Standard No. 42-1.

2. Any other recognized method of test procedure for determining the surface-burning characteristics of finish materials that will give comparable results to those specified in method No. 1 above.

(b) **Classification.** The classes of materials based upon their flame-spread index shall be as set forth in Table No. 42-A. The smoke density shall be no greater than 450 when tested in accordance with U.B.C. Standard No. 42-1 in the way intended for use.

### Application of Controlled Interior Finish

**Sec. 4203.** Interior finish materials applied to walls and ceilings shall be tested as specified in Section 4202 and regulated for purposes of limiting surface-burning by the following provisions:

1. When walls and ceilings are required by any provision in this code to be of fire-resistive or noncombustible construction, the finish material shall be applied directly against such fire-resistive or noncombustible construction or to furring strips not exceeding 1 3/4 inches applied directly against such surfaces. The intervening spaces between such furring strips shall be filled with inorganic or Class I material or shall be fire-stopped not to exceed 8 feet in any direction.



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2. Where walls and ceilings are required to be of fire-resistive or noncombustible construction and walls are set out or ceilings are dropped distances greater than specified in paragraph 1 of this section, Class I finish materials shall be used except where the finish materials are protected on both sides by automatic sprinkler systems or are attached to a noncombustible backing or to furring strips installed as specified in paragraph 1. The hangers and assembly members of such dropped ceilings that are below the main ceiling line shall be of noncombustible materials except that in Types III and V construction fire-retardant treated wood may be used. The construction of each set-out wall shall be of fire-resistive construction as required elsewhere in this code. See Section 2516 (f) for fire and draft stops.

3. Wall and ceiling finish materials of all classes as permitted in this chapter may be installed directly against the wood decking or planking of Type IV heavy-timber construction or to wood furring strips applied directly to the wood decking or planking installed and fire-stopped as specified in paragraph 1.

4. All interior wall or ceiling finish other than Class I material which is less than ¼ inch thick shall be applied directly against a noncombustible backing unless the qualifying tests were made with the material suspended from the noncombustible backing.

## Maximum Allowable Flame Spread

**Sec. 4204.** (a) **General.** The maximum flame-spread class of finish materials used on interior walls and ceilings shall not exceed that set forth in Table No. 42-B.

**EXCEPTIONS:** 1. Except in Group I Occupancies and in enclosed vertical exitways, Class III may be used in other exitways and rooms as wainscoting extending not more than 48 inches above the floor and for tack and bulletin boards covering not more than 5 percent of the gross wall area of the room.

2. Where approved sprinkler system protection is provided, the flame-spread classification rating may be reduced one classification, but in no case shall materials having a classification greater than Class III be used.

3. The exposed faces of Type IV-H.T., structural members and Type IV-H.T., decking and planking, where otherwise permissible under this code are excluded from flame-spread requirements.

(b) **Carpeting on Ceilings.** When used as interior ceiling finish, carpeting and similar materials having a napped, tufted, looped or similar surface shall have a Class I flame spread.

## Textile Wall Coverings

**Sec. 4205.** When used as interior wall finish, textile wall coverings, including materials such as those having a napped, tufted, looped, nonwoven, woven or similar surface shall comply with the following:

1. Textile wall coverings shall have a Class I flame spread and shall be protected by automatic sprinklers, or
2. The textile wall covering shall meet the acceptance criteria of U.B.C. Standard No. 42-2 when tested using a product mounting system, including adhesive, representative of actual use.



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## TABLE NO. 42-A—FLAME-SPREAD CLASSIFICATION

| MATERIAL QUALIFIED BY: | |
|---|---|
| Class | Flame-spread Index |
| I | 0-25 |
| II | 26-75 |
| III | 76-200 |

## TABLE NO. 42-B—MAXIMUM FLAME-SPREAD CLASS[1]

| OCCUPANCY GROUP | ENCLOSED VERTICAL EXITWAYS | OTHER EXITWAYS[2] | ROOMS OR AREAS |
|---|---|---|---|
| A | I | II | II[3] |
| E | I | II | III |
| I | I | I[7] | II[4] |
| H | I | II | III[5] |
| B | I | II | III |
| R-1 | I | II | III |
| R-3 | III | III | III[6] |
| M | NO RESTRICTIONS | | |

[1]Foam plastics shall comply with the requirements specified in Section 1712. Carpeting on ceilings and textile wall coverings shall comply with the requirements specified in Sections 4204 (b) and 4205, respectively.

[2]Finish classification is not applicable to interior walls and ceilings of exterior exit balconies.

[3]In Group A, Divisions 3 and 4 Occupancies, Class III may be used.

[4]In rooms in which personal liberties of inmates are forcibly restrained, Class I material only shall be used.

[5]Over two stories shall be of Class II.

[6]Flame-spread provisions are not applicable to kitchens and bathrooms of Group R, Division 3 Occupancies.

[7]In Group I, Divisions 2 and 3 Occupancies, Class II may be used or Class III when the Division 2 or 3 is sprinklered.



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# Chapter 43
# FIRE-RESISTIVE STANDARDS

## General

**Sec. 4301.** In addition to all the other requirements of this code, fire-resistive materials shall meet the requirements for fire-resistive construction given in this chapter.

## Fire-resistive Materials and Systems

**Sec. 4302.** (a) **General.** Materials and systems used for fire-resistive purposes shall be limited to those specified in this chapter unless accepted under the procedure given in Section 4302 (b) or 4302 (c). For standards referred to in this chapter, see Chapter 60.

The materials and details of construction for the fire-resistive systems described in this chapter shall be in accordance with all other provisions of this code except as modified herein.

For the purpose of determining the degree of fire resistance afforded, the materials of construction listed in this chapter shall be assumed to have the fire-resistance rating indicated in Table No. 43-A, 43-B or 43-C.

As an alternate to Tables Nos. 43-A, B and C, fire-resistive construction may be approved by the building official on the basis of evidence submitted by the person responsible for the structural design showing that the construction meets the required fire-resistive classification.

(b) **Qualification by Testing.** Material or assembly of materials of construction tested in accordance with the requirements set forth in U.B.C. Standard No. 43-1 shall be rated for fire resistance in accordance with the results and conditions of such tests.

> **EXCEPTION:** The acceptance criteria of U.B.C. Standard No. 43-1 for exterior bearing walls shall not be required to be greater with respect to heat transmission and passage of flame or hot gases than would be required of a nonbearing wall in the same building with the same distance to the property line. The fire exposure time period, water pressure and duration of application for the hose stream test shall be based upon the fire-resistive rating determined by this exception.

Fire-resistive assemblies tested under U.B.C. Standard No. 43-1 shall not be considered to be restrained unless evidence satisfactory to the building official is furnished by the person responsible for the structural design showing that the construction qualifies for a restrained classification in accordance with U.B.C. Standard No. 43-1. Restrained construction shall be identified on the plans.

(c) **Calculating Fire Resistance.** The fire-resistive rating of a material or assembly may be established by calculations. The procedures used for such calculations shall be in accordance with U.B.C. Standard No. 43-9.

(d) **Concrete.**

**CARBONATE AGGREGATE CONCRETE** is concrete made with aggregates consisting mainly of calcium or magnesium carbonate, e.g., limestone or dolomite, and containing 40 percent or less quartz, chert or flint.



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**LIGHTWEIGHT AGGREGATE CONCRETE** is concrete made with aggregates of expanded clay, shale, slag or slate or sintered fly ash and weighting 85 to 115 pcf.

**SAND-LIGHTWEIGHT CONCRETE** is concrete made with a combination of expanded clay, shale, slag or slate or sintered fly ash and natural sand. Its unit weight is generally between 105 and 120 pcf.

**SILICEOUS AGGREGATE CONCRETE** is concrete made with normal-weight aggregates consisting mainly of silica or compounds other than calcium or magnesium carbonate, and may contain more than 40 percent quartz, chert or flint.

(e) **Shotcrete.** Shotcrete without coarse aggregate shall be classified in accordance with the aggregate used.

## Protection of Structural Members

**Sec. 4303.** (a) **General.** Structural members having the fire-resistive protection set forth in Table No. 43-A shall be assumed to have the fire-resistance ratings set forth therein.

(b) **Protective Coverings.** 1. **Thickness of protection.** The thickness of fire-resistive materials required for protection of structural members shall be not less than set forth in Table No. 43-A, except as modified in this section. The figures shown shall be the net thickness of the protecting materials and shall not include any hollow space back of the protection.

2. **Unit masonry protection.** Where required, metal ties shall be embedded in transverse joints of unit masonry for protection of steel columns. Such ties shall be as set forth in Table No. 43-A or be equivalent thereto.

3. **Reinforcement for cast-in-place concrete column protection.** Cast-in-place concrete protection for steel columns shall be reinforced at the edges of such members with wire ties of not less than .18 inch in diameter wound spirally around the columns on a pitch of not more than 8 inches or by equivalent reinforcement.

4. **Embedment of pipes.** Conduits and pipes shall not be embedded in required fire protection of structural members.

5. **Column jacketing.** Where the fire-resistive covering on columns is exposed to injury from moving vehicles, the handling of merchandise or other means, it shall be protected in an approved manner.

6. **Ceiling protection.** Where a ceiling forms the protective membrane for fire-resistive assemblies, the constructions and their supporting horizontal structural members need not be individually fire protected except where such members support directly applied loads from more than one floor or roof. The required fire resistance shall be not less than that required for individual protection of members.

Ceilings shall form continuous fire-resistive membranes but may have openings for copper, sheet steel or ferrous plumbing pipes, ducts and electrical outlet boxes, provided the areas of such openings through the ceiling aggregate not more than 100 square inches for any 100 square feet of ceiling area. Regardless of size, duct openings in such ceilings shall be protected by approved ceiling fire



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dampers. Access doors installed in such ceilings shall be approved horizontal access door assemblies listed for such purpose.

**EXCEPTIONS:** 1. Larger openings than permitted above may be installed where such openings and the assemblies in which they are utilized are in accordance with the results of tests pursuant to the provisions of Section 4302 (b).

2. Ceiling fire dampers may be omitted from duct openings where fire-resistive tests have shown that fire dampers are not necessary to maintain the fire resistance of the assembly.

Individual electrical outlet boxes shall be of steel and not greater than 16 square inches in area.

7. **Plaster application.** Plaster protective coatings may be applied with the finish coat omitted when they comply with the design mix and thickness requirements of Tables Nos. 43-A, 43-B and 43-C.

8. **Truss protection.** Where trusses are used as all or part of the structural frame and protection is required by Table No. 17-A, such protection may be provided by fire-resistive materials enclosing the entire truss assembly on all sides for its entire length and height. The required thickness and construction of fire-resistive assemblies enclosing trusses shall be based upon the results of full-scale tests or combinations of tests on truss components or upon approved calculations based on such tests which satisfactorily demonstrate that the assembly has the required fire resistance.

(c) **Protected Members.** 1. **Attached metal members.** The edges of lugs, brackets, rivets and bolt heads attached to structural members may extend to within 1 inch of the surface of the fire protection.

2. **Reinforcing.** Thickness of protection for concrete or masonry reinforcement shall be measured to the outside of the reinforcement except that stirrups and spiral reinforcement ties may project not more than 1/2 inch into the proteetion.

3. **Bonded prestressed concrete tendons.** For members having a single tendon or more than one tendon installed with equal concrete cover measured from the nearest surface, the cover shall be not less than that set forth in Table No. 43-A.

For members having multiple tendons installed with variable concrete cover, the average tendon cover shall be not less than that set forth in Table No. 43-A, provided:

A. The clearance from each tendon to the nearest exposed surface is used to determine the average cover.

B. In no case can the clear cover for individual tendons be less than one half of that set forth in Table No. 43-A. A minimum cover of 3/4 inch for slabs and 1 inch for beams is required for any aggregate concrete.

C. For the purpose of establishing a fire-resistive rating, tendons having a clear covering less than that set forth in Table No. 43-A shall not contribute more than 50 percent of the required ultimate moment capacity for members less than 350 square inches in cross-sectional area and 65 percent for larger members. For structural design purposes, however, tendons having a reduced cover are assumed to be fully effeetive.



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(d) **Fire Protection Omitted.** Fire protection may be omitted from the bottom flange of lintels spanning not over 6 feet, shelf angles, or plates that are not a part of the structural frame.

(e) **Spray-applied Fireproofing.** The density and thickness of spray-applied fireproofing shall be determined following the procedures set forth in U.B.C. Standard No. 43-8.

## Walls and Partitions

**Sec. 4304.** (a) **General.** Fire-resistive walls and partitions shall be assumed to have the fire-resistance ratings set forth in Table No. 43-B.

(b) **Combustible Members.** Combustible members framed into a wall shall be protected at their ends by not less than one half the required fire-resistive thickness of such wall.

(c) **Exterior Walls.** In fire-resistive exterior wall construction the fire-resistive rating shall be maintained for such walls passing through attic areas.

(d) **Nonsymmetrical Wall Construction.** Walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to the furnace, and the assigned fire-resistive rating will be the shortest duration obtained from the two tests conducted in conformance with U.B.C. Standard No. 43-1. When evidence is furnished to show that the wall was tested with the least fire-resistive side exposed to the furnace, the building official may not require that the wall be subjected to tests from the opposite side.

(e) **Penetrations.** Penetrations in walls requiring protected openings shall be fire stopped. Firestopping shall be of an approved material securely installed and capable of maintaining its integrity when subjected to test temperatures prescribed in U.B.C. Standard No. 43-1 for the specific wall or partition.

Openings in walls and partitions shall be protected as specified in Section 4306. Where fire-rated walls and partitions require protected openings, the following penetrations into or through such construction are permitted:

1. Copper or ferrous pipes or conduits may penetrate the walls or partitions, provided firestopping is provided in accordance with the first paragraph of this section.

2. Openings for steel electrical outlet boxes not exceeding 16 square inches in area, provided the area of such openings does not aggregate more than 100 square inches for any 100 square feet of wall or partition area. Outlet boxes on opposite sides of walls or partitions shall be separated by a horizontal distance of 24 inches.

3. Where walls are penetrated by other materials or where larger openings are required than permitted in Item 2 above, they shall be qualified by tests conducted in accordance with the provisions of Section 4302 (b).

The space between the penetrating materials described in Items 1, 2 and 3 and the wall shall be designed to prevent the movement of hot flame or gases.

## Floor-Ceilings or Roof-Ceilings

**Sec. 4305.** (a) **General.** Fire-resistive floor-ceiling or roof-ceiling construction systems shall be assumed to have the fire-resistance ratings set forth in Table



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No. 43-C. Penetrations in floors and ceilings requiring protected openings shall be fire stopped. Firestopping shall be of an approved material, securely installed and capable of maintaining its integrity when subjected to the time-temperature curve of U.B.C. Standard No. 43-1 for the specific floor-ceiling or roof-ceiling construction.

**EXCEPTION:** Where penetrations are protected as shaft enclosures as required in Section 1706.

When materials are incorporated into an otherwise fire-resistive assembly which may change the capacity for heat dissipation, fire test results or other substantiating data shall be made available to the building official to show that the required fire-resistive time period is not reduced.

(b) **Floors.** Fire-resistive floors shall be continuous and all openings for mechanical and electrical equipment shall be enclosed as specified in Section 1706.

**EXCEPTIONS:** 1. Occasional pipes, conduits, sleeves and electrical outlets of copper, sheet steel or ferrous construction may be installed within or through fire-resistive floor systems, provided such installations do not unduly impair the required fire resistance of the assembly. The space between the pipe, conduit and sleeves and the floor shall be designed to prevent the movement of hot flame or gases.

2. The provisions of this section shall not apply when such openings are in accordance with the results of tests conducted pursuant to the provisions of Section 4302 (b).

(c) **Roofs.** Fire-resistive roofs may have the same openings as permitted for floors and may contain other openings as permitted by this code. See Chapter 34 for skylight construction.

(d) **Ceiling Panels.** Where the weight of lay-in roof-ceiling panels, used as part of fire-resistive floor-ceiling assemblies is not adequate to resist an upward force of one pound per square foot, wire or other approved devices shall be installed above the panels to prevent vertical displacement under such upward force.

(e) **Wiring in Plenums.** Wiring in plenums shall comply with the Mechanical Code.

## Fire-resistive Assemblies for Protection of Openings

**Sec. 4306.** (a) **General.** Where required by this code for the fire protection of openings, fire-resistive assemblies shall meet the requirements of this chapter.

(b) **Definitions.**

**FIRE ASSEMBLY** is the assembly of a fire door, fire windows or fire damper, including all required hardware, anchorage, frames and sills.

**FIRE ASSEMBLY, AUTOMATIC-CLOSING,** is a fire assembly which may remain in an open position and which will close automatically when subjected to one or the other of the following:

1. An increase in temperature.

Unless otherwise specified, the closing device shall be one rated at a maximum temperature of 165°F.

2. Actuation of a smoke detector.



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The closing device shall operate by the activation of an approved smoke detector set to operate when smoke reduces the intensity of a 1-foot-long beam of white light by 4 percent. Smoke detectors shall meet the approval of the building official as to installation and locations and shall be subject to such periodic tests as may be required by the building official.

**FIRE ASSEMBLY, SELF-CLOSING,** is a fire assembly which is kept in a normally closed position and is equipped with an approved device to ensure closing and latching after having been opened for use.

(c) **Identification of Fire Doors, Fire Windows and Fire Dampers.** Fire doors, fire windows and fire dampers shall have a label or other identification showing the fire protection rating. Such label shall be approved and shall be permanently affixed. The label shall be applied at the factory where fabrication and assembly are done. Inspection shall be made by an approved inspection agency during fabrication and assembly.

Oversized fire doors may be installed when approved by the building official. The doors shall be labeled or be furnished with a certificate of inspection from an approved agency.

(d) **Installation of Fire Assemblies.** Approved fire door hardware and fire door frames including the anchorage thereof shall be installed in accordance with their listing. Fire dampers shall be fabricated and installed in accordance with U.B.C. Standard No. 43-7.

(e) **Fire-resistive Tests.** The fire-protection rating of all types of required fire assemblies shall be determined in accordance with the requirements specified in U.B.C. Standards Nos. 43-2, 43-3, 43-4 and 43-7.

(f) **Hardware.** 1. **Closing devices.** Every fire assembly shall be provided with a closing device as follows:

A. Fire assemblies required to have a three-hour fire-protection rating shall be automatic-closing fire assemblies. Automatic-closing fire assemblies to be activated by an increase in temperature shall have one heat-actuating device installed on each side of the wall at the top of the opening and one on each side of the wall at the ceiling height where the ceiling is more than 3 feet above the top of the opening.

B. Fire assemblies required to have a one and one-half-hour, one-hour or three-fourths-hour fire-protection rating shall be either automatic- or self-closing fire assemblies. Automatic-closing fire assemblies to be activated by an increase in temperature shall have heat-actuating devices located as required in Item A or by a single fusible link in the opening incorporated in the closing device.

C. Swinging fire door assemblies of any fire-protection rating which are installed across a corridor shall be smoke-detector-activated automatic-closing fire assemblies. All hold-open devices shall be an approved type which will release the door in the event of a power failure.

D. Fire assemblies required by provisions of Chapter 33 shall have closing devices as specified in Chapter 33.



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Fire doors which are automatic closing by smoke detection shall not have a closing or reclosing delay of more than 10 seconds.

2. **Hinges.** Swinging fire doors shall have not less than two hinges; and when such door exceeds 60 inches in height an additional hinge shall be installed for each additional 30 inches of height or fraction thereof. Hinges, except for spring hinges, shall be of the ball-bearing or antifriction type. When spring hinges are used for door-closing purposes not less than one half of the hinges shall be spring hinges.

3. **Latch.** Unless otherwise specifically permitted, all single doors and both leaves of pairs of side-hinged swinging doors shall be provided with an automatic latch which will secure the door when it is closed.

(g) **Glazed Openings in Fire Doors.** Glazed openings in fire doors shall not be permitted in a fire assembly required to have a three-hour fire-resistive rating.

The area of glazed openings in a fire door required to have one and one-half hour or one-hour fire-resistive rating shall be limited to 100 square inches with a minimum dimension of 4 inches. When both leaves of a pair of doors have observation panels, the total area of the glazed openings shall not exceed 100 square inches for each leaf.

Glazed openings shall be limited to 1296 square inches in wood and plastic-faced composite or hollow metal doors, per light, when fire-resistive assemblies are required to have a three-fourths-hour fire-resistive rating.

(h) **Glazed Openings in Fire Windows.** Windows required to have a three-fourths-hour fire-resistive rating may have an area not greater than 84 square feet with neither width nor height exceeding 12 feet.

(i) **Glazing.** Glazing shall be glass not less than 1/4 ineh thick and shall be reinforced with wire mesh No. 24 gauge or heavier embedded in the glass with openings not larger than 1 inch square. Glass or glass block assemblies not conforming to these requirements may be used when qualified by tests in accordance with U.B.C. Standard No. 43-2 (for doors) or No. 43-4 (for windows). Glass shall be held in place by steel glazing angles, except that in casement windows wire elips may be used.

(j) **Fire Dampers.** Except where fire tests have shown that fire dampers are not necessary to maintain the required fire resistance of the construetion, fire dampers complying with the requirements of U.B.C. Standard No. 43-7 shall be installed and be readily accessible for servicing in the following locations:

1. Duct penetrations of area or occupancy separation walls. When the wall is required to have a rating of more than two hours, a fire door meeting the requirements of U.B.C. Standard No. 43-2 is required.
2. Ducts passing through horizontal exit walls.
3. Ducts penetrating shafts.

   **EXCEPTION:** Steel exhaust air subducts extending at least 22 inches vertically in a vented shafi and the airflow is upward.

4. Ducts penetrating the ceiling of a fire-resistive floor-ceiling or roof-ceiling assembly shall be protected in accordance with Section 4303 (b) 6.



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5. Ducts penetrating fire-resistive elements of fire-rated corridor walls.

**EXCEPTION:** A minimum of 0.019-inch (No. 26 gauge) steel ducts do not require dampers when the duct has no openings into the corridor.

(k) **Installation.** Fire assemblies shall be installed in accordance with their listing.

(l) **Signs.** When required by the building official, a sign shall be displayed permanently near or on each required fire door in letters not less than 1 inch high to read as follows:

FIRE DOOR
DO NOT OBSTRUCT

## Roof Coverings

**Sec. 4307.** Fire-retardant roof coverings shall be as specified in Table No. 32-A.



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## TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]

| STRUCTURAL PARTS TO BE PROTECTED | ITEM NUMBER | INSULATING MATERIAL USED | MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 1. Steel Columns and All Members of Primary Trusses | 1-1.1 | Carbonate, lightweight and sand-lightweight aggregate concrete, members 6" by 6" or greater (not including sandstone, granite and siliceous gravel).[1] | 2½ | 2 | 1½ | 1 |
| | 1-1.2 | Carbonate, lightweight and sand-lightweight aggregate concrete, members 8" by 8" or greater (not including sandstone, granite and siliceous gravel).[1] | 2 | 1½ | 1 | 1 |
| | 1-1.3 | Carbonate, lightweight and sand-lightweight aggregate concrete, members 12" by 12" or greater (not including sandstone, granite and siliceous gravel).[1] | 1½ | 1 | 1 | 1 |
| | 1-1.4 | Siliceous aggregate concrete and concrete excluded in Item No. 1-1.1, members 6" by 6" or greater.[1] | 3 | 2 | 1½ | 1 |
| | 1-1.5 | Siliceous aggregate concrete and concrete excluded in Item No. 1-1.1, members 8" by 8" or greater.[1] | 2½ | 2 | 1 | 1 |
| | 1-1.6 | Siliceous aggregate concrete and concrete excluded in Item No. 1-1.1, members 12" by 12" or greater.[1] | 2 | 1 | 1 | 1 |
| | 1-2.1 | Clay or shale brick with brick and mortar fill.[1] | 3¾ | | | 2¼ |
| | 1-3.1 | 4" Hollow clay tile in two 2" layers: ½" mortar between tile and column; ⅜" metal mesh (.046" wire diameter) in horizontal joints; tile fill.[1] | 4 | | | |
| | 1-3.2 | 2" Hollow clay tile; ¾" mortar between tile and column; ⅜" metal mesh (.046" wire diameter) in horizontal joints; limestone concrete fill;[1] plastered with ¾" gypsum plaster. | 3 | | | |
| | 1-3.3 | 2" Hollow clay tile with outside wire ties (.08" diameter) at each course of tile or ⅜" metal mesh (.046" diameter wire) in horizontal joints; limestone or trap-rock concrete fill[1] extending 1" outside column on all sides. | | | 3 | |

*(Continued)*





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## TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

| STRUCTURAL PARTS TO BE PROTECTED | ITEM NUMBER | INSULATING MATERIAL USED | MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 1. Steel Columns and All Members of Primary Trusses | 1-3.4 | 2" Hollow clay tile with outside wire ties (.08" diameter) at each course of tile with or without concrete fill; 3/4" mortar between tile and column. | | | | 2 |
| | 1-4.1 | Portland cement plaster over metal lath wire tied to 3/4" cold-rolled vertical channels with No. 18 gauge wire ties spaced 3" to 6" on center. Plaster mixed 1:2 1/2 by volume, cement to sand. | | | 2 1/2[2] | 7/8 |
| | 1-5.1 | Vermiculite concrete, 1:4 mix by volume over paperbacked wire fabric lath wrapped directly around column with additional 2" by 2" No. 16/16 gauge wire fabric placed 3/4" from outer concrete surface. Wire fabric tied with No. 18 gauge wire spaced 6" on center for inner layer and 2" on center for outer layer. | 2 | | | |
| | 1-6.1 | Perlite or vermiculite gypsum plaster over metal lath wrapped around column and furred 1 1/4" from column flanges. Sheets lapped at ends and tied at 6" intervals with No. 18 gauge tie wire. Plaster pushed through to flanges. | 1 1/2 | 1 | | |
| | 1-6.2 | Perlite or vermiculite gypsum plaster over self-furring metal lath wrapped directly around column, lapped 1" and tied at 6" intervals with No. 18 gauge wire. | 1 3/4 | 1 3/8 | 1 | |
| | 1-6.3 | Perlite or vermiculite gypsum plaster on metal lath applied to 3/4" cold-rolled channels spaced 24 inches apart vertically and wrapped flatwise around column. | 1 1/2 | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 1. Steel Columns and All Members of Primary Trusses | 1-6.4 | Perlite or vermiculite gypsum plaster over 2 layers of 1/2" plain full-length gypsum lath applied tight to column flanges. Lath wrapped with 1" hexagonal mesh of No. 20 gauge wire and tied with doubled No. 18 gauge wire ties spaced 23" on center. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2 1/2 cubic feet of aggregate for the three-hour system. | 2 1/2 | 2 | | |
| | 1-6.5 | Perlite or vermiculite gypsum plaster over one layer of 1/2" plain full-length gypsum lath applied tight to column flanges. Lath tied with doubled No. 18 gauge wire ties spaced 23" on center and scratch coat wrapped with 1" hexagonal mesh No. 20 gauge wire fabric. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2 1/2 cubic feet of aggregate. | | 2 | | |
| | 1-7.1 | Multiple layers of 1/2" gypsum wallboard[3] adhesively[4] secured to column flanges and successive layers. Wallboard applied without horizontal joints. Corner edges of each layer staggered. Wallboard layer below outer layer secured to column with doubled No. 18 gauge wire ties spaced 15" on center. Exposed corners taped and treated. | | | 2 | 1 |

*(Continued)*





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## TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

| STRUCTURAL PARTS TO BE PROTECTED | ITEM NUMBER | INSULATING MATERIAL USED | MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 1. Steel Columns and All Members of Primary Trusses | 1-7.2 | Three layers of 5/8" Type X gypsum wallboard.[3] First and second layer held in place by 1/8" diameter by 1 3/8" long ring shank nails with 5/16" diameter heads spaced 24" on center at corners. Middle layer also secured with metal straps at mid-height and 18" from each end, and by metal corner bead at each corner held by the metal straps. Third layer attached to corner bead with 1" long gypsum wallboard screws spaced 12" on center. | | | 1 7/8 | |
| | 1-7.3 | Three layers of 5/8" Type X gypsum wallboard,[3] each layer screw attached to 1 5/8" steel studs (No. 25 gauge) at each corner of column. Middle layer also secured with No. 18 gauge double strand tie wire, 24" on center for inner layer, No. 6 by 1 5/8" spaced 12" on center for middle layer and No. 8 by 2 1/4" spaced 12" on center for outer layer. | | 1 7/8 | | |
| | 1-8.1 | Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath lapped 1" and tied 6" on center at all ends, edges and spacers with No. 18 gauge tie wire. Lath applied over 1/2" spacers made of 3/4" furring channel with 2" legs bent around each corner. Spacers located 1" from top and bottom of member and a maximum of 40" on center and wire tied with a single strand of No. 18 gauge wire. Corner bead tied to the lath at 6" on center along each corner to provide plaster thickness. | | | 1 5/8 | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Webs or Flanges of Steel Beams and Girders | 2-1.1 | Carbonate, lightweight and sand-lightweight aggregate concrete (not including sandstone, granite and siliceous gravel) with 3" or finer metal mesh placed 1" from the finished surface anchored to the top flange and providing not less than .025 square inch of steel area per foot in each direction. | 2 | 1½ | 1 | 1 |
| | 2-1.2 | Siliceous aggregate concrete and concrete excluded in Item 2-1.1 with 3" or finer metal mesh placed 1" from the finished surface anchored to the top flange and providing not less than .025 square inch of steel area per foot in each direction. | 2½ | 2 | 1½ | 1 |
| | 2-2.1 | Portland cement plaster on metal lath attached to ¾" cold-rolled channels with No. 18 gauge wire ties spaced 3" to 6" on center. Plaster mixed 1:2½ by volume, cement to sand. | | | 2½[2] | ⅞ |
| | 2-3.1 | Vermiculite gypsum plaster on a metal lath cage, wire tied to No. 8 steel wire hangers wrapped around beam and spaced 16" on center. Metal lath ties spaced approximately 5" on center at cage sides and bottom. | | ⅞ | | |

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## TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

| STRUCTURAL PARTS TO BE PROTECTED | ITEM NUMBER | INSULATING MATERIAL USED | MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 2. Webs or Flanges of Steel Beams and Girders | 2-4.1 | Two layers of 5/8" Type X gypsum wallboard[3] are attached to U-shaped brackets spaced 24" on center. No. 25 gauge 1 5/8" deep by 1" galvanized steel runner channels are first installed parallel to and on each side of the top beam flange to provide a 1/2" clearance to the flange. The channel runners are attached to steel deck or concrete floor construction with approved fasteners spaced 12" on center. U-shaped brackets are formed from members identical to the channel runners. At the bent portion of the U-shaped bracket, the webs of the channel are cut out so that 1 3/8" deep corner channels can be inserted without attachment parallel to each side of the lower flange. As an alternate No. 24 gauge 1" by 2" runner and corner angles may be used in lieu of channels and the web cutouts in the U-shaped brackets may be omitted. Each angle is attached to the bracket with 1/2" long No. 8 self-drilling screws. The vertical legs of the U-shaped bracket are attached to the runners with one 1/2" long No. 8 self-drilling screw. The completed steel framing provides a 2 1/8" and 1 1/2" space between the inner layer of wallboard and the sides and bottom of the steel beam respectively. The inner layer of wallboard is attached to the top runners and bottom corner channels or corner angles with 1 1/4" long No. 6 self-drilling screws spaced 16" on center. The outer layer of wallboard is applied with 1 3/4" long No. 6 self-drilling screws spaced 8" on center. The bottom corners are reinforced with metal corner beads. | | | 1 1/4 | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Webs or Flanges of Steel Beams and Girders | 2-4.2 | Three layers of 5/8" Type X gypsum wallboard[3] attached to a steel suspension system as described immediately above utilizing the No. 25 gauge 1" by 2" lower corner angles. The framing is located so that a 2 1/8" and 2" space is provided between the inner layer of wallboard and the sides and bottom of the beam respectively. The first two layers of wallboard are attached as described immediately above. A layer of No. 20 gauge 1" hexagonal galvanized wire mesh is applied under the soffit of the middle layer and up the sides approximately 2". The mesh is held in position with the No. 6 1 5/8" long screws installed in the vertical leg of the bottom corner angles. The outer layer of wallboard is attached with No. 6 2 1/4" long screws spaced 8" on center. One screw is also installed at the mid-depth of the bracket in each layer. Bottom corners are finished as described above. | | 1 7/8 | | |
| 3. Bonded Pretensioned Reinforcement in Prestressed Concrete[5] | 3-1.1 | Carbonate, lightweight and sand-lightweight aggregate[6] concrete<br>Beams or girders<br>Solid slabs[8] | <br>4[7] | <br>3[7]<br>2 | <br>2 1/2[7]<br>1 1/2 | <br>1 1/2<br>1 |
| 4. Bonded or Unbonded Posttensioned Tendons in Prestressed Concrete[5 10] | 4-1.1 | Carbonate, lightweight, sand-lightweight and siliceous aggregate concrete<br>Unrestrained Members:<br>Solid Slabs[8]<br>Beams and Girders[11]<br>8 in. wide<br>> 12 in. wide | <br><br><br><br>3 | <br>2<br><br>4 1/2<br>2 1/2 | <br>1 1/2<br><br>2 1/2<br>2 | <br><br><br>1 3/4<br>1 1/2 |

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## TABLE NO. 43-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

| STRUCTURAL PARTS TO BE PROTECTED | ITEM NUMBER | INSULATING MATERIAL USED | MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 4. Bonded or Unbonded Posttensioned Tendons in Prestressed Concrete[5,10] | 4-1.2 | Carbonate, lightweight, sand-lightweight and siliceous aggregate<br>Restrained Members:[12]<br>Solid Slabs[8]<br>Beams and Girders[11]<br>8 in. Wide<br>> 12 in. wide | <br><br>1 1/4<br><br>2 1/2<br>2 | <br><br>1<br><br>2<br>1 3/4 | <br><br>3/4<br><br>1 3/4<br>1 1/2 | |
| 5. Reinforcing Steel in Reinforeed Concrete Columns, Beams, Girders and Trusses | 5-1.1 | Carbonate, lightweight and sand-lightweight aggregate concrete, members 12" or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.) | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 |
| | 5-1.2 | Siliceous aggregate concrete, members 12" or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.) | 2 | 1 1/2 | 1 1/2 | 1 1/2 |
| 6. Reinforcing Steel in Reinforeed Concrete Joists[9] | 6-1.1 | Carbonate, lightweight and sand-lightweight aggregate concrete. | 1 1/4 | 1 1/4 | 1 | 3/4 |
| | 6-1.2 | Siliceous aggregate concrete. | 1 3/4 | 1 1/2 | 1 | 3/4 |
| 7. Reinforcing and Tie Rods in Floor and Roof Slabs[9] | 7-1.1 | Carbonate, lightweight and sand-lightweight aggregate concrete. | 1 | 1 | 3/4 | 3/4 |
| | 7-1.2 | Siliceous aggregate concrete. | 1 1/4 | 1 | 1 | 3/4 |



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[A]Generic fire-resistance ratings (those not designated by a company code letter) as listed in the Fire Resistance Design Manual, Eleventh Edition, dated October, 1984, as published by the Gypsum Association, may be accepted as if herein listed.

[1]Reentrant parts of protected members to be filled solidly.

[2]Two layers of equal thickness with a 3/4-inch air space between.

[3]For all of the construction with gypsum wallboard described in Table No. 43-A, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard and the joints on the face layer are reinforced and the entire surface is covered with a minimum of 1/16-inch gypsum veneer plaster. The gypsum base for veneer plaster and the veneer plaster shall comply with U.B.C. Standard No. 47-15.

[4]An approved adhesive qualified under U.B.C. Standard No. 43-1.

[5]Where lightweight or sand-lightweight concrete having an oven-dry weight of 110 pounds per cubic foot or less is used, the tabulated minimum cover may be reduced 25 percent, except that in no case shall the cover be less than 3/4 inch in slabs nor 1 1/2 inches in beams or girders.

[6]For siliceous aggregate concrete increase tendon cover 20 percent.

[7]Adequate provisions against spalling shall be provided by U-shaped or hooped stirrups spaced not to exceed the depth of the member with a clear cover of 1 inch.

[8]Prestressed slabs shall have a thickness not less than that required in Table No. 43-C for the respective fire-resistive time period.

[9]For use with concrete slabs having a comparable fire endurance where members are framed into the structure in such a manner as to provide equivalent performance to that of monolithic concrete construction.

[10]Fire coverage and end anchorages shall be as follows: Cover to the prestressing steel at the anchor shall be 1/2 inch greater than that required away from the anchor. Minimum cover to steel bearing plate shall be 1 ineh in beams and 3/4 inch in slabs.

[11]For beam widths between 8 and 12 inches, cover thickness can be determined by interpolation.

[12]Interior spans of continuous slabs, beams and girders may be considered restrained.





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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 1. Brick of Clay or Shale | 1-1.1 | Solid units (at least 75 percent solid). | 8 | | 6[3] | 4 |
| | 1-1.2 | Solid units plastered each side with 5/8" gypsum or portland cement plaster. Portland cement plaster mixed 1:2½ by weight; cement to sand. | | | 4 3/4[4] | |
| | 1-2.1 | Hollow brick units[5] at least 71 percent solid. | | 8 | | |
| | 1-2.2 | Hollow brick units[5] at least 71 percent solid, plastered each side with 5/8" gypsum plaster. | 8 3/4 | | | |
| | 1-3.1 | Hollow (rowlock[6]). | 12 | | 8 | |
| | 1-3.2 | Hollow (rowlock[6]) plastered each side with 5/8" gypsum or portland cement plaster. Portland cement plaster mixed 1:2½ by weight, cement to sand. | 9 | | | |
| | 1-4.1 | Hollow cavity wall consisting of two 4" nominal clay brick units with air space between. | 10 | | | |
| | 1-4.2. | Cavity wall consisting of two 3-inch nominal thick solid clay units with air space. | | 8 | | |
| | 1-5.1 | Hollow brick units at least 60 percent solid, cells filled with perlite loose fill insulation. | 8 | | | |
| | 1-6.1 | 4" nominal thick units at least 75 percent solid backed with a hat-shaped metal furring channel ¾ inch thick formed from 0.021-inch sheet metal attached to the brick wall on 24-inch centers with approved fasteners; and ½ inch Type X gypsum wallboard[7] attached to the metal furring strips with 1-inch-long Type S screws spaced 8 inches on center. | | | 5[4] | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 2. Hollow Clay Tile, Non-load-bearing (End or Side Construction) | 2-1.1 | One cell in wall thickness, units at least 50 percent solid, plastered each side with 5/8" gypsum plaster. | | | | 4 1/4 |
| | 2-1.2 | Two cells in wall thickness, units at least 45 percent solid. | | | | 6 |
| | 2-1.3 | Two cells in wall thickness, units at least 45 percent solid. Plastered each side with 5/8" gypsum plaster. | | | 7 | |
| | 2-1.4 | Two cells in wall thickness, units at least 60 percent solid. Plastered each side with 5/8" gypsum plaster. | | | 5 | |
| 3. Hollow Clay Tile, Load-bearing (End or Side Construction) | 3-1.1 | Two cells in wall thickness, units at least 40 percent solid. | | | | 8 |
| | 3-1.2 | Two cells in wall thickness, units at least 40 percent solid. Plastered one side with 5/8" gypsum plaster. | | | 8 1/2 | |
| | 3-1.3 | Two cells in wall thickness, units at least 49 percent solid. | | | 8 | |
| | 3-1.4 | Three cells in wall thickness, units at least 40 percent solid. | | | 12 | |
| | 3-1.5 | Two units and three cells in wall thickness, units at least 40 percent solid. | | 12 | | |
| | 3-1.6 | Two units and four cells in wall thickness, units at least 45 percent solid. | 12 | | | |
| | 3-2.1 | Two units and three cells in wall thickness, units at least 40 percent solid. Plastered one side with 5/8" gypsum plaster. | 12 1/2 | | | |
| | 3-2.2 | Three cells in wall thickness, units at least 43 percent solid. Plastered one side with 5/8" gypsum plaster. | | 8 1/2 | | |

*(Continued)*





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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 3. Hollow Clay Tile, Load-bearing (End or Side Construction) | 3-2.3 | Two cells in wall thickness, units at least 40 percent solid. Plastered each side with 5/8" gypsum plaster. | | 9 | | |
| | 3-2.4 | Three cells in wall thickness, units at least 43 percent solid. Plastered each side with 5/8" gypsum plaster. | 9 | | | |
| | 3-2.5 | Three cells in wall thickness, units at least 40 percent solid. Plastered each side with 5/8" gypsum plaster. | 13 | | | |
| | 3-3.1 | Hollow cavity wall consisting of two 4" nominal clay tile units (at least 40 percent solid) with air space between. Plastered one side (exterior) with 3/4" portland cement plaster and other side with 5/8" gypsum plaster. Portland cement plaster mixed 1:3 by volume, cement to sand. | 10 | | | |
| 4. Combination of Clay Brick and Load-bearing Hollow Clay Tile | 4-1.1 | 4" brick and 8" tile. | 12 | | | |
| | 4-1.2 | 4" brick and 4" tile. | | 8 | | |
| | 4-1.3 | 4" brick and 4" tile plastered on the tile side with 5/8" gypsum plaster. | 8 1/2 | | | |
| 5. Concrete Masonry Units[8] | 5-1.1[13 14] | Expanded slag or pumice. | 4.7 | 4.0 | 3.2 | 2.1 |
| | 5-1.2[13 14] | Expanded clay, shale or slate. | 5.1 | 4.4 | 3.6 | 2.6 |
| | 5-1.3[13] | Limestone, cinders or air-cooled slag. | 5.9 | 5.0 | 4.0 | 2.7 |
| | 5-1.4[13 14] | Calcareous or siliceous gravel. | 6.2 | 5.3 | 4.2 | 2.8 |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 6. Solid Concrete[8 15] | 6-1.1 | Siliceous Aggregate Concrete. | 7.0 | 6.2 | 5.0 | 3.5 |
| | | Carbonate Aggregate Concrete. | 6.6 | 5.7 | 4.6 | 3.2 |
| | | Sand-lightweight Concrete.. | 5.4 | 4.6 | 3.8 | 2.7 |
| | | Lightweight Concrete. | 5.1 | 4.4 | 3.6 | 2.5 |
| 7. Glazed or Unglazed Facing Tile, Nonload-bearing | 7-1.1 | One 2″ unit cored 15 percent maximum and one 4″ unit cored 25 percent maximum with 3/4″ mortar filled collar joint. Unit positions reversed in alternate courses. | | 6 3/8 | | |
| | 7-1.2 | One 2″ unit cored 15 percent maximum and one 4″ unit cored 40 percent maximum with 3/8″ mortar filled collar joint. Plastered one side with 3/4″ gypsum plaster. Two wythes tied together every fourth course with No. 22 gauge corrugated metal ties. | | 6 3/4 | | |
| | 7-1.3 | One unit with three cells in wall thickness, cored 29 percent maximum. | | | 6 | |
| | 7-1.4 | One 2″ unit cored 22 percent maximum and one 4″ unit cored 41 percent maximum with 1/4″ mortar filled collar joint. Two wythes tied together every third course with No. 22 gauge corrugated metal ties. | | | 6 | |
| | 7-1.5 | One 4″ unit cord 25 percent maximum with 3/4″ gypsum plaster on one side. | | | 4 3/4 | |
| | 7-1.6 | One 4″ unit with two cells in wall thickness, cored 22 percent maximum. | | | | 4 |

*(Continued)*





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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 7. Glazed or Unglazed Facing Tile, Nonload-bearing | 7-1.7 | One 4" unit cored 30 pereent maximum with 3/4" vermiculite gypsum plaster on one side. | | | 4 1/2 | |
| | 7-1.8 | One 4" unit cored 39 percent maximum with 3/4" gypsum plaster on one side. | | | | 4 1/2 |
| 8. Solid Gypsum Plaster | 8-1.1 | 3/4" by No. 16 gauge vertical cold-rolled channels, 16" on center with 2.5-pound flat metal lath applied to one face and tied with No. 18 gauge wire at 6" spacing. Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate. | | | | 2[4] |
| | 8-1.2 | 3/4" by No. 16 gauge cold-rolled channels 16" on eenter with metal lath applied to one face and tied with No. 18 gauge wire at 6" spacing. Perlite or vermiculite gypsum plaster each side. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2 1/2 cubic feet of aggregate for the one-hour system. | | | 2 1/2[4] | 2[4] |
| | 8-1.3 | 3/4" by No. 16 gauge vertical cold-rolled channels, 16" on center, with 3/8" gypsum lath applied to one face and attached with sheet metal clips: Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate. | | | | 2[4] |
| | 8-2.1 | Studless with 1/2" full-length plain gypsum lath and gypsum plaster each side. Plaster mixed 1:1 for scratch coat and 1:2 for brown coat, by weight, gypsum to sand aggregate. | | | | 2[4] |
| | 8-2.2 | Studless with 1/2" full-length plain gypsum lath and perlite or vermiculite gypsum plaster each side. | | | 2 1/2[4] | 2[4] |
| | 8-2.3 | Studless partition with 3/8" rib metal lath installed vertically, adjacent edges tied 6" on center with No. 18 gauge wire ties, gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate. | | | | 2[4] |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 9. Solid Perlite and Portland Cement | 9-1.1 | Perlite mixed in the ratio of 3 cubic feet to 100 pounds of portland cement and machine applied to stud side of 1½" mesh by No. 17 gauge paper-backed woven wire fabric lath wire-tied to 4" deep steel trussed wire[9] studs 16" on center. Wire ties of 18 gauge galvanized steel wire 6" on center vertically. | | | 3⅛[4] | |
| 10. Solid Neat Wood Fibered Gypsum Plaster | 10-1.1 | ¾" by No. 16 gauge cold-rolled channels, 12" on center with 2.5-pound flat metal lath applied to one face and tied with No. 18 gauge wire at 6" spacing. Neat gypsum plaster applied each side. | | | 2[4] | |
| 11. Solid Gypsum Wallboard Partition | 11-1.1 | One full-length layer ½" Type X gypsum wallboard[7] laminated to each side of 1" full-length V-edge gypsum coreboard with approved laminating compound. Vertical joints of face layer and coreboard staggered at least 3". | | | 2[4] | |
| 12. Hollow (Studless) Gypsum Wallboard Partition | 12-1.1 | One full-length layer of ⅝" Type X gypsum wallboard[7] attached to both sides of wood or metal top and bottom runners laminated to each side of 1" x 6" full-length gypsum coreboard ribs spaced 24" on center with approved laminating compound. Ribs centered at vertical joints of face plies and joints staggered 24" in opposing faces. Ribs may be recessed 6" from the top and bottom. | | | | 2¼[4] |

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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 12. Hollow (Studless) Gypsum Wallboard Partition | 12-1.2 | 1" regular gypsum V-edge full-length backing board attached to both sides of wood or metal top and bottom runners with nails or 1 5/8" drywall screws at 24" on center. Minimum width of runners 1 5/8". Face layer of 1/2" regular full-length gypsum wallboard laminated to outer faces of backing board with approved laminating compound. | - | — | 4 5/8[4] | - |
| 13. Noncombustible Studs—Interior Partition with Plaster Each Side | 13-1.1 | 3 1/4" by No. 18 gauge steel studs spaced 24" on center. 5/8" gypsum plaster on metal lath each side mixed 1:2 by weight, gypsum to sand aggregate. | | | | 4 3/4[4] |
| | 13-1.2 | 3 5/8" No. 16 gauge approved nailable[10] studs spaced 24" on center. 5/8" neat gypsum wood fibered plaster each side over 3/8" rib metal lath nailed to studs with 6d common nails, 8" on center. Nails driven 1 1/4" and bent over. | | | 5 5/8 | |
| | 13-1.3 | 4" No. 18 gauge channel-shaped steel studs at 16" on center. On each side approved resilient clips pressed onto stud flange at 16" vertical spacing, 1/4" pencil rods snapped into or wire-tied onto outer loop of clips, metal lath wire-tied to pencil rods at 6" intervals. 1" perlite gypsum plaster, each side. | | 7 5/8[4] | | - |
| | 13-1.4 | 2 1/2" No. 18 gauge steel studs spaced 16" on center. Wood fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied on 3.4 pound metal lath wire tied to studs, each side. 3/4" plaster applied over each face, including finish coat. | | | 4 1/4[4] | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 14. Wood Studs Interior Partition with Plaster Each Side | 14-1.1[11 16] | 2″ x 4″ wood studs 16″ on center with $^5/_8$″ gypsum plaster on metal lath. Lath attached by 4d common nails bent over or No. 14 gauge by 1 $^1/_4$″ x $^3/_4$″ crown width staples spaced 6″ on center. Plaster mixed 1:1 $^1/_2$ for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate. | | | | 5 $^1/_8$ |
| | 14-1.2[11] | 2″ x 4″ wood studs 16″ on center with metal lath and $^7/_8$″ neat wood fibered gypsum plaster each side. Lath attached by 6d common nails, 7″ on center. Nails driven 1 $^1/_4$″ and bent over. | | | 5 $^1/_2$[4] | |
| | 14-1.3[11 16] | 2″ x 4″ wood studs 16″ on center with $^3/_8$″ perforated or plain gypsum lath and $^1/_2$″ gypsum plaster each side. Lath nailed with 1 $^1/_8$″ by No. 13 gauge by $^{19}/_{64}$″ head plasterboard blued nails, 4″ on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate. | | | | 5 $^1/_4$ |
| | 14-1.4[11 16] | 2″ x 4″ wood studs 16″ on center with $^3/_8$″ Type X gypsum lath and $^1/_2$″ gypsum plaster each side. Lath nailed with 1 $^1/_8$″ by No. 13 gauge by $^{19}/_{64}$″ head plasterboard blued nails, 5″ on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate. | | | | 5 $^1/_4$ |
| 15. Noncombustible Studs—Interior Partition with Gypsum Wallboard Each Side | 15-1.1 | No. 25 gauge channel-shaped studs 24″ on center with one full-length layer of $^5/_8$″ Type X gypsum wallboard[7] applied vertically attached with 1″ long No. 6 drywall screws to each stud. Screws are 8″ on center around the perimeter and 12″ on center on the intermediate stud. The wallboard may be applied horizontally when attached to 3 $^5/_8$″ studs and the horizontal joints are staggered with those on the opposite side. Screws for the horizontal application shall be 8″ on center at vertical edges and 12″ on center at intermediate studs. | | | | 2 $^7/_8$[4] |
| | 15-1.2 | No. 25 gauge channel-shaped studs 24″ on center with two full-length layers of $^1/_2$″ Type X gypsum wallboard[7] applied vertically each side. First layer attached with 1″ long, No. 6 drywall screws, 8″ on center around the perimeter and 12″ on center on the intermediate stud. Second layer applied with vertical joints offset one stud space from first layer using 1 $^5/_8$″ long, No. 6 drywall screws spaced 9″ on center along vertical joints, 12″ on center at intermediate studs and 24″ on center along top and bottom runners. | | | 3 $^5/_8$[4] | |

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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 15. Noncombustible Studs—Interior Partition with Gypsum Wallboard Each Side | 15-1.3 | No. 16 gauge approved nailable metal studs[10] 24″ on center with full-length 5/8″ Type X gypsum wallboard[7] applied vertically and nailed 7″ on center with 6d cement-coated common nails. Approved metal fastener grips used with nails at vertical butt joints along studs. | | | | 4 7/8 |
| 16. Wood Studs—Interior Partition with Gypsum Wallboard Each Side | 16-1.1[11 16] | 2″ x 4″ wood studs 16″ on center with two layers of 3/8″ regular gypsum wallboard[7] each side, 4d cooler[12] or wallboard[12] nails at 8″ on center first layer, 5d cooler[12] or wallboard[12] nails at 8″ on center second layer with laminating compound between layers. Joints staggered. First layer applied full length vertically, second layer applied horizontally or vertically. | | | | 5 |
| | 16-1.2[11 16] | 2″ x 4″ wood studs 16″ on center with two layers 1/2″ regular gypsum wallboard[7] applied vertically or horizontally each side, joints staggered. Nail base layer with 5d cooler[12] or wallboard[12] nails at 8″ on center, face layer with 8d cooler[12] or wallboard[12] nails at 8″ on center. | | | | 5 1/2 |
| | 16-1.3[11 16] | 2″ x 4″ wood studs 24″ on center with 5/8″ Type X gypsum wallboard[7] applied vertically or horizontally nailed with 6d cooler[12] or wallboard[12] nails at 7″ on center with end joints on nailing members. | | | | 4 3/4 |
| | 16-1.4[11] | 2″ x 4″ fire-retardant-treated wood studs spaced 24″ on center with one layer of 5/8″ thick Type X gypsum wallboard[7] applied with face paper grain (long dimension) parallel to studs. Wallboard attached with 6d cooler[12] or wallboard[12] nails at 7″ on center. | – | | | 4 3/4[4] |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 16. Wood Studs—Interior Partition With Gypsum Wallboard Each Side | 16-1.5[11 16] | 2″ x 4″ wood studs 16″ on center with two layers 5/8″ Type X gypsum wallboard[7] each side. Base layers applied vertically and nailed with 6d cooler[12] or wallboard[12] nails at 9″ on center. Face layer applied vertically or horizontally and nailed with 8d cooler[12] or wallboard[12] nails at 7″ on center. For nail-adhesive application, base layers are nailed 6″ on center. Face layers applied with coating of approved wallboard adhesive and nailed 12″ on center. | | | 6 | |
| | 16-1.6[11] | 2″ x 3″ fire-retardant-treated wood studs spaced 24″ on center with one layer of 5/8″ thick Type X gypsum wallboard[7] applied with face paper grain (long dimension) at right angles to studs. Wallboard attached with 6d cement-coated box nails spaced 7″ on center. | | | | 3 5/8[4] |
| 17. Exterior or Interior Walls | 17-1.1[11 16] | Exterior surface with 3/4″ drop siding over 1/2″ gypsum sheathing on 2″ x 4″ wood studs at 16″ on center; interior surface treatment as required for one-hour-rated exterior or interior 2″ x 4″ wood stud partitions. Gypsum sheathing nailed with 1 3/4″ by No. 11 gauge by 7/16″ head galvanized nails at 8″ on center. Siding nailed with 7d galvanized smooth box nails. | | | | Varies |
| | 17-1.2[11 16] | 2″ x 4″ wood studs 16″ on center with metal lath and 3/4″ exterior cement plaster on each side. Lath attached with 6d common nails 7″ on center driven to 1″ minimum penetration and bent over. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand. | | | | 5 3/8 |

(Continued)





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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 17. Exterior or Interior Walls | 17-1.3[11 16] | 2" x 4" wood studs 16" on center with 7/8" exterior cement plaster (measured from the face of studs) on the exterior surface with interior surface treatment as required for interior wood stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand. | | | | Varies |
| | 17-1.4 | 3 5/8" No. 16 gauge noncombustible studs 16" on center with 7/8" exterior cement plaster (measured from the face of the studs) on the exterior surface with interior surface treatment as required for interior, nonbearing, noncombustible stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand. | | | | Varies[4] |
| | 17-1.5[16] | 2 1/4" x 3 3/4" clay face brick with cored holes over 1/2" gypsum sheathing on exterior surface of 2" x 4" wood studs at 16" on center and two layers 5/8" Type X gypsum wallboard[7] on interior surface. Sheathing placed horizontally or vertically with vertical joints over studs nailed 6" on center with 1 3/4" by No. 11 gauge by 7/16" head galvanized nails. Inner layer of wallboard placed horizontally or vertically and nailed 8" on center with 6d cooler[12] or wallboard[12] nails. Outer layer of wallboard placed horizontally or vertically and nailed 8" on center with 8d cooler[12] or wallboard[12] nails. All joints staggered with vertical joints over studs. Outer layer joints taped and finished with compound. Nailheads covered with joint compound. No. 20 gauge corrugated galvanized steel wall ties 3/4" by 6 5/8" attached to each stud with two 8d cooler[12] or wallboard[12] nails every sixth course of bricks. | | | 10 | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| 17. Exterior or Interior Walls | 17-1.6[11 16] | 2" x 6" fire-retardant-treated wood studs 16" on center. Interior face has two layers of 5/8" Type X gypsum wallboard[7] with the base layer placed vertically and attached with 6d box nails 12" on center. The face layer is placed horizontally and attached with 8d box nails 8" on center at joints and 12" on center elsewhere. The exterior face has a base layer of 5/8" Type X gypsum wallboard placed vertically with 6d box nails 8" on center at joints and 12" on center elsewhere. An approved building paper is next applied, followed by self-furred exterior lath attached with 2 1/2", No. 12 gauge galvanized roofing nails with a 3/8" diameter head and spaced 6" on center along each stud. Exterior cement plaster consisting of a 1/2" brown coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight, cement to sand with 10 pounds of hydrated lime and 3 pounds of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat. | | | 8 1/4 | | |
| | 17-1.7[11 16] | 2" x 6" wood studs 16" on center. The exterior face has a layer of 5/8" Type X gypsum wallboard[7] placed vertically with 6d box nails 8" on center at joints and 12" on center elsewhere. An approved building paper is next applied, followed by 1" by No. 18 gauge self-furred exterior lath attached with 8d by 2 1/2" long galvanized roofing nails spaced 6" on center along each stud. Exterior cement plaster consisting of a 1/2" scratch coat, a bonding agent and a 1/2" brown coat and a finish coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight; cement to sand with 10 pounds of hydrated lime and 3 pounds of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat. The interior is covered with 3/8" gypsum lath with 1" hexagonal mesh of No. 20 gauge woven wire lath furred out 5/16" and 1" perlite or vermiculite gypsum plaster. Lath nailed with 1 1/8" by No. 13 gauge by 19/64" head plasterboard blued nails spaced 5" on center. Mesh attached by 1 3/4" by No. 12 gauge by 3/8" head nails with 3/8" furrings, spaced 8" on center. The plaster mix shall not exceed 100 pounds of gypsum to 2 1/2 cubic feet of aggregate. | | | 8 3/8 | | |

(Continued)





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## TABLE NO. 43-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a] [1]—(Continued)

| MATERIAL | ITEM NUMBER | CONSTRUCTION | MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (In Inches) | | | |
|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 17. Exterior or Interior Walls | 17-1.8[11 16] | 2" x 6" wood studs 16" on center. The exterior face has a layer of 5/8" Type X gypsum wallboard[7] placed vertically with 6d box nails 8" on center at joints and 12" on center elsewhere. An approved building paper is next applied, followed by 1 1/2", by No. 17 gauge self-furred exterior lath attached with 8d by 2 1/2" long galvanized roofing nails spaced 6" on center along each stud. Exterior cement plaster consisting of a 1/2" scratch coat, and a 1/2" brown coat is then applied: The plaster may be placed by machine. The scratch coat is mixed in the proportion of 1:4 by weight, plastic cement to sand. The brown coat is mixed in the proportion of 1:5 by weight; plastic cement to sand. The interior is covered with 3/8" gypsum lath with 1" hexagonal mesh of No. 20 gauge woven wire lath furred out 5/16" and 1" perlite or vermiculite gypsum plaster. Lath nailed with 1 1/8" by No. 13 gauge by 19/64" head plasterboard blued nails spaced 5" on center. Mesh attached by 1 3/4" by No. 12 gauge by 3/8" head nails with 3/8" furrings, spaced 8" on center. The plaster mix shall not exceed 100 pounds of gypsum to 2 1/2 cubic feet of aggregate. | | | 8 3/8 | |
| | 17-1.9 | 4" No. 18 gauge, nonload-bearing metal studs, 16" on center, with 1" portland cement lime plaster (measured from the back side of the 3.4# expanded metal lath) on the exterior surface. Interior surface to be covered with 1" of gypsum plaster on 3.4# expanded metal lath proportioned by weight—1:2 for scratch coat, 1:3 for brown, gypsum to sand. Lath on one side of the partition fastened to 1/4" diameter pencil rods supported by No. 20 gauge metal clips, located 16" on center vertically, on each stud. 3" thick mineral fiber insulating batts friction fitted between the studs. | | | 6 1/2[4] | |

[a]Generic fire-resistance ratings (those not designated by company code letter) as listed in the Fire Resistance Design Manual, Eleventh Edition, dated October, 1984, as published by the Gypsum Association, may be accepted as if herein listed.

[1]Staples with equivalent holding power and penetration may be used as alternate fasteners to nails for attachment to wood framing.



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[2]Thickness shown for brick and clay tile are nominal thicknesses unless plastered, in which case thicknesses are net. Thickness shown for concrete masonry is equivalent thickness defined as the average thickness of solid material in the wall and is represented by the formula:

$$T_E = \frac{V_n}{L \times H}$$

**WHERE:**

$T_E$ = Equivalent thickness, in inches
$V_n$ = Net volume (gross volume less volume of voids), in cubic inches
$L$ = Length of block, in inches
$H$ = Height of block, in inches

Thickness includes plaster, lath and gypsum wallboard, where mentioned, and grout when all cells are solid grouted.

[3]Single-wythe brick.

[4]Shall be used for nonbearing purposes only.

[5]Hollow brick units 4-inch by 8-inch by 12-inch nominal with two interior cells having a 1½-inch web thickness between cells and 1¾-inch-thick face shells.

[6]Rowlock design employs clay brick with all or part of bricks laid on edge with the bond broken vertically.

[7]For all of the construction with gypsum wallboard described in Table No. 43-B, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard and the joints on the face layer are reinforced and the entire surface is covered with a minimum of 1/16-inch gypsum veneer plaster. The gypsum base for veneer plaster and the veneer plaster shall comply with U.B.C. Standard No. 47-15.

[8]See also Footnote 2. The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 47 of the code.

[9]Studs are welded truss wire studs with No. 7 gauge flange wire and No. 7 gauge truss wires.

[10]Nailable metal studs consist of two channel studs spot welded back-to-back with a crimped web forming a nailing groove.

[11]Plywood may be installed between the fire protection and the wood studs on either the interior or exterior side of the wood frame assemblies in this table, provided the length of the fasteners used to attach the fire protection are increased by an amount at least equal to the thickness of the plywood.

[12]For properties of cooler or wallboard nails, see U.B.C. Standard No. 25-17, Table No. 25-17-I.

[13]The fire-resistive time period for concrete masonry units meeting the equivalent thicknesses required for a two-hour fire-resistive rating in Item 5, and having a thickness of not less than 7⅝ inches is four hours when cores which are not grouted are filled with silicone-treated perlite loose-fill insulation conforming to U.B.C. Standard No. 43-10; vermiculite loose-fill insulation conforming to U.B.C. Standard No. 43-11; or expanded clay, shale or slate lightweight aggregate conforming to U.B.C. Standard No. 26-3; sand or slag having a maximum particle size of ⅜ inch.

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*(Continued)*

[14]For determining equivalent thickness of concrete masonry units made from unblended aggregates, see Footnote 2. The equivalent thickness of units composed of blends of two or more aggregate categories shall be determined by interpolating between the equivalent thickness values specified in Table No. 43-B in proportion to the percent by volume of each aggregate.

The equivalent thickness required to provide a desired fire-resistive time period for concrete masonry composed of units manufactured with fine aggregates passing a No. 4 sieve listed in Item 5-1.4 of Table No. 43-B blended with aggregates listed in Item 5-1.1 or 5-1.2 shall be determined by interpolating between the equivalent thickness values specified in Table No. 43-B in proportion to the percent by volume of each aggregate as follows:

1. $ET_{required} = ET_{1.4} \times V_{1.4} + ET_{1.1} \times V_{1.1}$

2. $ET_{required} = ET_{1.4} \times V_{1.4} + ET_{1.2} \times V_{1.2}$

The required equivalent thickness of concrete masonry units manufactured with aggregates listed in Items 5-1.1, 5-1.2 and 5-1.4 of Table No. 43-B shall be determined as follows:

3. $ET_{required} = ET_{1.4} \times V_{1.4} + ET_{1.2} \times (V_{1.1} + V_{1.2})$

**WHERE:**

$ET_{1.1}; ET_{1.2}, ET_{1.4}$ = specified equivalent thickness for Items 5-1.1, 5-1.2 and 5-1.4 of Table No. 43-B.

$V_{1.1}, V_{1.2}, V_{1.4}$ = volume of aggregates expressed as a percentage of the total aggregate volume for Item 5-1.1, 5-1.2 or 5-1.4 of Table No. 43-B.

[15]Concrete walls shall be reinforced with horizontal and vertical temperature reinforcement as required by Subsections 2614 (d) 2 and 3.

[16]The design stress of studs shall be reduced to 78 percent of allowable $F'_c$ with the maximum not greater than 78 percent of the calculated stress with studs having a slenderness ratio $\frac{le}{d}$ of 33.



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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a] [1]

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 1. Siliceous Aggregate Concrete | 1-1.1 | Slab (no ceiling required). Minimum cover over nonprestressed reinforcement shall be not less than 3/4 inch.[18] | | 6.2 | 5.0 | 3.5 | | | | |
| 2. Carbonate Aggregate Concrete | 2-1.1 | | | 5.7 | 4.6 | 3.2 | | | | |
| 3. Sand-lightweight Concrete | 3-1.1 | | | 4.6 | 3.8 | 2.7 | | | | |
| 4. Lightweight Concrete | 4-1.1 | | | 4.4 | 3.6 | 2.5 | | | | |
| 5. Reinforced Concrete Joists | 5-1.1 | Slab with suspended ceiling of vermiculite gypsum plaster over metal lath attached to 3/4" cold-rolled channels spaced 12" on center. Ceiling located 6" minimum below joists. | 3 | 2 | | | 1 | 3/4 | | |





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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 5. Reinforced Concrete Joists | 5-2.1 | 3/8 Type X gypsum wallboard[3] attached to No. 25 gauge by 7/8" deep by 2 5/8" hat-shaped galvanized steel channels with 1" long No. 6 screws. The channels are spaced 24" on center, span 35" and are supported along their length at 35" intervals by No. 21 gauge galvanized steel flat strap hangers having formed edges which engage the lips of the channel. The strap hangers are attached to the side of the concrete joists with 5/32" by 1 1/4" long powder-driven fasteners. The wallboard is installed with the long dimension perpendicular to the channels. All end joints occur on channels and supplementary channels and supplementary channels are installed parallel to the main channels, 12" each side, at end joint occurrences. The finish ceiling is located approximately 12" below the soffit of the floor slab. | | | 2 1/2 | | | | 5/8 | |





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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6. Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units[4] | 6-1.1 | Gypsum plaster on metal lath attached to the bottom cord with single No. 16 gauge or doubled No. 18 gauge wire ties spaced 6″ on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat, by weight, gypsum to sand aggregate for two-hour system. For three-hour system plaster is neat. | | 2½ | 2¼ | | | ¾ | ⅝ | |
| | 6-2.1 | Vermiculite gypsum plaster on metal lath attached to the bottom chord with single No. 16 gauge or doubled No. 18 gauge wire ties 6″ on center. | | 2 | | | | ⅝ | | |
| | 6-3.1 | Portland cement plaster over metal lath attached to the bottom chord of joists with single No. 16 gauge or doubled No. 18 gauge wire ties spaced 6″ on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat for one-hour system and 1:1 for scratch coat, 1:1½ for brown coat for two-hour system, by weight, cement to sand. | | | | 2 | | | | ⅝[5] |

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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 6. Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units[4] | 6-4.1 | Ceiling of 5/8" Type X wallboard[3] attached to 7/8" deep by 2 5/8" by No. 25 gauge hat-shaped furring channels 12" on center with 1" long No. 6 wallboard screws at 8" on center. Channels wire tied to bottom chord of joists with doubled No. 18 gauge wire or suspended below joists on wire hangers.[9] | | | 2 1/2 | | | | 5/8 | |
| | 6-5.1 | Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath tied 6" on center to 3/4" channels spaced 13 1/2" on center. Channels secured to joists at each intersection with two strands of No. 18 gauge galvanized wire. | | | 2 1/2 | | | | 3/4 | |
| 7. Reinforced Concrete Slab and Joists with Hollow Clay Tile Fillers Laid End to End in Rows 2 1/2" or More Apart; Reinforcement Placed Between Rows and Concrete Cast Around and Over Tile | 7-1.1 | 5/8" gypsum plaster on bottom of floor or roof construction. | | | 8[10] | | | | 5/8 | |
| | 7-1.2 | None. | | | | 5 1/2[11] | | | | |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8. Steel Joists Constructed with a Reinforced Concrete Slab on Top Poured on a 1/2" Deep Steel Deck. | 8-1.1 | Vermiculite gypsum plaster on metal lath attached to 3/4" cold-rolled channels with No. 18 gauge wire ties spaced 6" on center. | 2 1/2[12] | | | | 3/4 | | | | |
| 9. 3" Deep Cellular Steel Deck with Concrete Slab on Top. Slab Thickness Measured to Top of Cells. | 9-1.1 | Suspended ceiling of vermiculite gypsum plaster base coat and vermiculite acoustical plaster on metal lath attached at 6" intervals to 3/4" cold-rolled channels spaced 12" on center and secured to 1 1/2" cold-rolled channels spaced 36" on center with No. 16 gauge wire. 1 1/2" channels supported by No. 8 gauge wire hangers at 36" on center. Beams within envelope and with a 2 1/2" air space between beam soffit and lath have a 4-hour rating. | 2 1/2 | | | | 1 1/8[13] | | | | |
| 10. 1 1/2" Deep Steel Roof Deck on Steel Framing. Insulation Board, 30 lbs. per Cubic Foot Density, Composed of Wood Fibers with Cement Binders of Thickness Shown Bonded to Deck with Unfilled Asphalt Adhesive. Covered with a Fire-retardant Roof Covering | 10-1.1 | Ceiling of gypsum plaster on metal lath. Lath attached to 3/4" furring channels with No. 18 gauge wire ties spaced 6" on center. 3/4" channel saddled-tied to 2" channels with doubled No. 16 gauge wire ties. 2" channels spaced 36" on center suspended 2" below steel framing and saddle-tied with No. 8 gauge wire. Plaster mixed 1:2 by weight, gypsum to sand aggregate. | | | 1 7/8 | 1 | | | 3/4[7] | 3/4[7] | |







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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a] [1]—(Continued)

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 11. 1½" Deep Steel Roof Deck on Steel Framing Wood Fiber Insulation Board, 17.5 lbs. per Cubic Foot Density on Top Applied Over a 15-lb. Asphalt Saturated Felt. Fire-retardant Roof Covering. | 11-1.1 | Ceiling of gypsum plaster on metal lath. Lath attached to ¾" furring channels with No. 18 gauge wire ties spaced 6" on center. ¾" channels saddle tied to 2" channels with doubled No. 16 gauge wire ties. 2" channels spaced 36" on center suspended 2" below steel framing and saddle tied with No. 8 gauge wire. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate for one-hour system. For two-hour system plaster mix is 1:2 by weight, gypsum to sand aggregate.[a] [1] | | | 1½ | 1 | | | 7/8[7] | ¾[7] |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12. 1½" Deep Steel Roof Deck on Steel Framing Insulation of Rigid Board Consisting of Expanded Perlite and Fibers Impregnated With Integral Asphalt Waterproofing; Density 9 to 12 Lbs./Cu. Ft. Secured to Metal Roof Deck by ½" Wide Ribbons of Waterproof, Cold-process Liquid Adhesive Spaced 6" Apart. Steel Joist or Light Steel Construction with Metal Roof Deck, Insulation, and Built-up Fire-retardant Roof Covering. | 12-1.1 | Gypsum-vermiculite plaster on metal lath wire tied at 6" intervals to ¾" furring channels spaced 12" on center and wire tied to 2" runner channels spaced 32" on center. Runners wire tied to bottom chord of steel joists. | | | 1 | | | | ⅞ | |

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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)



| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 13. Double Wood Floor Over Wood Joists Spaced 16" on Center[14,15] | 13-1.1 | Gypsum plaster over 3/8" Type X gypsum lath. Lath initially applied with not less than four 1 1/8" by No. 13 gauge by 19/64" head plasterboard blued nails per bearing. Continuous stripping over lath along all joist lines. Stripping consists of 3" wide strips of metal lath attached by 1 1/2" by No. 11 gauge by 1/2" head roofing nails spaced 6" on center. Alternate stripping consists of 3" wide .049" diameter wire stripping weighing one pound per sq. yd. and attached by No. 16 gauge by 1 1/2" by 3/4" crown width staples, spaced 4" on center. Where alternate stripping is used the lath nailing may consist of two nails at each end and one nail at each intermediate bearing. Plaster mixed 1:2 by weight, gypsum to sand aggregate. | | | | | | | 7/8 |
| | 13-1.2 | Portland cement or gypsum plaster on metal lath. Lath fastened with 1 1/2" by No. 11 gauge by 7/16" head barbed shank roofing nails spaced 5" on center. Plaster mixed | | | | | | | | 5/8 |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 13. Double Wood Floor Over Wood Joists Spaced 16″ On Center[14 15] | 13-1.2 | 1:2 for scratch coat and 1:3 for brown coat, by weight, cement to sand aggregate. | | | | | | | | |
| | 13-1.3 | Perlite or vermiculite gypsum plaster on metal lath secured to joists with 1 1/2″ by No. 11 gauge by 7/16″ head barbed shank roofing nails spaced 5″ on center. | | | | | | | | 5/8 |
| | 13-1.4 | 1/2″ Type X gypsum wallboard[3] nailed to joists with 5d cooler[12] or wallboard[12] nails at 6″ on center. End joints of wallboard centered on joists. | | | | | | | | 1/2 |
| 14. Plywood Stressed Skin Panels Consisting of 5/8″ Thick Interior C-D (Exterior Glue) Top Stressed Skin on 2″ by 6″ Nominal (Minimum) Stringers. Adjacent Panel Edges Joined with 8d Common Wire Nails Spaced 6″ on Center. Stringers Spaced 12″ Maximum on Center. | 14-1.1 | 1/2″ thick wood fiberboard weighing 15 to 18 lbs. per cu. ft. installed with long dimension parallel to stringers or 3/8″ C-D (exterior glue) plywood glued and/or nailed to stringers. Nailing to be with 5d cooler[12] or wallboard[12] nails at 12″ on center. Second layer of 1/2″ Type X gypsum wallboard[3] applied with long dimension perpendicular to joists and attached with 8d cooler[12] or wallboard[12] nails at 6″ on center at end joints and 8″ on center elsewhere. Wallboard joints staggered with respect to fiberboard joints. | | | | | | | | 1 |

*(Continued)*





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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[1]—(Continued)

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 15. Vermiculite Concrete Slab Proportioned 1:4 (Portland Cement to Vermieulite Aggregate) on a 1½" Deep Steel Deck Supported on Individually Protected Steel Framing. Maximum span of deck 6' 10" where deck is less than No. 26 gauge and 8' 0" where deck is No. 26 gauge or greater. Slab Reinforeed with 4" by 8" No. 12/14 gauge Welded Wire Mesh. | 15-1.1 | None. | | | | $3^{12}$ | | | | |
| 16. Perlite Concrete Slab Proportioned 1:6 (Portland Cement to Perlite Aggregate) on a 1¼" Deep Steel Deck Supported on Individually Protected Steel Framing. Slab Reinforced with 4" by 8" No. 12/14 gauge Welded Wire Mesh. | 16-1.1 | None. | | | | $3^{1}/_{2}{}^{12}$ | | | | |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 17. Perlite Concrete Slab Proportioned 1:6 (Portland Cement to Perlite Aggregate) on a 9/16" Deep Steel Deck Supported by Steel Joists, 4' on Center. Fire-retardant roof covering on top. | 17-1.1 | Perlite gypsum plaster on metal lath wire tied to 3/4" furring channels attached with No. 16 gauge wire ties to lower chord of joists. | | 2[17] | 2[17] | | | 7/8 | 3/4 | |
| 18. Perlite Concrete Slab Proportioned 1:6 (Portland Cement to Perlite Aggregate) on 1 1/4" Deep Steel Deck Supported on Individually Protected Steel Framing. Maximum span of deck 6' 10" where deck is less than No. 26 gauge and 8' 0" where deck is No. 26 gauge or greater. Slab Reinforced with No. 19 Gauge Hexagonal Wire mesh. Fire-retardant roof covering on top. | 18-1.1 | None. | | | 2 1/4[17] | | | | | |
| 19. Floor and Beam Construction Consisting of 3" Deep Cellular Steel Floor Units Mounted on Steel Members with 1:4 (Proportion of Portland Cement to Perlite Aggregate) Perlite-concrete floor slab on top. | 19-1.1 | Suspended envelope ceiling of perlite gypsum plaster on metal lath attached to 3/4" cold-rolled channels, secured to 1 1/2" cold-rolled channels spaced 42" on center supported by No. 6 wire 36" on center. Beams in envelope with 3" minimum air space between beam soffit and lath have a 4-hour rating. | 2[17] | | | | [17] | | | |

(Continued)





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## TABLE NO. 43-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a] [1]—(Continued)

| FLOOR OR ROOF CONSTRUCTION | ITEM NUMBER | CEILING CONSTRUCTION | THICKNESS OF FLOOR OR ROOF SLAB (In Inches) | | | | MINIMUM THICKNESS OF CEILING (In Inches) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. | 4 Hr. | 3 Hr. | 2 Hr. | 1 Hr. |
| 20. Perlite concrete proportioned 1:6 (portland cement to perlite aggregate) poured to 1/8-inch thickness above top of corrugations of 1 5/16-inch-deep galvanized steel deck maximum span 8′ 0″ for No. 24 gauge or 6′ 0″ for No. 26 gauge with deck supported by individually protected steel framing. Approved polystyrene foam plastic insulation board having a flame spread not exceeding 75 (1″ to 4″ thickness with vent holes which approximate 3 percent of the board surface area) placed on top of perlite slurry. A 2′ by 4′ insulation board contains six 2 3/4″ diameter holes. Board covered with 2 1/4″ minimum perlite concrete slab. Slab reinforced with mesh consisting of No. 19 gauge (0.041″ galvanized) steel wire twisted together to form 2″ hexagons with | 20-1.1 | None. | | | Varies | | | | | | |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| straight No. 16 gauge (0.0625″ galvanized) steel wire woven into mesh and spaced 3″. Alternate slab reinforcement may consist of 4 by 8, No. 12/4 SWG, or 2 by 2, No. 14/14 SWG welded wire fabric. Fire-retardant roof covering on top. | | | | | | | | | | | |
| 21. Wood joist, floor trusses and roof trusses spaced 24″ o.c., with 1/2″ plywood with exterior glue applied at right angles to top of joist or truss with 8d nails. The plywood thickness shall not be less than 1/2″ nor less than required by Chapter 25. | 21-1.1. | Base layer 5/8″ Type X gypsum wallboard applied at right angles to joist or truss 24″ o.c. with 1 1/4″ Type S or Type W drywall screws 24″ o.c. Face layer 5/8″ Type X gypsum wallboard or veneer base applied at right angles to joist or truss through base layer with 1 7/8″ Type S or Type W drywall screws 12″ o.c. at joints and intermediate joist or truss. Face layer joints offset 24″ from base layer joints, 1 1/2″ Type G drywall screws placed 2″ back on either side of face layer end joints, 12″ o.c. | | | | Varies | | | | 1 1/4 | |

*(Footnotes on following page.)*





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## FOOTNOTES FOR TABLE NO. 43-C

[a]Generic fire-resistance ratings (those not designated by company code letter) as listed in the Fire Resistance Design Manual, Eleventh Edition, dated October, 1984, as published by the Gypsum Association, may be accepted as if herein listed.

[1]Staples with equivalent holding power and penetration may be used as alternate fasteners to nails for attachment to wood framing.

[2]The thickness may be reduced to 3 inches where limestone aggregate is used.

[3]For all of the construction with gypsum wallboard described in Table No. 43-C, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard and the joints on the face layer are reinforced and the entire surface is covered with a minimum of 1/16-inch gypsum veneer plaster. The gypsum base for veneer plaster and the veneer plaster shall comply with U.B.C. Standard No. 47-15.

[4]Slab thickness over steel joists measured at the joists for metal lath form and at the top of the form for steel form units.

[5]Portland cement plaster with 15 pounds of hydrated lime and 3 pounds of approved additives or admixtures per bag of cement.

[6]One-inch by No. 20 gauge hexagonal wire mesh installed below lath and tied to each furring channel at joints between lath.

[7]Furring channels spaced 12 inches on center.

[8]No. 14 gauge wires spaced 11.3 inches on center or 10 inches on center (for channel spacing of 16 inches and 12 inches, respectively) installed below lath sheets in a diagonal pattern. Wires tied to furring channels or clips at lath edges.

[9]Gypsum wallboard ceilings attached to steel framing may be suspended with 1 1/2-inch cold-formed carrying channels spaced 48 inches on center which are suspended with No. 8 SWG galvanized wire hangers spaced 48 inches on center. Cross-furring channels are tied to the carrying channels with No. 18 SWG galvanized wire (double strand) and spaced as required for direct attachment to the framing. This alternative is also applicable to those assemblies recognized under Footnote a.

[10]Six-inch hollow clay tile with 2-inch concrete slab above.

[11]Four-inch hollow clay tile with 1 1/2-inch concrete slab above.

[12]Thickness measured to bottom of steel form units.

[13]Five-eighths inch of vermiculite gypsum plaster plus 1/2 inch of approved vermiculite acoustical plastic.

[14]Double wood floor may be either of the following:

(a) Subfloor of 1-inch nominal boarding, a layer of asbestos paper weighing not less than 14 pounds per 100 square feet and a layer of 1-inch nominal tongue-and-groove finish flooring; or

(b) Subfloor of 1-inch nominal tongue-and-groove boarding or 15/32-inch interior-type plywood with exterior glue and a layer of 1-inch nominal tongue-and-groove finish flooring or 19/32-inch interior-type plywood finish flooring or a layer of Type I Grade M-1 particleboard not less than 5/8 inch thick.

[15]The ceiling may be omitted over unusable space, and flooring may be omitted where unusable space occurs above.

[16]For properties of cooler or wallboard nails, see U.B.C. Standard No. 25-17, Table 25-17-H.

[17]Thickness measured on top of steel deck unit.

[18]When the slab is in an unrestrained condition, minimum reinforcement cover shall not be less than 1 1/4 inches for three-hour; 1 inch for two-hour (siliceous aggregate only); and 3/4 inch for all other restrained or unrestrained conditions.



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# Part VIII

# REGULATIONS FOR USE OF PUBLIC STREETS AND PROJECTIONS OVER PUBLIC PROPERTY

## Chapter 44

## PROTECTION OF PEDESTRIANS DURING CONSTRUCTION OR DEMOLITION

### General

**Sec. 4401.** No person shall use or occupy a street, alley or public sidewalk for the performance of work under a building permit except in accordance with the provisions of this chapter.

No person shall perform any work on any building or structure adjacent to a public way in general use by the public for pedestrian travel, unless the pedestrians are protected as specified in this chapter.

Any material or structure temporarily occupying public property, including fences and walkways, shall be adequately lighted between sunset and sunrise.

### Temporary Use of Streets and Alleys

**Sec. 4402.** The use of public property shall meet the requirements of the public agency having jurisdiction. Whenever requested, plot plans and construction details shall be submitted for review by the agencies concerned.

### Storage on Public Property

**Sec. 4403.** Material and equipment necessary for work to be done under a permit shall not be placed or stored on public property so as to obstruct free and convenient approach to and use of any fire hydrant, fire or police alarm box, utility box, catch basin or manhole or so as to interfere with the free flow of water in any street or alley gutter.

### Mixing Mortar on Public Property

**Sec. 4404.** The mixing or handling of mortar, concrete or other material on public property shall be done in a manner that will not deface public property or create a nuisance.

### Protection of Utilities

**Sec. 4405.** A substantial protective frame and boarding shall be built around and over every street lamp, utility box, fire or police alarm box, fire hydrant, catch basin and manhole that may be damaged by any work being done under the permit. This protection shall be maintainced while such work is being done and shall not obstruct the normal functioning of the device.



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## Walkway

**Sec. 4406.** A walkway not less than 4 feet wide shall be maintained on the sidewalk in front of the building site during construction, alteration or demolition unless the public agency having jurisdiction authorizes the sidewalk to be fenced and closed. Adequate signs and railings shall be provided to direct pedestrian traffic. Railings shall be provided when required by Section 4407.

The walkway shall be capable of supporting a uniform live load of 150 pounds per square foot. A durable wearing surface shall be provided.

## Pedestrian Protection

**Sec. 4407.** (a) **Protection Required.** Pedestrian traffic shall be protected by a railing on the street side when the walkway extends into the roadway, by a railing adjacent to excavations and by such other protection as set forth in Table No. 44-A. The construction of such protective devices shall be in accordance with the provisions of this chapter.

(b) **Railings.** Railings shall be substantially built and, when of wood, shall be constructed of new material having a nominal size of at least 2 inches by 4 inches. Railings shall be at least 3 feet 6 inches in height and when adjacent to excavations shall be provided with a midrail.

(c) **Fences.** Fences shall be solid and substantially built, be not less than 8 feet in height above grade and be placed on the side of the walkway nearest to the building site. Fences shall extend the entire length of the building site and each end shall be returned to the building line.

Openings in such fences shall be protected by doors which normally are kept closed.

All fences shall be provided with 2-inch by 4-inch plate, top and bottom, and shall be well braced. The fence material shall be a minimum of 3/4-inch boards or 1/4-inch plywood. Plywood fences shall conform to the following requirements:

1. Plywood panels shall be bonded with an adhesive identical to that for exterior plywood.

2. Plywood 1/4 inch or 5/16 inch in thickness shall have studs spaced not more than 2 feet on center.

3. Plywood 3/8 inch or 1/2 inch in thickness shall have studs spaced not more than 4 feet on center, provided a 2-inch by 4-inch stiffener is placed horizontally at the midheight when the stud spacing exceeds 2 feet on center.

4. Plywood 5/8 inch or thicker shall not span over 8 feet.

(d) **Canopies.** The protective canopy shall have a clear height of 8 feet above the walkway. The roof shall be tightly sheathed. The sheathing shall be 2-inch nominal wood planking or equal. Every canopy shall have a solid fence built along its entire length on the construction side.

If materials are stored or work is done on the roof of the canopy, the street sides and ends of the canopy roof shall be protected by a tight curb board not less than 1 foot high and a railing not less than 3 feet 6 inches high.



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The entire structure shall be designed to carry the loads to be imposed on it, provided the live load shall be not less than 150 pounds per square foot. In lieu of such design a protection canopy supporting not more than 150 pounds per square foot may be constructed as follows:

1. Footings shall be continuous 2-inch by 6-inch members with scabbed joints.
2. Posts not less than 4 inches by 6 inches in size shall be provided on both sides of the canopy and spaced not more than 12 feet, center to center.
3. Stringers not less than 4 inches by 12 inches in size shall be placed on edge upon the posts.
4. Joists resting upon the stringers shall be at least 2 inches by 8 inches in size and shall be spaced not more than 2 feet, center to center.
5. The deck shall be of planks at least 2 inches thick nailed to the joists.
6. Each post shall be knee-braced to joists and stringers by members 4 feet long, not less than 2 inches by 4 inches in size.
7. A curb not less than 2 inches by 12 inches in size shall be set on edge along the outside edge of the deck.

**EXCEPTION:** Protection canopies for new, light-frame construction not exceeding two stories in height may be designed for a live load of 75 pounds per square foot or the loads to be imposed on it, whichever is the greater.

## Maintenance and Removal of Protective Devices

**Sec. 4408.** (a) **Maintenance.** Such protection shall be maintained in place and kept in good order for the entire length of time pedestrians may be endangered.

(b) **Removal.** Every protection fence or canopy shall be removed within 30 days after such protection is no longer required by this chapter for protection of pedestrians.

## Demolition

**Sec. 4409.** The work of demolishing any building shall not be commenced until the required pedestrian protection structures are in place.

The building official may require the permittee to submit plans and a complete schedule for demolition. Where such are required, no work shall be done until such plans and/or schedule are approved by the building official.



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## TABLE NO. 44-A—TYPE OF PROTECTION REQUIRED FOR PEDESTRIANS

| HEIGHT OF CONSTRUCTION | DISTANCE FROM CONSTRUCTION | PROTECTION REQUIRED |
|---|---|---|
| 8 feet or less | Less than 6 feet | Railing |
| | 6 feet or more | None |
| More than 8 feet | Less than 6 feet | Fence and canopy |
| | 6 feet or more but not more than one-fourth the height of construction | Fence and canopy |
| | 6 feet or more, but between one-fourth to one-half the height of construction | Fence |
| | 6 feet or more but exceeding one-half the construction height | None |



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# Chapter 45

# PERMANENT OCCUPANCY OF PUBLIC PROPERTY

## General

**Sec. 4501.** No part of any structure or any appendage thereto, except signs, shall project beyond the property line of the building site, except as specified in this chapter.

Structures or appendages regulated by this code shall be constructed of materials as specified in Section 1710.

The projection of any structure or appendage shall be the distance measured horizontally from the property line to the outermost point of the projection.

Nothing in this code shall prohibit the construction and use of a structure between buildings and over or under a public way, provided the structure complies with all requirements of this code.

No provisions of this chapter shall be construed to permit the violation of other laws or ordinances regulating the use and occupancy of public property.

## Projection into Alleys

**Sec. 4502.** No part of any structure or any appendage thereto shall project into any alley.

**EXCEPTIONS:** 1. A curb or buffer block may project not more than 9 inches and not exceed a height of 9 inches above grade.

2. Footings located at least 8 feet below grade may project not more than 12 inches.

## Space Below Sidewalk

**Sec. 4503.** The space adjoining a building below a sidewalk on public property may be used and occupied in connection with the building for any purpose not inconsistent with this code or other laws or ordinances regulating the use and occupancy of such spaces on condition that the right so to use and occupy may be revoked by the city at any time and that the owner of the building will construct the necessary walls and footings to separate such space from the building and pay all costs and expenses attendant therewith.

Footings located at least 8 feet below grade may project not more than 12 inches.

## Balconies, Sun-control Devices and Appendages

**Sec. 4504.** Oriel windows, balconies, sun-control devices, unroofed porches, cornices, belt courses and appendages such as water tables, sills, capitals, bases and architectural projections may project over the public property of the building site a distance as determined by the clearance of the lowest point of the projection above the grade immediately below, as follows:

Clearance above grade less than 8 feet—no projection is permitted.

Clearance above grade over 8 feet—1 inch of projection is permitted for each additional inch of clearance, provided that no such projection shall exceed a distance of 4 feet.



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## Marquees

**Sec. 4505.** (a) **General.** For the purpose of this section a marquee shall include any object or decoration attached to or a part of said marquee.

(b) **Projection and Clearance.** The horizontal clearance between a marquee and the curb line shall be not less than 2 feet.

A marquee projeeting more than two thirds of the distance from the property line to the curb line shall be not less than 12 feet above the ground or pavement below.

A marquee projecting less than two thirds of the distance from the property line to the eurb line shall be not less than 8 feet above the ground or pavement below.

(c) **Length.** A marquee projecting more than two thirds of the distance from the property line to the curb line shall not exceed 25 feet in length along the direetion of the street.

(d) **Thickness.** The maximum height or thickness of a marquee measured vertically from its lowest to its highest point shall not exceed 3 feet when the marquee projects more than two thirds of the distance from the property line to the curb line and shall not exceed 9 feet when the marquee is less than two thirds of the distance from the property line to the curb line.

(e) **Construction.** A marquee shall be supported entirely by the building and constructed of noncombustible material or, when supported by a building of Type V construction, may be of one-hour fire-resistive construction.

(f) **Roof Construction.** The roof or any part thereof may be a skylight, provided glass skylights are of laminated or wired glass complying with Chapter 34. Plastic skylights shall comply with Section 5207.

Every roof and skylight of a marquee shall be sloped to downspouts which shall conduct any drainage from the marquee under the sidewalk to the curb.

(g) **Location Prohibitcd.** Every marquee shall be so located as not to interfere with the operation of any exterior standpipe or to obstruct the clear passage of stairways or exits from the building or the installation or maintenanee of electroliers.

## Awnings

**Sec. 4506.** (a) **Definition.** For the purpose of this section:

**AWNING** is a temporary shelter supported entirely from the exterior wall of a building.

(b) **Construction.** Awnings shall have noncombustible frames but may have combustible coverings. Every awning shall be collapsible, retractable or capable of being folded against the face of the supporting building. When collapsed, retracted or folded, the design shall be such that the awning does not block any required exit.

**EXCEPTION:** A fixed awning not more than 10 feet in length may be erected over a doorway to the building.

(e) **Projection.** Awnings may extend over publie property not more than 7 feet from the face of a supporting building, but no portion shall extend nearer than 2 feet to the face of the nearest curb line measured horizontally. In no case shall the



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awning extend over public property greater than two thirds of the distance from the property line to the nearest curb in front of the building site.

(d) **Clearances.** All portions of any awning shall be at least 8 feet above any public walkway.

**EXCEPTION:** Any valance attached to an awning shall not project above the roof of the awning at the point of attachment and shall not extend more than 12 inches below the roof of the awning at the point of attachment, but in no case shall any portion of a valance be less than 7 feet in height above a public way.

## Doors

**Sec. 4507.** Power-operated doors and their guide rails shall not project over public property. Other doors, either fully opened or when opening, shall not project more than 1 foot beyond the property line, except that in alleys no projection beyond the property line is permitted.

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# Chapter 46
# NO REQUIREMENTS



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# Part IX

# WALL AND CEILING COVERINGS

## Chapter 47
## INSTALLATION OF WALL AND CEILING COVERINGS

### Scope

**Sec. 4701.** (a) **General.** The installation of lath, plaster and gypsum board shall be done in a manner and with materials as specified in this chapter and, when required for fire-resistive construction, also shall conform with the provisions of Chapter 43.

Other approved wall or ceiling coverings may be installed in accordance with the recommendations of the manufacturer and the conditions of approval.

(b) **Inspection.** No lath or gypsum board or their attachments shall be covered or finished until it has been inspected and approved by the building official in accordance with Section 305 (e).

(c) **Tests.** The building official may require tests to be made in accordance with approved standards to determine compliance with the provisions of this chapter, provided the permit holder has been notified 24 hours in advance of the time of making such tests.

The testing of gypsum and gypsum products shall conform with U.B.C. Standard No. 47-17.

(d) **Definitions.** For purposes of this chapter, certain terms are defined as follows:

**CORNER BEAD** is a rigid formed unit or shape used at projecting or external angles to define and reinforce the corners of interior surfaces.

**CORNERITE** is a shaped reinforcing unit of expanded metal or wire fabric used for angle reinforcing and having minimum outstanding legs of not less than 2 inches.

**CORROSION-RESISTANT MATERIALS** are materials that are inherently rust resistant or materials to which an approved rust-resistive coating has been applied either before or after forming or fabrication.

**EXTERIOR SURFACES** are weather-exposed surfaces as defined in Section 424.

**EXTERNAL CORNER REINFORCEMENT** is a shaped reinforcing unit for external corner reinforcement for portland cement plaster formed to ensure mechanical bond and a solid plaster corner.



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**INTERIOR SURFACES** are surfaces other than weather-exposed surfaces.

**MOIST CURING** is any method employed to retain sufficient moisture for hydration of portland cement plaster.

**PORTLAND CEMENT PLASTER** is a mixture of portland cement or portland cement and lime and aggregate and other approved materials as specified in this code.

**STEEL STUDS, LOAD-BEARING AND NONLOAD-BEARING,** are prefabricated channel shapes, welded wire or combination wire and steel angle types, galvanized or coated with rust-resistive material.

**STRIPPING** is flat reinforcing units of expanded metal or wire fabric or other materials not less than 3 inches wide to be installed as required over joints of gypsum lath.

**TIE WIRE** is wire for securing together metal framing or supports, for tying metal and wire fabric lath and gypsum lath and wallboard together and for securing accessories.

**WIRE BACKING** is horizontal strands of tautened wire attached to surfaces of vertical wood supports which, when covered with building paper, provide a backing for portland cement plaster.

(e) **Suspended Acoustical Ceiling Systems.** Suspended acoustical ceiling systems shall be installed in accordance with U.B.C. Standard No. 47-18.

(f) **Gypsum Veneer Plaster Systems.** Gypsum veneer base and gypsum veneer plaster shall be installed in accordance with U.B.C. Standard No. 47-19.

## Materials

**Sec. 4702.** Lathing, plastering, wallboard materials, ceiling suspension systems and plywood paneling shall conform to the applicable standards listed in Chapter 60.

## Vertical Assemblies

**Sec. 4703.** (a) **General.** In addition to the requirements of this section, vertical assemblies of plaster or gypsum board shall be designed to resist the loads specified in Chapter 23 of this code. For wood framing, see Chapter 25. For metal framing, see Chapter 27.

**EXCEPTION:** Wood-framed assemblies meeting the requirements of Section 2517 need not be designed.

(b) **Wood Framing.** Wood supports for lath or gypsum board shall be not less than 2 inches nominal in least dimension. Wood stripping or furring shall be not less than 2 inches nominal thickness in the least dimension except that furring strips not less than 1-inch by 2-inch nominal dimension may be used over solid backing.

(c) **Studless Partitions.** The minimum thickness of vertically erected studless solid plaster partitions of 3/8-inch and 3/4-inch rib metal lath or 1/2-inch-thick long-length gypsum lath and gypsum board partitions shall be 2 inches. The installation of metal lath used in studless partitions shall conform with the provisions of U.B.C. Standard No. 47-4.



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## Horizontal Assemblies

**Sec. 4704.** (a) **General.** In addition to the requirements of this section, supports for horizontal assemblies of plaster or gypsum board shall be designed to support all loads as specified in Chapter 23 of this code.

**EXCEPTION:** Wood-framed assemblies meeting the requirements of Section 2517 need not be designed.

(b) **Wood Framing.** Wood stripping or suspended wood systems, where used, shall be not less than 2 inches nominal thickness in the least dimension, except that furring strips not less than 1-inch by 2-inch nominal dimension may be used over solid backing.

(c) **Hangers.** Hangers for suspended ceilings shall be not less than the sizes set forth in Table No. 47-A, fastened to or embedded in the structural framing, masonry or concrete.

Hangers shall be saddle-tied around main runners to develop the full strength of the hangers. Lower ends of flat hangers shall be bolted with 3/8-inch bolts to runner channels or bent tightly around runners and bolted to the main part of the hanger.

(d) **Runners and Furring.** The main runner and cross-furring shall be not less than the sizes set forth in Table No. 47-A, except that other steel sections of equivalent strength may be substituted for those set forth in this table. Cross-furring shall be securely attached to the main runner by saddle-tying with not less than one strand of No. 16 or two strands of No. 18 U.S. gauge tie wire or approved equivalent attachments.

## Interior Lath

**Sec. 4705.** (a) **General.** Gypsum lath shall not be installed until weather protection for the installation is provided. Where wood frame walls and partitions are covered on the interior with portland cement plaster or tile of similar material and are subject to water splash, the framing shall be protected with an approved moisture barrier.

Showers and public toilet walls shall conform to Section 510 (b).

(b) **Application of Gypsum Lath.** The thickness, spacing of supports and the method of attachment of gypsum lath shall be as set forth in Tables No. 47-B and No. 47-C. Approved wire and sheet metal attachment clips may be used.

Gypsum lath shall be applied with the long dimension perpendicular to supports and with end joints staggered in successive courses. End joints may occur on one support when stripping is applied the full length of the joints.

Where electrical radiant heat cables are installed on ceilings, the stripping, if conductive, may be omitted a distance not to exceed 12 inches from the walls.

Where lath edges are not in moderate contact and have joint gaps exceeding 3/8 inch, the joint gaps shall be covered with stripping or cornerite. Stripping or cornerite may be omitted when the entire surface is reinforced with not less than 1-inch No. 20 U.S. gauge woven wire. When lath is secured to horizontal or vertical supports not used as structural diaphragms, end joints may occur between supports when lath ends are secured together with approved fasteners. Vertical assemblies also shall conform with Section 2309 (b).



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Cornerite shall be installed so as to retain position during plastering at all internal corners. Cornerite may be omitted when plaster is not continuous from one plane to an adjacent plane.

(e) **Application of Metal Plaster Bases.** The type and weight of metal lath, and the gauge and spacing of wire in welded or woven lath, the spacing of supports, and the methods of attachment to wood supports shall be as set forth in Tables No. 47-B and No. 47-C.

Metal lath shall be attached to metal supports with not less than No. 18 U.S. gauge tie wire spaced not more than 6 inches apart or with approved equivalent attachments.

Metal lath or wire fabric lath shall be applied with the long dimension of the sheets perpendicular to supports.

Metal lath shall be lapped not less than 1/2 inch at sides and 1 inch at ends. Wire fabric lath shall be lapped not less than one mesh at sides and ends, but not less than 1 inch. Rib metal lath with edge ribs greater than 1/8 inch shall be lapped at sides by nesting outside ribs. When edge ribs are 1/8 inch or less, rib metal lath may be lapped 1/2 inch at sides, or outside ribs may be nested. Where end laps of sheets do not occur over supports, they shall be securely tied together with not less than No. 18 U.S. gauge wire.

Cornerite shall be installed in all internal corners to retain position during plastering. Cornerite may be omitted when lath is continuous or when plaster is not continuous from one plane to an adjacent plane.

## Exterior Lath

**Sec. 4706.** (a) **General.** Exterior surfaces are weather-exposed surfaces as defined in Section 424. For eave overhangs required to be fire resistive, see Section 1710.

(b) **Corrosion Resistance.** All lath and lath attachments shall be of corrosion-resistant material. See Section 4701 (d).

(c) **Backing.** Backing or a lath shall provide sufficient rigidity to permit plaster application.

Where lath on vertical surfaces extends between rafters or other similar projecting members, solid backing shall be installed to provide support for lath and attachments.

Gypsum lath or gypsum board shall not be used, except that on horizontal supports of ceilings or roof soffits it may be used as backing for metal lath or wire fabric lath and portland cement plaster.

Backing is not required under metal lath or paperbacked wire fabric lath.

(d) **Weather-resistive Barriers.** Weather-resistive barriers shall be installed as required in Section 1707 (a) and, when applied over wood base sheathing, shall include two layers of Grade D paper.

(e) **Application of Metal Plaster Bases.** The application of metal lath or wire fabric lath shall be as specified in Section 4705 (c) and they shall be furred out from vertical supports or backing not less than 1/4 inch except as set forth in Footnote No. 2, Table No. 47-B.



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Where no external corner reinforcement is used, lath shall be furred out and carried around corners at least one support on frame construction.

A minimum 0.021-inch (No. 26 gauge) corrosion-resistant weep screed with a minimum vertical attachment flange of 3 1/2 inches shall be provided at or below the foundation plate line on all exterior stud walls. The screed shall be placed a minimum of 4 inches above grade and shall be of a type which will allow trapped water to drain to the exterior of the building. The weather-resistive barrier and exterior lath shall cover and terminate on the attachment flange of the screed.

## Interior Plaster

**Sec. 4707.** (a) **General.** Plastering with gypsum plaster or portland cement plaster shall be not less than three coats when applied over metal lath or wire fabric lath and shall be not less than two coats when applied over other bases permitted by this chapter. Showers and public toilet walls shall conform to Section 510 (b).

Plaster shall not be applied directly to fiber insulation board. Portland cement plaster shall not be applied directly to gypsum lath, gypsum masonry or gypsum plaster except as specified in Section 4706 (c).

When installed, grounds shall assure the minimum thickness of plaster as set forth in Table No. 47-D. Plaster thickness shall be measured from the face of lath and other bases.

(b) **Base Coat Proportions.** Proportions of aggregate to cementitious materials shall not exceed the volume set forth in Table No. 47-E for gypsum plaster and Table No. 47-F for portland cement and portland cement-lime plaster.

(c) **Base Coat Application.** Base coats shall be applied with sufficient material and pressure to form a complete key or bond.

1. **Gypsum plaster.** For two-coat work, the first coat shall be brought out to grounds and straightened to a true surface, leaving the surface rough to receive the finish coat. For three-coat work, the surface of the first coat shall be scored sufficiently to provide adequate bond for the second coat and shall be permitted to harden and set before the second coat is applied. The second coat shall be brought out to grounds and straightened to a true surface, leaving the surface rough to receive the finish coat.

2. **Portland cement plaster.** The first two coats shall be as required for the first coats of exterior plaster, except that the moist-curing time period between the first and second coats shall be not less than 24 hours and the thickness shall be as set forth in Table No. 47-D. Moist curing shall not be required where job and weather conditions are favorable to the retention of moisture in the portland cement plaster for the required time period.

(d) **Finish Coat Application.** Finish coats shall be applied with sufficient material and pressure to form a complete bond. Finish coats shall be proportioned and mixed in an approved manner. Gypsum and lime and other interior finish coats shall be applied over gypsum base coats which have hardened and set. Thicknesses shall be not less than 1/16 inch.

Portland cement and lime finish coats may be applied over interior portland cement base coats which have been in place not less than 48 hours.



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Approved acoustical finish plaster may be applied over any base coat plaster, over lean masonry or concrete, or other approved surfaces.

(e) **Interior Masonry or Concrete.** Condition of surfaces shall be as specified in Seetion 4708 (h). Approved specially prepared gypsum plaster designed for application to concrete surfaces or approved acoustical plaster may be used. The total thickness of base coat plaster applied to concrete ceilings shall be as set forth in Table No. 47-D. Should ceiling surfaces require more than the maximum thickness permitted in Table No. 47-D, metal lath or wire fabric lath shall be installed on such surfaces before plastering.

## Exterior Plaster

**Sec. 4708.** (a) **General.** Plastering with portland cement plaster shall be not less than three coats when applied over metal lath or wire fabric lath and shall be not less than two coats when applied over masonry, concrete or gypsum backing as specified in Section 4706 (c). If plaster surface is completely covered by veneer or other facing material, or is completely concealed by another wall, plaster application need be only two coats, provided the total thickness is as set forth in Table No. 47-F.

On wood frame or metal stud construction with an on-grade concrete floor slab system, exterior plaster shall be applied in such a manner as to cover, but not extend below, lath and paper. See Section 4706 (e) for the application of paper and lath, and flashing or drip screeds.

Only approved plasticity agents and approved amounts thereof may be added to portland cement. When plastic cement is used, no additional lime or plasticizers shall be added. Hydrated lime or the equivalent amount of lime putty used as a plasticizer may be added to portland cement plaster in an amount not to exceed that set forth in Table No. 47-F.

Gypsum plaster shall not be used on exterior surfaces. See Section 424.

(b) **Base Coat Proportions.** The proportion of aggregate to cementitious materials shall be as set forth in Table No. 47-F.

(c) **Base Coat Application.** The first coat shall be applied with sufficient material and pressure to fill solidly all openings in the lath. The surface shall be scored horizontally sufficiently rough to provide adequate bond to receive the second coat.

The second coat shall be brought out to proper thickness, rodded and floated sufficiently rough to provide adequate bond for finish coat. The second coat shall have no variation greater than 1/4 inch in any direction under a 5-foot straight edge.

(d) **Environmental Conditions.** Portland cement based plaster shall not be applied to frozen base or those containing frost. Plaster mixes shall not contain frozen ingredients. Plaster coats shall be protected from freezing for a period of not less than 24 hours after set has occurred.

(e) **Curing and Interval.** First and second coats of plaster shall be applied and moist cured as set forth in Table No. 47-F.

When applied over gypsum backing as specified in Section 4706 (c) or directly to unit masonry surfaces, the second coat may be applied as soon as the first coat has attained sufficient hardness.



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(f) **Alternate Method of Application.** As an alternate method of application, the second coat may be applied as soon as the first coat has attained sufficient rigidity to receive the second coat.

When using this method of application, calcium aluminate cement up to 15 percent of the weight of the portland cement may be added to the mix.

Curing of the first coat may be omitted and the second coat shall be cured as set forth in Table No. 47-F.

(g) **Finish Coats.** Finish coats shall be proportioned and mixed in an approved manner and in accordance with Table No. 47-F.

Portland cement and lime finish coats shall be applied over base coats which have been in place for the time periods set forth in Table No. 47-F. The third or finish coat shall be applied with sufficient material and pressure to bond to and to cover the brown coat and shall be of sufficient thickness to conceal the brown coat.

(h) **Preparation of Masonry and Concrete.** Surfaces shall be clean, free from efflorescence, sufficiently damp and rough to assure proper bond. If surface is insufficiently rough, approved bonding agents or a portland cement dash bond coat mixed in the proportions of 1½ cubic feet of sand to 1 cubic foot of portland cement shall be applied. Approved bonding agents shall conform with the provisions of U.B.C. Standard No. 47-1. Dash bond coat shall be left undisturbed and shall be moist cured not less than 24 hours. When dash bond is applied, first coat of base coat plaster may be omitted. See Table No. 47-D for thickness.

## Exposed Aggregate Plaster.

**Sec. 4709.** (a) **General.** Exposed natural or integrally colored aggregate may be partially embedded in a natural or colored bedding coat of portland cement or gypsum plaster, subject to the provisions of this section.

(b) **Aggregate.** The aggregate may be applied manually or mechanically and shall consist of marble chips, pebbles or similar durable, nonreactive materials, moderately hard (three or more on the MOH scale).

(c) **Bedding Coat Proportions.** The exterior bedding coat shall be composed of one part portland cement, one part Type S lime and a maximum three parts of graded white or natural sand by volume. The interior bedding coat shall be composed of 100 pounds neat gypsum plaster and a maximum 200 pounds of graded white sand, or exterior or interior may be a factory-prepared bedding coat. The exterior bedding coat shall have a minimum compressive strength of 1000 pounds per square inch.

(d) **Application.** The bedding coat may be applied directly over the first (scratch) coat of plaster, provided the ultimate overall thickness is a minimum of ⅞ inch including lath. Over concrete or masonry surfaces the overall thickness shall be a minimum of ½ inch.

(e) **Bases.** Exposed aggregate plaster may be applied over concrete, masonry, portland cement plaster base coats or gypsum plaster base coats.

(f) **Preparation of Masonry and Concrete.** Masonry and concrete surfaces shall be prepared in accordance with the provisions of Section 4708 (h).



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(g) **Curing.** Portland cement base coats shall be cured in accordance with Table No. 47-F. Portland cement bedding coat shall retain sufficient moisture for hydration (hardening) for 24 hours minimum or, where necessary, shall be kept damp for 24 hours by light water spraying.

## Pneumatically Placed Plaster (Gunite)

**Sec. 4710.** Pneumatically placed portland cement plaster shall be a mixture of portland cement and sand, mixed dry, conveyed by air through a pipe or flexible tube, hydrated at the nozzle at the end of the conveyor and deposited by air pressure in its final position.

Rebound material may be screened and reused as sand in an amount not greater than 25 percent of the total sand in any batch.

Pneumatically placed portland cement plaster shall consist of a mixture of one part cement to not more than five parts sand. Plasticity agents may be used as specified in Section 4708 (a). Except when applied to concrete or masonry, such plaster shall be applied in not less than two coats to a minimum total thickness of 7/8 inch. The first coat shall be rodded as specified in Section 4708 (c) for the second coat. The curing period and time interval shall be as set forth in Table No. 47-F.

## Gypsum Wallboard

**Sec. 4711.** (a) **General.** All gypsum wallboard shall conform to U.B.C. Standard No. 47-11 and shall be installed in accordance with the provisions of this section. Gypsum wallboard shall not be installed on exterior surfaces. See Section 424. For use as backing under stucco, see Section 4706 (c).

Gypsum wallboard shall not be installed until weather protection for the installation is provided.

(b) **Supports.** Supports shall be spaced not to exceed the spacing set forth in Table No. 47-G for single-ply application and Table No. 47-H for two-ply application. Vertical assemblies shall conform with Section 4703. Horizontal assemblies shall comply with Section 4704.

(c) **Single-ply Application.** All edges and ends of gypsum wallboard shall occur on the framing members, except those edges and ends which are perpendicular to the framing members. All edges and ends of gypsum wallboard shall be in moderate contact except in concealed spaces where fire-resistive construction or diaphragm action is not required.

The size and spacing of fasteners shall conform with Table No. 47-G except where modified by fire-resistive construction meeting the requirements of Section 4302 (b). Fasteners shall be spaced not less than 3/8 inch from edges and ends of gypsum wallboard. Fasteners at the top and bottom plates of vertical assemblies, or the edges and ends of horizontal assemblies perpendicular to supports, and at the wall line may be omitted except on shear-resisting elements or fire-resistive assemblies. Fasteners shall be applied in such a manner as not to fracture the face paper with the fastener head.



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Gypsum wallboard may be applied to wood framing members with an approved adhesive conforming with U.B.C. Standard No. 47-2. A continuous bead of the adhesive shall be applied to the face of all framing members, except top and bottom plates, of sufficient size as to spread to an average width of 1 inch and thickness of 1/16 inch when the gypsum wallboard is applied. Where the edges or ends of two pieces of gypsum wallboard occur on the same framing member, two continuous parallel beads of adhesive shall be applied to the framing member. Fasteners shall be used with adhesive application in accordance with Table No. 47-G.

(d) **Two-ply Application.** The base of gypsum wallboard shall be applied with fasteners of the type and size as required for the nonadhesive application of single-ply gypsum wallboard. Fastener spacings shall be in accordance with Table No. 47-H except where modified by fire-resistive construction meeting the requirements of Section 4302 (b).

The face ply of gypsum wallboard may be applied with gypsum wallboard joint compound or approved adhesive furnishing full coverage between the plies or with fasteners in accordance with Table No. 47-H. When the face ply is installed with joint compound or adhesive, the joints of the face ply need not occur on supports. Temporary nails or shoring shall be used to hold face ply in position until the joint compound or adhesive develops adequate bond.

(e) **Joint Treatment.** Gypsum wallboard single-layer fire-rated assemblies shall have joints treated.

**EXCEPTIONS:** Joint treatment need not be provided when any of the following conditions occur:

1. Where the wallboard is to receive a decorative finish such as wood paneling, battens, acoustical finishes or any similar application which would be equivalent to joint treatment.
2. Joints occur over wood-framing members.
3. Assemblies tested without joint treatment.

Gypsum wallboard tape and joint compound shall conform with the provisions of U.B.C. Standard No. 47-6.

## Use of Gypsum In Showers and Water Closets

**Sec. 4712.** When gypsum is used as a base for tile or wall panels for tub or shower enclosures or water closet compartment walls, water-resistant gypsum backing board complying with U.B.C. Standard No. 47-14 shall be used, except that water-resistant gypsum board shall not be used in the following locations:

1. Over a vapor retarder.
2. In areas subject to continuous high humidity, such as saunas, steam rooms or gang shower rooms.
3. On ceilings.

## Softwood Plywood Paneling

**Sec. 4713.** All softwood plywood paneling shall conform with the provisions of Chapters 25 and 42 and shall be installed in accordance with Table No. 47-J.



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## Shear-resisting Construction with Wood Frame

**Sec. 4714.** (a) **General.** Portland cement plaster, gypsum lath and plaster, gypsum veneer base, gypsum sheathing board and gypsum wallboard may be used on wood studs for vertical diaphragms if applied in accordance with this section. Shear-resisting values shall not exceed those set forth in Table No. 47-I. The effects of overturning on vertical diaphragms shall be investigated in accordance with Section 2303 (b) 3.

The shear values tabulated shall not be cumulative with the shear value of other materials applied to the same wall. The shear values may be additive when the identical materials applied as specified in this section are applied to both sides of the wall.

(b) **Masonry and Concrete Construction.** Portland cement plaster, gypsum lath and plaster, gypsum veneer base, gypsum sheathing board and gypsum wallboard shall not be used in vertical diaphragms to resist forces imposed by masonry or concrete construction.

(c) **Wall Framing.** Framing for vertical diaphragms shall conform with Section 2517 (g) for bearing walls, and studs shall be spaced not farther apart than 16 inches center to center. Sills, plates and marginal studs shall be adequately connected to framing elements located above and below to resist all design forces.

(d) **Height-to-Length Ratio.** The maximum allowable height-to-length ratio for the construction in this section shall be 2 to 1. Wall sections having height-to-length ratios in excess of 1 1/2 to 1 shall be blocked.

(e) **Application.** End joints of adjacent courses of gypsum lath, gypsum veneer base, gypsum sheathing board or gypsum wallboard sheets shall not occur over the same stud.

Where required in Table No. 47-I, blocking having the same cross-sectional dimensions as the studs shall be provided at all joints that are perpendicular to the studs.

The size and spacing of nails shall be as set forth in Table No. 47-I. Nails shall be spaced not less than 3/8 inch from edges and ends of gypsum lath, gypsum veneer base, gypsum sheathing board, gypsum wallboard or sides of studs, blocking and top and bottom plates.

1. **Gypsum lath.** Gypsum lath shall be applied perpendicular to the studs. Maximum allowable shear values shall be as set forth in Table No. 47-I.

2. **Gypsum sheathing board.** Four-foot-wide pieces may be applied parallel or perpendicular to studs. Two-foot-wide pieces shall be applied perpendicular to the studs. Maximum allowable shear values shall be as set forth in Table No. 47-I.

3. **Gypsum wallboard or veneer base.** Gypsum wallboard or veneer base may be applied parallel or perpendicular to studs. Maximum allowable shear values shall be as set forth in Table No. 47-I.



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## TABLE NO. 47-A—SUSPENDED AND FURRED CEILINGS[1]
(For Support of Ceilings Weighing Not More than 10 Pounds per Square Foot)

| Minimum Sizes for Wire and Rigid Hangers | | | | |
|---|---|---|---|---|
| SIZE AND TYPE | | | MAXIMUM AREA SUPPORTED (In Square Feet) | SIZE |
| Hangers for Suspended Ceilings | | | 12.5 | No. 9 gauge wire |
| | | | 16 | No. 8 gauge wire |
| | | | 18 | 3/16" diameter, mild steel rod[2] |
| | | | 20 | 7/32" diameter, mild steel rod[2] |
| | | | 22.5 | 1/4" diameter, mild steel rod[2] |
| | | | 25.0 | 1" x 3/16" mild steel flats[3] |
| Hangers for Attaching Runners and Furring Directly to Beams and Joists | For Supporting Runners | Single Hangers Between Beams[4] | 8 | No. 12 gauge wire |
| | | | 12 | No. 10 gauge wire |
| | | | 16 | No. 8 gauge wire |
| | | Double Wire Loops at Beams or Joists[3] | 8 | No. 14 gauge wire |
| | | | 12 | No. 12 gauge wire |
| | | | 16 | No. 11 gauge wire |
| | For Supporting Furring without Runners[4] (Wire Loops at Supports) | Type of Support: | 8 | |
| | | Concrete | | No. 14 gauge wire |
| | | Steel | | No. 16 gauge wire (2 loops)[5] |
| | | Wood | | No. 16 gauge wire (2 loops)[5] |



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| Minimum Sizes and Maximum Spans for Main Runners[6,7] | | |
|---|---|---|
| SIZE AND TYPE | MAXIMUM SPACING OF HANGERS OR SUPPORTS (ALONG RUNNERS) | MAXIMUM SPACING OF RUNNERS (TRANSVERSE) |
| ¾"— .3 pound per foot, cold- or hot-rolled channel | 2'0" | 3'0" |
| 1½"— .475 pound per foot, cold-rolled channel | 3'0" | 4'0" |
| 1½"— .475 pound per foot, cold-rolled channel | 3'6" | 3'6" |
| 1½"— .475 pound per foot, cold-rolled channel | 4'0" | 3'0" |
| 1½"—1.12 pounds per foot, hot-rolled channel | 4'0" | 5'0" |
| 2 "—1.26 pounds per foot, hot-rolled channel | 5'0" | 5'0" |
| 2 "— .59 pound per foot, cold-rolled channel | 5'0" | 3'6" |
| 1½" x 1½" x ⅛" angle | 5'0" | 3'6" |

| Minimum Sizes and Maximum Spans for Cross Furring[6,7] | | |
|---|---|---|
| SIZE AND TYPE OF CROSS FURRING | MAXIMUM SPACING OF RUNNERS OR SUPPORTS | MAXIMUM SPACING OF CROSS FURRING MEMBERS (TRANSVERSE) |
| ¼" diameter pencil rods | 2'0" | 12" |
| ⅜" diameter pencil rods | 2'0" | 19" |
| ⅜" diameter pencil rods | 2'6" | 12" |
| ¾"—.3 pound per foot, cold- or hot-rolled channel | 3'0" | 24" |
| | 3'6" | 16" |
| | 4'0" | 12" |
| 1 "—.410 pound per foot, hot-rolled channel | 4'0" | 24" |
| | 4'6" | 19" |
| | 5'0" | 12" |

[1]Metal suspension systems for acoustical tile and lay-in panel ceiling systems weighing not more than 4 pounds per square foot, including light fixtures and all ceiling-supported equipment and conforming to U.B.C. Standard No. 47-18, are exempt from Table No. 47-A.

For furred and suspended ceilings with metal lath construction, see U.B.C. Standard No. 47-4.

[2]All rod hangers shall be protected with a zinc or cadmium coating or with a rust-inhibitive paint.

[3]All flat hangers shall be protected with a zinc or cadmium coating or with a rust-inhibitive paint.

[4]Inserts, special clips or other devices of equal strength may be substituted for those specified.

[5]Two loops of No. 18 gauge wire may be substituted for each loop of No. 16 gauge wire for attaching steel furring to steel or wood joists.

[6]Spans are based on webs of channels being erected vertically.

[7]Furred members of equivalent strength may be substituted for those specified.





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## TABLE NO. 47-B[1]—TYPES OF LATH—MAXIMUM SPACING OF SUPPORTS

| TYPE OF LATH[2] | | MINIMUM WEIGHT (Per Square Yard) GAUGE AND MESH SIZE | VERTICAL (In Inches) | | | HORIZONTAL (In Inches) | |
|---|---|---|---|---|---|---|---|
| | | | Wood | Metal | | Wood or Concrete | Metal |
| | | | | Solid Plaster Partitions | Other | | |
| 1. Expanded Metal Lath (Diamond Mesh) | | 2.5<br>3.4 | 16[3]<br>16[3] | 16[3]<br>16[3] | 12<br>16 | 12<br>16 | 12<br>16 |
| 2. Flat Rib Expanded Metal Lath | | 2.75<br>3.4 | 16<br>19 | 16<br>24 | 16<br>19 | 16<br>19 | 16<br>19 |
| 3. Stucco Mesh Expanded Metal Lath | | 1.8 and 3.6 | 16[4] | — | — | — | — |
| 4. 3/8" Rib Expanded Metal Lath | | 3.4<br>4.0 | 24<br>24 | 24[5]<br>24[5] | 24<br>24 | 24<br>24 | 24<br>24 |
| 5. Sheet Lath | | 4.5 | 24 | [5] | 24 | 24 | 24 |
| 6. Wire Fabric Lath | Welded | 1.95 pounds, No. 11 gauge, 2" × 2"<br>1.16 pounds, No. 16 gauge, 2" × 2"<br>1.4 pounds, No. 18 gauge, 1" × 1"[6] | 24<br>16<br>16[4] | 24<br>16<br>— | 24<br>16<br>— | 24<br>16<br>— | 24<br>16<br>— |
| | Woven[4] | 1.1 pounds, No. 18 gauge, 1½" Hexagonal[6]<br>1.4 pounds, No. 17 gauge, 1½" Hexagonal[6]<br>1.4 pounds, No. 18 gauge, 1" Hexagonal[6] | 24<br>24<br>24 | 16<br>16<br>16 | 16<br>16<br>16 | 24<br>24<br>24 | 16<br>16<br>16 |
| 7. 3/8" Gypsum Lath (plain) | | | 16 | — | 16[7] | 16 | 16 |
| 8. ½" Gypsum Lath (plain) | | | 24 | — | 24 | 24 | 24 |



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[1]For fire-resistive construction, see Tables No. 43-A, No. 43-B and No. 43-C. For shear-resisting elements, see Table No. 47-I. Metal lath, wire lath, wire fabric lath and metal accessories shall conform with the provisions of U.B.C. Standard No. 47-4. Gypsum lath shall conform with the provisions of U.B.C. Standard No. 47-8.

[2]Metal lath and wire fabric lath used as reinforcement for portland cement plaster shall be furred out away from vertical supports at least 1/4 inch. Self-furring lath meets furring requirements. Exception: Furring of expanded metal lath is not required on supports having a bearing surface width of 1-5/8 inches or less.

[3]Span may be increased to 24 inches with self-furred metal lath over solid sheathing assemblies approved for this use.

[4]Wire backing required on open vertical frame construction except under expanded metal lath and paperbacked wire fabric lath.

[5]May be used for studless solid partitions.

[6]Woven wire or welded wire fabric lath, not to be used as base for gypsum plaster without absorbent paperbacking or slot-perforated separator.

[7]Span may be increased to 24 inches on vertical screw or approved nailable assemblies.





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## TABLE NO. 47-C—TYPES OF LATH—ATTACHMENT TO WOOD AND METAL[1] SUPPORTS

| TYPE OF LATH | NAILS[2 3] | | | SCREWS[3 6] | | STAPLES[3 4] Round or Flattened Wire | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TYPE AND SIZE | MAXIMUM SPACING[5] | | MAX. SPACING[5] | | Wire Gauge No. | Crown | Leg[7] | MAX. SPACING[5 6] | |
| | | Vertical | Horizontal | Vertical | Horizontal | | | | Vertical | Horizontal |
| | | (In Inches) | | (In Inches) | | | (In Inches) | | | |
| 1. Diamond Mesh Expanded Metal Lath and Flat Rib Metal Lath | 4d blued smooth box $1\frac{1}{2}$"[11] No. 14 gauge $\frac{7}{32}$" head (clinched)[8]<br>1" No. 11 gauge $\frac{7}{16}$" head, barbed<br>$1\frac{1}{2}$" No. 11 gauge $\frac{7}{16}$" head, barbed | 6<br>6<br>6 | —<br>—<br>6 | 6 | 6 | 16 | $\frac{3}{4}$ | $\frac{7}{8}$ | 6 | 6 |
| 2. $\frac{3}{8}$" Rib Metal Lath and Sheet Lath | $1\frac{1}{2}$" No. 11 gauge $\frac{7}{16}$" head, barbed | 6 | 6 | 6 | 6 | 16 | $\frac{3}{4}$ | $1\frac{1}{4}$ | At Ribs | At Ribs |
| 3. $\frac{3}{4}$" Rib Metal Lath | 4d common $1\frac{1}{2}$" No. $12\frac{1}{2}$ gauge $\frac{1}{4}$" head<br>2" No. 11 gauge $\frac{7}{16}$" head, barbed | At Ribs | —<br>At Ribs | At Ribs | At Ribs | 16 | $\frac{3}{4}$ | $1\frac{3}{8}$ | At Ribs | At Ribs |



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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4. Wire Fabric Lath[9] | 4d blued smooth box (clinched)[8] | 6 | — | 6 | 6 | 16 | 3/4 | 7/8 | 6 | 6 |
| | 1" No. 11 gauge 7/16" head, barbed | 6 | — | | | | | | | |
| | 1½" No. 11 gauge 7/16" head; barbed | 6 | 6 | | | 16 | 7/16[9] | 7/8 | 6 | 6 |
| | 1¼" No. 12 gauge 3/8" head, furring | 6 | 6 | | | | | | | |
| | 1" No. 12 gauge 3/8" head | 6 | | | | | | | | |
| 5. 3/8" Gypsum Lath | 1⅛" No. 13 gauge 19/64" head, blued | 8[10] | 8[10] | 8[10] | 8[10] | 16 | 3/4 | 7/8 | 8[10] | 8[10] |
| 6. 1/2" Gypsum Lath | 1¼" No. 13 gauge 19/64" head, blued | 8 | 8[10] 6[11] | 8[10] | 8[10] 6[11] | 16 | 3/4 | 1⅛ | 8[10] | 8[10] 6[11] |

[1]Metal lath, wire lath, wire fabric lath and metal accessories shall conform with the provisions of U.B.C. Standard No. 47-4.

[2]For nailable nonload-bearing metal supports, use annular threaded nails or approved staples.

[3]For fire-resistive construction, see Tables No. 43-B and No. 43-C. For shear-resisting elements, see Table No. 47-I. Approved wire and sheet metal attachment clips may be used.

[4]With chisel or divergent points.

[5]Maximum spacing of attachments from longitudinal edges shall not exceed 2 inches.

[6]Screws shall be an approved type long enough to penetrate into wood framing not less than ⅝ inch and through metal supports adaptable for screw attachment not less than ¼ inch.

[7]When lath and stripping are stapled simultaneously, increase leg length of staple ⅛ inch.

[8]For interiors only.

[9]Attach self-furring wire fabric lath to supports at furring device.

[10]Three attachments per 16-inch-wide lath per bearing. Four attachments per 24-inch-wide lath per bearing.

[11]Supports spaced 24 inches o.c. Four attachments per 16-inch-wide lath per bearing. Five attachments per 24-inch-wide lath per bearing.





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## TABLE NO. 47-D—THICKNESS OF PLASTER[1]

| PLASTER BASE | FINISHED THICKNESS OF PLASTER FROM FACE OF LATH, MASONRY, CONCRETE | |
|---|---|---|
| | Gypsum Plaster | Portland Cement Plaster |
| 1. Expanded Metal Lath | 5/8" minimum[2] | 5/8" minimum[2] |
| 2. Wire Fabric Lath | 5/8" minimum[2] | 3/4" minimum (interior)[3]<br>7/8" minimum (exterior)[3] |
| 3. Gypsum Lath | 1/2" minimum | |
| 4. Masonry Walls[4] | 1/2" minimum | 1/2" minimum |
| 5. Monolithic Concrete Walls[4 5] | 5/8" maximum[6] | 7/8" maximum[6] |
| 6. Monolithic Concrete Ceilings[4 5] | 3/8" maximum[6 7 8] | 1/2" maximum[7 8] |

[1]For fire-resistive construction, see Tables Nos. 43-A, 43-B and 43-C.

[2]When measured from back plane of expanded metal lath, exclusive of ribs, or self-furring lath, plaster thickness shall be 3/4-inch minimum.

[3]When measured from face of support or backing.

[4]Because masonry and concrete surfaces may vary in plane, thickness of plaster need not be uniform.

[5]When applied over a liquid bonding agent, finish coat may be applied directly to concrete surface.

[6]Approved acoustical plaster may be applied directly to concrete, or over base coat plaster, beyond the maximum plaster thickness shown.

[7]On concrete ceilings, where the base coat plaster thickness exceeds the maximum thickness shown, metal lath or wire fabric lath shall be attached to the concrete.

[8]An approved skim-coat plaster 1/16 inch thick may be applied directly to concrete.



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## TABLE NO. 47-E—GYPSUM PLASTER PROPORTIONS [1]

| NUMBER | COAT | PLASTER BASE OR LATH | MAXIMUM VOLUME AGGREGATE PER 100 POUNDS NEAT PLASTER [2 3] (Cubic Feet) | |
|---|---|---|---|---|
| | | | Damp Loose Sand [4] | Perlite or Vermiculite [4] |
| 1. Two-coat Work | Base Coat | Gypsum Lath | 2½ | 2 |
| | Base Coat | Masonry | 3 | 3 |
| 2. Three-coat Work | First Coat | Lath | 2 [5] | 2 |
| | Second Coat | Lath | 3 [5] | 2 [6] |
| | First and Second Coats | Masonry | 3 | 3 |

[1] Wood-fibered gypsum plaster may be mixed in the proportions of 100 pounds of gypsum to not more than 1 cubic foot of sand where applied on masonry or concrete.

Gypsum plasters shall conform with the provisions of U.B.C. Standard No. 47-9.

[2] For fire-resistive construction, see Tables No. 43-A, No. 43-B and No. 43-C.

[3] When determining the amount of aggregate in set plaster, a tolerance of 10 percent shall be allowed.

[4] Combinations of sand and lightweight aggregate may be used, provided the volume and weight relationship of the combined aggregate to gypsum plaster is maintained. Sand and lightweight aggregate shall conform with U.B.C. Standard No. 47-3.

[5] If used for both first and second coats, the volume of aggregate may be 2½ cubic feet.

[6] Where plaster is 1 inch or more in total thickness, the proportions for the second coat may be increased to 3 cubic feet.





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## TABLE NO. 47-F—PORTLAND CEMENT PLASTERS[1]

| PORTLAND CEMENT PLASTER | | | | | | |
|---|---|---|---|---|---|---|
| COAT | VOLUME CEMENT | MAXIMUM WEIGHT (OR VOLUME) LIME PER VOLUME CEMENT[2] | MAXIMUM VOLUME SAND PER VOLUME CEMENT[3] | APPROXIMATE MINIMUM THICKNESS[4] | MINIMUM PERIOD MOIST CURING | MINIMUM INTERVAL BETWEEN COATS |
| First | 1 | 20 lbs. | 4 | ⅜"[5] | 48[6] Hours | 48[7] Hours |
| Second | 1 | 20 lbs. | 5 | 1st and 2nd Coats total ¾" | 48 hours | 7 Days[8] |
| Finish | 1 | 1[9] | 3 | 1st, 2nd and Finish Coats ⅞" | — | [8] |
| **PORTLAND CEMENT-LIME PLASTER[10]** | | | | | | |
| COAT | VOLUME CEMENT[11] | MAXIMUM VOLUME LIME PER VOLUME CEMENT | MAXIMUM VOLUME SAND PER COMBINED VOLUMES CEMENT AND LIME | APPROXIMATE MINIMUM THICKNESS[4] | MINIMUM PERIOD MOIST CURING | MINIMUM INTERVAL BETWEEN COATS |
| First | 1 | 1 | 4 | ⅜"[5] | 48[6] Hours | 48[7] Hours |
| Second | 1 | 1 | 4½ | 1st and 2nd Coats total ¾" | 48 hours | 7 Days[8] |
| Finish | 1 | 1[9] | 3 | 1st, 2nd and Finish Coats ⅞" | — | [8] |

[1]Exposed aggregate plaster shall be applied in accordance with Section 4709. Minimum overall thickness shall be ¾ inch.

[2]Up to 20 pounds of dry hydrated lime (or an equivalent amount of lime putty) may be used as a plasticizing agent in proportion to each sack (cubic foot) of Type I and Type II standard portland cement in first and second coats of plaster. See Section 4708 (a) for use of plastic cement.

[3]When determining the amount of sand in set plaster, a tolerance of 10 percent may be allowed.

[4]See Table No. 47-D.

[5]Measured from face of support of backing to crest of scored plaster.

[6]See Section 4707 (c) 2.

[7]Twenty-four hours minimum interval between coats of interior portland cement plaster. For alternate method of application, see Section 4708 (e).

[8]Finish coat plaster may be applied to interior portland cement base coats after a 48-hour period.

[9]For finish coat plaster, up to an equal part of dry hydrated lime by weight (or an equivalent volume of lime putty) may be added to Types I, II and III standard portland cement.

[10]No additions of plasticizing agents shall be made.

[11]Type I, II or III standard portland cement. See Section 4708 (a) for use of plastic cement.



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## TABLE NO. 47-G—APPLICATION OF SINGLE-PLY GYPSUM WALLBOARD

| THICKNESS OF GYPSUM WALLBOARD (inch) | PLANE OF FRAMING SURFACE | LONG DIMENSION OF GYPSUM WALLBOARD SHEETS IN RELATION TO DIRECTION OF FRAMING MEMBERS | MAXIMUM SPACING OF FRAMING MEMBERS[1] (Center to Center) (In Inches) | MAXIMUM SPACING OF FASTENERS[1] (Center to Center) (In Inches) | | NAILS[2]—TO WOOD |
|---|---|---|---|---|---|---|
| | | | | Nails[3] | Screws[4] | |
| 1/2 | Vertical | Either direction | 16 | 8 | 16 | No. 13 gauge, 1 3/8" long, 19/64" head; 0.098" diameter, 1 1/4" long, annular ringed; 5d, cooler or wallboard[5] nail (0.086" dia., 1 5/8" long, 15/64" head). |
| | Horizontal | Either direction | 16 | 7 | 12 | |
| | Horizontal | Perpendicular | 24 | 7 | 12 | |
| | Vertical | Either direction | 24 | 8 | 12 | |
| 5/8 | Vertical | Either direction | 16 | 8 | 16 | No. 13 gauge, 1 5/8" long, 19/64" head; 0.098" diameter, 1 3/8" long, annular ringed; 6d, cooler or wallboard[5] nail (0.092" dia., 1 7/8" long, 1/4" head). |
| | Horizontal | Either direction | 16 | 7 | 12 | |
| | Horizontal | Perpendicular | 24 | 7 | 12 | |
| | Vertical | Either direction | 24 | 8 | 12 | |
| Nail or Screw Fastenings With Adhesives (Maximum Center to Center In Inches) | | | | | | |
| (Column headings as above) | | | | End | Edges | Field |
| 1/2 or 5/8 | Horizontal | Either direction | 16 | 16 | 16 | 24 | As required for 1/2" and 5/8" gypsum wallboard, see above. |
| | | Perpendicular | 24 | 16 | 24 | 24 | |
| | Vertical | Either direction | 24 | 16 | 24 | [6] | |

[1]For fire-resistive construction, see Tables Nos. 43-B and 43-C. For shear-resisting elements, see Table No. 47-I.

[2]Where the metal framing has a clinching design formed to receive the nails by two edges of metal, the nails shall be not less than 5/8 inch longer than the wallboard thickness, and shall have ringed shanks. Where the metal framing has a nailing groove formed to receive the nails, the nails shall have barbed shanks or be 5d, No. 13 1/2 gauge, 1 5/8 inch long, 15/64-inch head for 1/2-inch gypsum wallboard; 6d, No. 13 gauge, 1 7/8-inch long, 15/64-inch head for 5/8-inch gypsum wallboard.

[3]Two nails spaced 2 inches to 2 1/2 inches apart may be used where the pairs are spaced 12 inches on center except around the perimeter of the sheets.

[4]Screws shall conform with U.B.C. Standard No. 47-5 and be long enough to penetrate into wood framing not less than 5/8 inch and through metal framing not less than 1/4 inch.

[5]For properties of cooler or wallboard nails, see U.B.C. Standard No. 25-17, Table No. 25-17-H.

[6]





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## TABLE NO. 47-H—APPLICATION OF TWO-PLY GYPSUM WALLBOARD[1]

| FASTENERS ONLY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| THICKNESS OF GYPSUM WALLBOARD (Each Ply) (Inch) | PLANE OF FRAMING SURFACE | LONG DIMENSION OF GYPSUM WALLBOARD SHEETS | MAXIMUM SPACING OF FRAMING MEMBERS (Center to Center) (In Inches) | MAXIMUM SPACING OF FASTENERS (Center to Center) (In Inches) | | | | |
| | | | | Base Ply | | | Face Ply | |
| | | | | Nails[2] | Screws[3] | Staples[4] | Nails[2] | Screws[3] |
| 3/8 | Horizontal | Perpendicular only | 16 | 16 | 24 | 16 | 7 | 12 |
| | Vertical | Either Direction | 16 | | | | 8 | |
| 1/2 | Horizontal | Perpendicnlar only | 24 | | | | 7 | |
| | Vertical | Either Direction | 24 | | | | 8 | |
| 5/8 | Horizontal | Perpendicular only | 24 | | | | 7 | |
| | Vertical | Either Direction | 24 | | | | 8 | |
| **Fasteners and Adhesives** | | | | | | | | |
| 3/8 Base Ply | Horizontal | Perpendicular only | 16 | 7 | 12 | 5 | Temporary Nailing or Shoring to Comply with Section 4711 (d) | |
| | Vertical | Either Direction | 24 | 8 | | 7 | | |
| 1/2 Base Ply | Horizontal | Perpendicular only | 24 | 7 | | 5 | | |
| | Vertical | Either Direction | 24 | 8 | | 7 | | |
| 5/8 Base Ply | Horizontal | Perpendicular only | 24 | 7 | | 5 | | |
| | Vertical | Either Direction | 24 | 8 | | 7 | | |

[1]For fire-resistive construction, see Tables Nos. 43-B and 43-C. For shear-resisting elements, see Table No. 47-I.

[2]Nails for wood framing shall be long enough to penetrate into wood members not less than 3/4 inch and the sizes shall conform with the provisions of Table No. 47-G. For nails not included in Table No. 47-G, use the appropriate size cooler or wallboard nails as set forth in Table No. 25-17-H of U.B.C. Standard No. 25-17. Nails for metal framing shall conform with the provisions of Table No. 47-G.

[3]Screws shall conform with the provisions of Table No. 47-G.

[4]Staples shall be not less than No. 16 gauge by 3/4-inch crown width with leg length of 7/8 inch, 1 1/8 inch and 1 3/8 inch for gypsum wallboard thicknesses of 3/8 inch, 1/2 inch and 5/8 inch, respectively.



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## TABLE NO. 47-I—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES IN POUNDS PER FOOT FOR VERTICAL DIAPHRAGMS OF LATH AND PLASTER OR GYPSUM BOARD FRAME WALL ASSEMBLIES[1]

| TYPE OF MATERIAL | THICKNESS OF MATERIAL | WALL CONSTRUCTION | NAIL SPACING[2] MAXIMUM (In Inches) | SHEAR VALUE | MINIMUM NAIL SIZE[3,4] |
|---|---|---|---|---|---|
| 1. Expanded metal, or woven wire lath and portland cement plaster | 7/8" | Unblocked | 6 | 180 | No. 11 gauge, 1 1/2" long, 7/16" head<br>No. 16 gauge staple, 7/8" legs |
| 2. Gypsum lath | 3/8" Lath and 1/2" Plaster | Unblocked | 5 | 100 | No. 13 gauge, 1 1/8" long, 19/64" head, plasterboard blued nail |
| 3. Gypsum sheathing board | 1/2" x 2' x 8' | Unblocked | 4 | 75 | No. 11 gauge, 1 3/4" long, 7/16" head, diamond-point, galvanized |
| | 1/2" x 4' | Blocked | 4 | 175 | |
| | 1/2" x 4' | Unblocked | 7 | 100 | |
| 4. Gypsum wallboard or veneer base. | 1/2" | Unblocked | 7 | 100 | 5d cooler or wallboard |
| | | | 4 | 125 | |
| | | Blocked | 7 | 125 | |
| | | | 4 | 150 | |
| | 5/8" | Unblocked | 7 | 115 | 6d cooler or wallboard |
| | | | 4 | 145 | |
| | | Blocked | 7 | 145 | |
| | | | 4 | 175 | |
| | | Blocked Two ply | Base ply 9<br>Face ply 7 | 250 | Base ply—6d cooler or wallboard<br>Face ply—8d cooler or wallboard |

[1]These vertical diaphragms shall not be used to resist loads imposed by masonry or concrete construction. See Section 4714 (b). Values are for short term loading due to wind. Values must be reduced 25 percent for normal loading. The values for gypsum products must be reduced 50 percent for dynamic loading due to earthquake in Seismic Zones Nos. 3 and 4.

[2]Applies to nailing at all studs, top and bottom plates and blocking.

[3]Alternate nails may be used if their dimensions are not less than the specified dimensions. For nails, see U.B.C. Standard No. 25-17, Table No. 25-17-H.





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## TABLE NO. 47-J—SOFTWOOD PLYWOOD PANELING
### (Meeting Requirements of U.B.C. Standard No. 25-9 )

| PLYWOOD THICKNESS (Inch) | MAX. SUPPORT SPACING (Inches) | NAIL SIZE & TYPE | NAIL SPACING (Inches) | |
|---|---|---|---|---|
| | | | Panel Edges | Intermediate |
| ¼ | 16[1] | 4d casing or finish | 6 | 12 |
| ⅜ | 24 | 6d casing or finish | 6 | 12 |

[1]Twenty inches if face grain of paneling is across supports.



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# *Part X*

# SPECIAL SUBJECTS

## Chapter 48

## CELLULOSE NITRATE

### Cellulose Nitrate

**Sec. 4801.** The handling and storage of cellulose nitrate film shall be in accordance with the Fire Code.

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# Chapter 49
# NO REQUIREMENTS

(See page 881—Appendix.)



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# Chapter 50
# PREFABRICATED CONSTRUCTION

## General

**Sec. 5001.** (a) **Purpose.** The purpose of this chapter is to regulate materials and establish methods of safe construction where any structure or portion thereof is wholly or partially prefabricated.

(b) **Scope.** Unless otherwise specifically stated in this chapter, all prefabricated construction and all materials used therein shall conform to all the requirements of this code. (See Section 105.)

(c) **Definition. PREFABRICATED ASSEMBLY** is a structural unit, the integral parts of which have been built up or assembled prior to incorporation in the building.

## Tests of Materials

**Sec. 5002.** Every approval of a material not specifically mentioned in this code shall incorporate as a proviso, the kind and number of tests to be made during prefabrication.

## Tests of Assemblies

**Sec. 5003.** The building official may require special tests to be made on assemblies to determine their durability and weather resistance.

## Connections

**Sec. 5004.** Every device designed to connect prefabricated assemblies shall be capable of developing the strength of the members connected, except in the case of members forming part of a structural frame designed as specified in Chapter 23. The connection device shall be designed as required by the other chapters in this code. Connections between roofs and supporting walls shall be capable of withstanding an uplift force equal to the requirements contained in Chapter 23.

## Pipes and Conduits

**Sec. 5005.** In structural design, due allowance shall be made for any material to be removed for the installation of pipes, conduits or other equipment.

## Certificate and Inspection

**Sec. 5006.** (a) **Materials.** Materials and the assembly thereof shall be inspected to determine compliance with this code. Every material shall be graded, marked or labeled where required elsewhere in this code.

(b) **Certificate.** A certificate of approval shall be furnished with every prefabricated assembly, except where the assembly is readily accessible to inspection at the site. The certificate of approval shall certify that the assembly in question has been inspected and meets all the requirements of this code. When mechanical equipment is installed so that it cannot be inspected at the site, the certificate of approval shall certify that such equipment complies with the laws applying thereto.



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(c) **Certifying Agency.** To be acceptable under this code, every certificate of approval shall be made by an approved agency.

(d) **Field Erection.** Placement of prefabricated assemblies at the building site shall be inspected by the building official to determine compliance with this code.

(e) **Continuous Inspection.** If continuous inspection is required for certain materials where construction takes place on the site, it shall also be required where the same materials are used in prefabricated construction.

**EXCEPTION:** Continuous inspection will not be required during prefabrication if the approved agency certifies to the construction and furnishes evidence of compliance.



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# Chapter 51

# ELEVATORS, DUMBWAITERS, ESCALATORS AND MOVING WALKS

## Scope

**Sec. 5101.** The provisions of this chapter shall apply to the design, construction, installation, operation, alteration and repair of elevators, dumbwaiters, escalators and moving walks and their hoistways.

## Elevator and Elevator Lobby Enclosures

**Sec. 5102.** Walls and partitions enclosing elevator and dumbwaiter hoistway shafts and escalator shafts shall be of not less than the fire-resistive construction required under Types of Construction in Part IV of this code.

## Special Provisions

**Sec. 5103.** (a) **Number of Cars in Hoistway.** When there are three or fewer elevator cars in a building, they may be located within the same hoistway enclosure. When there are four elevator cars, they shall be divided in such a manner that at least two separate hoistway enclosures are provided. When there are more than four elevators, not more than four elevator cars may be located within a single hoistway enclosure.

(b) **Door Operation.** Each elevator lobby or entrance area shall be provided with an approved smoke detector. The sensitivity of such detectors may be set at the maximum sensitivity.

(c) **Standby Power.** Standby power when required by Section 1807 shall be provided to at least one elevator in each bank. Standby power shall be manually transferable to all elevators in each bank. Standby power shall be provided by an approved self-contained generator set to operate automatically whenever there is a loss of electrical power to the building. The generator set shall be located in a separate room enclosed by at least a one-hour fire-resistive occupancy separation. The generator shall have a fuel supply adequate to operate the equipment connected to it for a minimum of two hours.

**EXCEPTION:** 1. Where a single elevator serves all floor levels in the building and is located so that all areas of the building can be reached within a travel distance of 300 feet from the elevator, then only that elevator need be provided with standby power.

2. Standby power shall be capable of operating one elevator at a time in any bank or group of banks having a common lobby.

**Note:** A bank of elevators is a group of elevators or a single elevator controlled by a common operating system; that is, all those elevators which respond to a single call button constitute a bank of elevators. There is no limit on the number of cars which may be in a bank or group, but there may be not more than four cars within a common hoistway.

(d) **Size of Cab and Control Locations.** In buildings three or more stories in height served by an elevator or a building served by an elevator required by Table



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No. 33-A, at least one elevator serving all floors shall accommodate a wheelchair, as follows:

1. **Operation and leveling.** The elevator shall be automatic and be provided with a self-leveling feature that will automatically bring the car to the floor landings within a tolerance of ± 1/2 inch under normal loading and unloading conditions. This self-leveling shall, within its zone, be entirely automatic and independent of the operating device and shall correct the overtravel or undertravel. The car shall also be maintained approximately level with the landing, irrespective of load.

2. **Door operation.** Power-operated horizontally sliding car and hoistway doors opened and closed by automatic means shall be provided.

3. **Door size.** Minimum clear width for elevator doors shall be 36 inches.

**EXCEPTION:** When approved by the building official, the minimum door width may be reduced to 32 inches for car with dimensions as permitted by the exception to Section 5103 (d) 6.

4. **Door protective and reopening device.** Doors closed by automatic means shall be provided with a door-reopening device which will function to stop and reopen a car door and adjacent hoistway door in case the car door is obstructed while closing. This reopening device shall also be capable of sensing an object or person in the path of a closing door without requiring contact for activation at a nominal 5 and 29 inches above the floor.

Door reopening devices shall remain effective for a period of not less than 20 seconds.

5. **Door delay (passenger service time).** A. **Hall call.** The minimum acceptable time from notification that a car is answering a call (lantern and audible signal) until the doors of that car start to close shall be as indicated in the following table:

| DISTANCE (In feet) | TIME |
|---|---|
| 0 to 5 | 4 Seconds |
| 10 | 7 Seconds |
| 15 | 10 Seconds |
| 20 | 13 Seconds |

The distance shall be established from a point in the center of the corridor or lobby (maximum 5 feet) directly opposite the farthest hall button to the center line of the hoistway entrance.

B. **Car call.** The minimum acceptable time for doors to remain fully open shall be not less than 3 seconds.

6. **Car inside.** The car inside shall allow for the turning of a wheelchair. The minimum clear distance between walls or between wall and door, excluding return panels, shall be not less than 68 inches by 54 inches. Minimum distance from wall to return panel shall be not less than 51 inches.

**EXCEPTION:** When approved by the building official, elevators provided in schools, institutions or other buildings may have a minimum clear distance between



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walls or between wall and door, excluding return panels, of not less than 54 inches by 54 inches. Minimum distance from wall to return panel shall be not less than 51 inches.

7. **Car controls.** Controls shall be readily accessible from a wheelchair upon entering an elevator.

The center line of the alarm button and emergency stop switch shall be at a nominal 35 inches, and the highest floor button no higher than 54 inches from the floor. Floor registration buttons, exclusive of border, shall be a minimum 3/4 inch in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when call is answered. Depth of flush or recessed buttons when operated shall not exceed 3/8 inch.

Markings shall be adjacent to the controls on a contrasting color background to the left of the controls. Letters or numbers shall be a minimum of 5/8 inch high and raised or recessed .030 inch.

Applied plates permanently attached shall be acceptable.

Emergency controls shall be grouped together at the bottom of the control panel.

Controls not essential to the automatic operation of the elevator may be located as convenient.

8. **Car position indicator and signal.** A car position indicator shall be provided above the car operating panel or over the opening of each car to show the position of the car in the hoistway by illumination of the indication corresponding to the landing at which the car is stopped or passing.

Indications shall be on a contrasting color background and a minimum of 1/2 inch in height.

In addition, an audible signal shall sound to tell a passenger that the car is stopping or passing a floor served by the elevator.

A special button located with emergency controls may be provided. Operation of the button will activate an audible signal only for the desired trip.

9. **Telephone or intercommunicating system.** A means of two-way communication shall be provided between the elevator and a point outside the hoistway.

If a telephone is provided, it shall be located a maximum of 54 inches from the floor with a minimum cord length of 29 inches. Markings or the international symbol for telephones shall be adjacent to the control on a contrasting color background. Letters or numbers shall be a minimum of 5/8 inch high and raised or recessed .030 inch.

Applied plates permanently attached shall be acceptable.

10. **Floor covering.** Floor covering shall have a nonslip hard surface which permits easy movement of wheelchairs.

If carpeting is used, it shall be securely attached, heavy duty, with a tight weave and low pile, installed without padding.

11. **Handrails.** A handrail shall be provided on one wall of the car, preferably



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the rear. The rails shall be smooth and the inside surface at least 1 1/2 inches clear of the walls at a nominal height of 32 inches from the floor.

Nominal = ± 1 inch.

**Note:** Thirty-two inches required to reduce interference with car controls where lowest button is centered at 35 inches above floor.

12. **Minimum illumination.** The minimum illumination at the car controls and the landing when the car and landing doors are open shall be not less than five footcandles.

13. **Hall buttons.** The center line of the hall call buttons shall be a nominal 42 inches above the floor.

Direction buttons, exclusive of border, shall be a minimum of 3/4 inch in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when the call is answered. Depth of flush or recessed button when operated shall not exceed 3/8 inch.

14. **Hall lantern.** A visual and audible signal shall be provided at each hoistway entrance indicating to the prospective passenger the car answering the call and its direction of travel.

The visual signal for each direction shall be a minimum of 2 1/2 inches in size and visible from the proximity of the hall call button.

The audible signal shall sound once for the up direction and twice for the down direction.

The center line of the fixture shall be located a minimum of 6 feet from the floor.

The use of in-car lanterns conforming to above and located in jamb shall be acceptable.

15. **Door jamb marking.** The floor designation shall be provided at each hoistway entrance on both sides of jamb visible from within the car and the elevator lobby at a height of 60 inches above the floor. Designations shall be on a contrasting background 2 inches high and raised .030 inch.

Applied plates permanently attached shall be acceptable.

(e) **Stretcher Requirements.** In all structures four or more stories in height, at least one elevator shall be provided with a minimum clear distance between walls or between walls and door excluding return panels, not less than 80 inches by 54 inches, and a minimum distance from wall to return panel not less than 51 inches with a 42-inch side slide door, unless otherwise designed to accommodate an ambulance-type stretcher 76 inches by 24 inches in the horizontal position.

In buildings where one elevator does not serve all floors, two or more elevators may be used. The elevators shall be identified.

(f) **Emergency Signs.** Except at the main entrance level, an approved pictorial sign of a standardized design shall be posted adjacent to each elevator call station which will indicate that, in case of fire, the elevator will not operate and that exit stairways should be used.

(g) **Restricted or Limited-use Elevators.** The building official may waive the



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requirements of this section for any elevator designed for limited or restricted use serving only specific floors or a specific function.

### Hoistway Venting

**Sec. 5104.** Shafts (hoistways) housing elevators extending through more than two floor levels shall be vented to the outside. The area of the vent shall be not less than 3½ percent of the area of the elevator shaft, provided a minimum of 3 square feet per elevator is provided.

> **EXCEPTION:** Where energy conservation or hoistway pressurization requires that the vents be normally closed, automatic venting by actuation of an elevator lobby detector or power failure may be accepted. A manual override may be provided.

The venting of each individual hoistway shall be independent from any other hoistway venting, and the interconnection of separate hoistways for the purpose of venting is prohibited.

### Elevator Machine Room Floors

**Sec. 5105.** Elevator hoistways shall not be vented through an elevator machine room unless such venting is accomplished by an approved duct system installed through the elevator machine room. Cable slots entering the machine room shall be sleeved beneath the machine room floor and extend to not less than 12 inches below the shaft vent to inhibit the passage of smoke into the machine room.

### Additional Doors

**Sec. 5106.** Doors other than the hoistway door and the elevator car door shall be prohibited at the point of access to an elevator car.

> **EXCEPTION:** Doors which are readily openable from the car side without a key, tool, or special knowledge or effort.



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# Chapter 52
# LIGHT-TRANSMITTING PLASTICS

## Scope

**Sec. 5201.** (a) **General.** The provisions of this chapter shall govern the quality and methods of application of plastics for use as light-transmitting materials in buildings and structures. For foam plastics, see Sections 1705 (e) and 1712. Light-transmitting plastic materials which meet the other code requirements for walls and roofs may be used in accordance with the other applicable chapters of the code.

(b) **Approval for Use.** The building official shall require that sufficient technical data be submitted to substantiate the proposed use of any light-transmitting material and, if it is determined that the evidence submitted is satisfactory for the use intended, he may approve its use subject to the requirements of this chapter.

(c) **Identification.** Each unit or package of plastic shall be identified with a mark or decal satisfactory to the building official, which includes identification as to the material classification in accordance with U.B.C. Standard No. 52-4.

(d) **Combination of Glazing and Exterior Wall Panels.** Combinations of plastic glazing and plastic exterior wall panels shall be subject to the area, height, percentage and separation requirements applicable to the class of plastics as prescribed for wall panel installation.

(e) **Combination of Roof Panels and Skylights.** Combinations of plastic roof panels and plastic skylights shall be subject to the area percentage and separation requirements applicable to roof panel installation.

## Definitions

**Sec. 5202.** For the purpose of this chapter, certain terms are defined as follows:

**EXTERIOR WALL PANELS** are materials which are not classified as plastic glazing and which are used as light-transmitting media in exterior walls.

**GLASS FIBER REINFORCED PLASTIC** is plastic reinforced with glass fiber having not less than 20 percent of glass fibers by weight.

**GLAZING** is material which has all edges set in frame or sash and is not held by mechanical fasteners which pass through the material.

**LIGHT-DIFFUSING SYSTEM** is construction consisting in whole or in part of lenses, panels, grids or baffles made with approved plastics positioned below independently mounted electrical light sources. Lenses, panels, grids and baffles which are part of an electrical fixture shall not be considered as a light-diffusing system.

**PLASTIC MATERIALS, APPROVED.** See Chapter 4.

**ROOF PANELS** are structural panels other than skylights which are fastened to structural members or structural panels or sheathing and which are used as light-transmitting media in the plane of the roof.

**THERMOPLASTIC MATERIAL** is a plastic material which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.



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**THERMOSETTING MATERIAL** is a plastic material which is capable of being changed into a substantially nonreformable product when cured.

## Design and Installation

**Sec. 5203.** (a) **Structural Requirements.** Plastic materials in their assembly shall be of adequate strength and durability to withstand the design loads as prescribed elsewhere in this code. Technical data shall be submitted to establish stresses, maximum unsupported spans and such other information for the various thicknesses and forms used as may be deemed necessary by the building official.

(b) **Fastening.** Fastening shall be adequate to withstand design loads as prescribed elsewhere in this code. Proper allowance shall be made for expansion and contraction of plastic materials in accordance with accepted data on coefficient of expansion of the material and other material in conjunction with which it is employed.

## Glazing of Unprotected Openings

**Sec. 5204.** In Type V-N construction, doors, sash and framed openings not required to be fire protected may be glazed or equipped with approved plastic material.

In types of construction other than Type V-N, openings not required to be fire protected may be glazed or equipped with approved plastic, subject to the following requirements:

1. The aggregate area of plastic glazing shall not exceed 25 percent of the area of any wall face of the story in which it is installed. The area of a single pane of glazing installed above the first story shall not exceed 16 square feet and the vertical dimension of a single pane shall not exceed 4 feet.

**EXCEPTION:** When an approved automatic sprinkler system is provided throughout, the area of glazing may be increased to a maximum of 50 percent of the wall face of the story in which it is installed with no limit on the maximum dimension or area of a single pane of glazing.

2. Approved flame barriers extending 30 inches beyond the exterior wall in the plane of the floor, or vertical panels not less than 4 feet in height, shall be installed between glazed units located in adjacent stories.

3. Plastics shall not be installed more than 65 feet above grade level.

## Light-transmitting Exterior Wall Panels

**Sec. 5205.** In Type V-N construction, approved plastics may be installed in exterior walls provided the walls are not required to have a fire-resistive rating.

In types of construction other than Type V-N, approved plastics may be installed in exterior walls, provided the walls are not required to have a fire-resistive rating, subject to the following requirements:

1. Approved exterior wall panels shall not be installed more than 40 feet above grade level.

2. Approved exterior wall panels shall not be installed in exterior walls located less than 10 feet from the property line determined in accordance with Section 504.

3. The area and size shall be limited to that set forth in Table No. 52-A.



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**EXCEPTIONS:** 1. In structures which are provided with approved flame barriers extending 30 inches beyond the exterior wall in the plane of the floor, there need be no vertical separation at the floor except that provided by the vertical thickness of the flame-barrier projection.

2. When an approved automatic sprinkler system is provided throughout the building, the maximum percentage area of plastic panels in the exterior wall and the maximum square feet of any individual panel may be increased 50 percent above that set forth in Table No. 52-A, and the separation requirements, both vertical and horizontal, as set forth in Table No. 52-A may be reduced by 50 percent.

## Roof Panels

**Sec. 5206.** Approved plastic roof panels may be installed in roofs of buildings not required to have a fire-resistive rating, subject to the following limitations:

1. Individual roof panels or units shall be separated from each other by distances of not less than 4 feet measured in a horizontal plane.

2. Roof panels or units shall not be installed within that portion of a roof located within a distance to property line or public way where openings in exterior walls are prohibited or required to be protected, whichever is most restrictive.

3. Roof panels of Class CC1 plastics shall be limited to a maximum individual panel area of 150 square feet, and the total maximum aggregate area of all panels shall not exceed 33 1/3 percent of the floor area of the room or space sheltered. Roof panels of Class CC2 plastics shall be limited to a maximum individual panel area of 100 square feet, and the total maximum aggregate area of all panels shall not exceed 25 percent of the floor area of the room or space sheltered.

**EXCEPTION:** Swimming pool shelters are exempt from the area limitations of Section 5206, provided such shelters do not exceed 5000 square feet in area and are not closer than 10 feet to the property line or adjacent building.

## Skylights

**Sec. 5207.** (a) **General.** Skylight assemblies may be glazed with approved plastic materials in accordance with the following provisions:

1. The plastics shall be mounted at least 4 inches above the plane of the roof by a curb constructed consistent with the requirements for the type of construction classification.

**EXCEPTION:** Curbs may be omitted on roofs of Group R, Division 3 Occupancies with a minimum slope of 3:12 when self-flashing skylights are used.

2. Flat or corrugated plastic skylights shall slope at least 4:12. Dome-shaped skylights shall rise above the mounting flange a minimum distance equal to 10 percent of the maximum span of the dome but not less than 5 inches.

**EXCEPTION:** Skylights which pass the Class B Burning Brand Test specified in U.B.C. Standard No. 32-7.

3. The edges of the plastic lights or domes shall be protected by metal or other noncombustible materials or shall be tested to show that equivalent fire protection is provided.

**EXCEPTION:** The metal or noncombustible edge is not required where ordinary roof coverings are permitted.



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4. Each skylight unit may have a maximum area within the curb of 100 square feet for CC2 material and 200 square feet for CC1 material.

**EXCEPTIONS:** 1. The maximum area within the curb need not be limited if the building on which the skylights are located is not more than one story in height, the building has an exterior separation from other buildings of at least 30 feet, and the room or space sheltered by the roof is not classified in a Group I, Division 1 or 3 Occupancy or as a required means of egress.

2. Except for Groups A, Divisions 1 and 2, I and H, Divisions 1 and 2 Occupancies, the maximum area within the curb need not be limited where skylights are:

(i) Serving as a fire venting system complying with this code; or

(ii) Used in a building completely equipped with an approved automatic sprinkler system.

5. The aggregate area of skylights installed in the roof shall not exceed 33 1/3 percent of the floor area of the room or space sheltered by the roof when CC1 materials are used and 25 percent when CC2 materials are used.

6. Skylight units shall be separated from each other by a distance of not less than 4 feet measured in a horizontal plane.

**EXCEPTION:** Except for Groups A, Divisions 1 and 2, I and H, Divisions 1 and 2 Occupancies, the separation is not required where the skylights are:

(i) Serving as a fire venting system complying with this code; or

(ii) Used in a building completely equipped with an approved automatic sprinkler system.

7. Skylights shall not be installed within that portion of a roof located within a distance to property line or public way where openings in exterior walls are prohibited or required to be protected, whichever is most restrictive.

(b) **Plastics Over Stair Shafts.** Approved plastic materials which will not automatically vent but which are able to be vented may be used over stairways and shafts, provided the installation conforms to the requirements of Section 5207 (a).

## Light-diffusing Systems

**Sec. 5208.** (a) **General.** Plastic diffusers in light-diffusing systems shall be supported directly or indirectly by the use of noncombustible hangers.

Light-transmitting plastic materials in light-diffusing systems shall comply with Chapter 42 unless the approved plastic used in the light-diffusing system meets the following requirements:

1. Diffusers shall fall from their mounting at an ambient temperature of at least 200°F. below the ignition temperature of the plastic material as measured by U.B.C. Standard No. 52-3.

2. Diffusers shall remain in place at an ambient room temperature of 175°F. for a period of not less than 15 minutes.

3. The maximum length of any single plastic panel shall not exceed 10 feet, and the maximum area of any single plastic panel shall not exceed 30 square feet.

4. The area of approved plastic materials when used in required exits as defined in Chapter 33 shall not exceed 30 percent of the aggregate area of the ceiling in which they are installed.



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**EXCEPTION:** The aggregate area need not be limited in a building equipped with an approved automatic sprinkler system.

(b) Plastic light-diffusing system shall not be installed in the areas to be equipped with automatic sprinklers unless appropriate tests have shown that the system does not prevent effective operation of the sprinklers or unless sprinklers are located both above and below the light-diffusing system to give effective sprinkler protection.

### Diffusers in Electrical Fixtures

**Sec. 5209.** Use of approved plastics as light-diffuser panels installed in approved electrical lighting fixtures in or on walls or ceilings shall comply with Chapter 42 unless the plastic panels meet the requirements of Seetion 5208 (a).

### Partitions

**Sec. 5210.** Light-transmitting plasties may be used in or as partitions, provided they meet the requirements of this code.

### Awnings and Patio Covers

**Sec. 5211.** Approved plastics may be used in awnings and patio covers. All such awnings shall be eonstructed in accordance with provisions specified in Section 4506 for projections and appendages. For patio covers, see Appendix Chapter 49.

### Greenhouses

**Sec. 5212.** Approved plasties may be used in lieu of plain glass in greenhouses.

### Canopies

**Sec. 5213.** Approved plastic panels may be installed in canopies erected over motor vehicle service station pumps, provided the panels are located at lcast 10 feet from any building on the same property and face yards or streets not less than 40 feet in width on the other sides. The aggregate area of plastics shall not exceed 1000 square feet. The maximum area of any individual panel shall not exceed 100 square feet.

### Solar Collectors

**Sec. 5214.** Solar collectors having noncombustible sides and bottoms may be equipped with plastic covers on buildings not over three stories in height or 9,000 square feet in total floor area, provided the plastic cover when exceeding a thickness of 0.010 inch shall be of approved plastic and the total area shall not exceed 33 1/3 percent of the roof area for CC1 materials or 25 percent of the roof area for CC2 materials.

**EXCEPTION:** Plastic covers having a thickness of 0.010 inch or less may be of any plastic, provided the total area of the collectors does not exceed 33 1/3 percent of the roof area.



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## TABLE NO. 52-A
## AREA LIMITATION AND SEPARATION REQUIREMENTS FOR EXTERIOR WALL PANELS[1]

| CLASS OF PLASTIC | MAXIMUM PERCENT AREA OF EXTERIOR WALLS IN PLASTIC PANELS | MAXIMUM SQUARE FEET SINGLE INDIVIDUAL PANELS | MAXIMUM PANEL HEIGHT (Feet) | MINIMUM SEPARATION OF PANELS (Feet) | |
|---|---|---|---|---|---|
| | | | | Vertical | Horizontal |
| CC1 | 25 | 100 | 16 | 6 | 4 |
| CC2 | 15 | 75 | 8 | 8 | 4 |

[1]The maximum percent area of exterior walls limitation shall be based upon the individual story wall area.



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# Chapter 53
# (SEE APPENDIX CHAPTER 53)

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# Chapter 54
# GLASS AND GLAZING

## Scope

**Sec. 5401.** (a) **General.** The provisions of this chapter apply to:

1. Exterior glass and glazing in all occupancies except Groups R and M not over three stories in height; and

2. Interior and exterior glass and glazing in all occupancies subject to human impact as specified in Section 5406.

(b) **Standards.** Standards for material shall be as specified in this chapter and U.B.C. Standard No. 54-1.

Standards for glazing subject to human impact (hazardous location) as specified in Section 5406 shall be as specified in U.B.C. Standard No. 54-2.

(c) **Other Provisions.** See Part IV of this code for additional glass requirements where openings are required to be fire protected and Section 5204 for openings glazed with plastics.

## Identification

**Sec. 5402.** Each light shall bear the manufacturer's label designating the type and thickness of glass. When approved by the building official, labels may be omitted, provided an affidavit is furnished by the glazing contractor certifying that each light is glazed in accordance with approved plans and specifications. Identification of glazing in hazardous locations shall be in accordance with Section 5406.

## Area Limitations

**Sec. 5403.** Glass in windows, curtain and window walls, skylights, doors and other exterior applications shall be chosen to withstand the loads for cladding as set forth in Section 2311.

The area of individual lights shall not be more than as set forth in Graph No. 54-1, as adjusted by Table No. 54-A. Glass sizing for skylight applications shall be adjusted per Section 3405.

Graph No. 54-1 is applicable for rectangular glass firmly supported on all four edges.

When approved by the building official, alternate means for selecting glass may be used in place of Graph No. 54-1 and Table No. 54-A.

Glass and glazing subject to ice or snow loads shall be designed in accordance with Chapter 23.



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## Glazing Support

**Sec. 5404.** Glass firmly supported on all four edges shall be glazed with minimum laps and edge clearances set forth in Table No. 54-B. For glass not firmly supported on all four edges, design shall be submitted to the building official for approval. Glass supports shall be considered firm when deflection of the support at design load does not exceed 1/175 of the span.

## Louvered Windows

**Sec. 5405.** Regular plate, sheet or patterned glass in jalousies and louvered windows shall be no thinner than nominal 7/32 inch and no longer than 48 inches. When other glass types are used, design shall be submitted to the building official for approval. Exposed glass edges shall be smooth.

Wired-glass with wire exposed on longitudinal edges shall not be used in jalousies or louvered windows.

## Safety Glazing

**Sec. 5406.** (a) **General.** Glazing subject to human impact shall comply with this section.

**EXCEPTION:** Louvered windows or jalousies complying with Section 5405 need not comply with Subsection (c) of this section.

(b) **Identification.** Each light of safety glazing material installed in hazardous locations as defined in Section 5406 (d) shall be identified by a label which will specify the labeler, whether the manufacturer or installer, and state that safety glazing material has been utilized in such installation. For additional identification requirements and for limitation on size and use by category classification, see U.B.C. Standard No. 54-2, Part I.

Each unit of tempered glass shall be permanently identified by the manufacturer. The identification shall be etched or ceramic fired on the glass and be visible when the unit is glazed. Tempered spandrel glass is exempted from permanent labeling but such glass shall be identified by the manufacturer with a removable paper label.

(c) **Human Impact Loads.** Individual glazed areas in hazardous locations such as those indicated in Section 5406 (d) shall pass the test requirements of Part I of U.B.C. Standard No. 54-2 or by comparative tests approved by the building official which shall be proved to produce at least equivalent performance.

**EXCEPTION:** Polished wired glass complying with Part II of U.B.C. Standard No. 54-2 may be used in fire assemblies and in locations specified in Items Nos. 6 and 7 of Section 5406 (d).

Plastic glazing used in exterior applications also shall comply with the weathering requirements in Part II of U.B.C. Standard No. 54-2.

(d) **Hazardous Locations.** The following shall be considered specific hazardous locations for the purposes of glazing:

1. Glazing in ingress and egress doors except jalousies.
2. Glazing in fixed panels and sliding or swinging panels of sliding- or swinging-type doors other than wardrobe doors.



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3. Glazing in storm doors.
4. Glazing in all unframed swinging doors.
5. Glazing in shower and bathtub doors and enclosures.
6. Glazing, operable or inoperable, adjacent to a door in all buildings and within the same wall plane as the door whose nearest vertical edge is within 12 inches of the door in a closed position and whose bottom edge is less than 60 inches above the floor or walking surface.
7. Glazing in fixed panels other than those covered by Item 6 which have a glazed area in excess of 9 square feet and the lowest edge is less than 18 inches above the finished floor level or walking surface within 36 inches of such glazing. In lieu of safety glazing, such glazed panels may be protected with a horizontal member not less than 1 1/2 inches in width when located between 24 and 36 inches above the walking surface.

**EXCEPTION:** The following products, materials and uses are exempt from the above hazardous locations:

1. Openings in doors through which a 3-inch sphere is unable to pass.
2. Assemblies of leaded glass or faceted glass and items of carved glass when used for decorative purposes in doors or in locations described in Section 5406 (d), Item 6 or 7, above.
3. Glazing materials used as curved glazed panels in revolving doors.
4. Commercial refrigerated cabinet glazed doors.

8. Glazing in railings regardless of height above a walking surface. Included are structural baluster panels and nonstructural in-fill panels.

(e) **Wardrobe Doors.** Glazing in wardrobe doors shall meet the impact test requirements for safety glazing as set forth in U.B.C. Standard No. 54-2, Part II. Laminated glass must also meet the boil test requirements of U.B.C. Standard No. 54-2, Part II.

**EXCEPTION:** The impact test shall be modified so that if no breakage occurs when the impacting object is dropped from the height of 18 inches, the test shall progress in height increments of 6 inches until the maximum of 48 inches is reached.

(f) **Glass Railings.** Glass used as structural balustrade panels in railings shall be one of the following types:

1. Single fully tempered glass.
2. Laminated fully tempered glass.
3. Laminated heat-strengthened glass.

The panels and their support system shall be designed to withstand the load specified in Table No. 23-B. A safety factor of 4 shall be used.

Each handrail or guardrail section shall be supported by a minimum of three glass balusters or otherwise supported so that it remains in place should one baluster panel fail.

Glass balusters shall not be installed without a handrail or guardrail attached.

Glazing in in-fill panels shall be an approved safety glazing material meeting the provisions of Section 5406 (c). For all glazing types the minimum nominal thickness shall be 1/4 inch.



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Glazing materials shall not be installed in railings in parking garages except for those locations where the railing is not exposed to impact from vehicles.

## Hinged Shower Doors

**Sec. 5407.** Hinged shower doors shall open outward.

## Racquetball and Squash Courts

**Sec. 5408.** (a) **Test Method.** Each panel of glass (including doors) in an actual installation or test mockup shall be impacted from the playing side at a point 59 inches from the playing surface and its horizontal midpoint. The impactor and test procedure shall be as described in U.B.C. Standard No. 54-2, Part I, Category II, using a drop height of 48 inches. Results from a test mockup shall apply only to actual installations in which the glass is no greater in either dimension and is at least as thick. Fittings and attachments for a mockup shall be identical to those used in actual installations. The conditions of Section 5408 (b) shall be met.

(b) **End Point Conditions.** The following conditions shall be met when the glass is impacted as described in Section 5408 (a):

1. The glass shall not break.
2. Deflection at the point of impact shall not exceed 1 1/2 inches.
3. Door hardware shall remain intact and operable.
4. The deflection of the door edges shall be no greater than the following for the listed drop heights. The impactor and procedures shall be as indicated in Section 5408 (a).

| Drop Height | Deflection |
|---|---|
| 24 inches | Thickness of adjacent glass + 1/8 inch |
| 36 inches | Thickness of adjacent glass + 1/4 inch |
| 48 inches | Thickness of adjacent glass + 1/2 inch |



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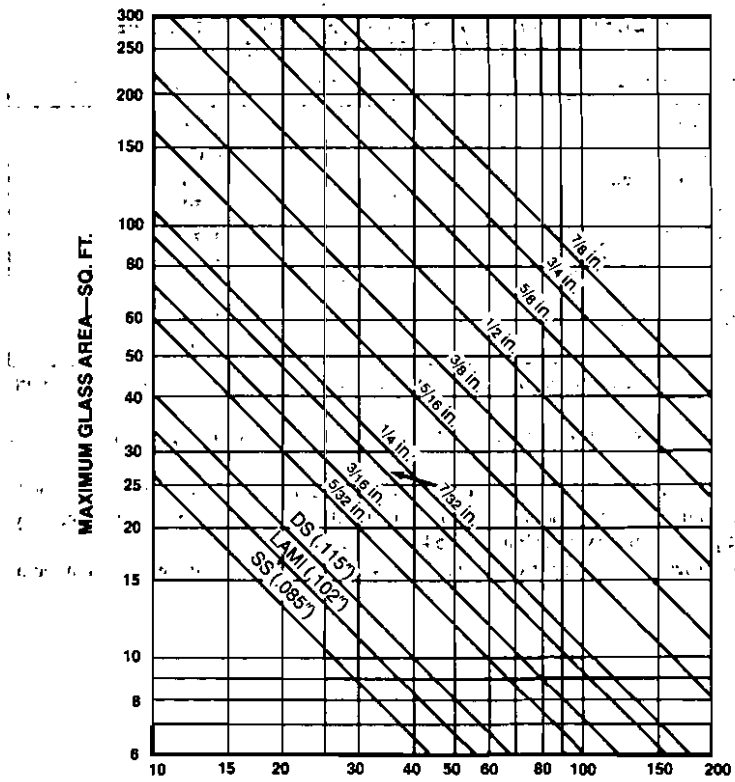


**GRAPH NO. 54-1—MAXIMUM ALLOWABLE AREA OF GLASS[1]**

[1]Applicable for ratios of width-to-length of 1:1 to 5:1. Design Factor = 2.5



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## TABLE NO. 54-A—ADJUSTMENT FACTORS—RELATIVE RESISTANCE TO WIND LOADS

| Glass Type | Adjustment Factor[1] |
|---|---|
| Laminated[2] | 0.75 |
| Fully Tempered | 4.00 |
| Heat Strengthened | 2.00 |
| Wired | 0.50 |
| Insulating Glass[3] - 2 panes | 1.70 |
| - 3 panes | 2.55 |
| Patterned[4] | 1.00 |
| Regular (annealed) | 1.00 |
| Sandblasted | 0.40[5] |

[1]Loads determined from Section 2311 shall be divided by this adjustment factor for use with Graph No. 54-1.

[2]Applies when two plies are identical in thickness and type: use total glass thickness, not thickness of one ply.

[3]Applies when each glass panel is the same thickness and type; use thickness of one panel.

[4]Use minimum glass thickness, i.e., measured at the thinnest part of the pattern; if necessary, interpolation of curves in Graph No. 54-1 may be required.

[5]Factor varies depending upon depth and severity of sand blasting; value shown is minimum.



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## TABLE NO. 54-B—MINIMUM GLAZING REQUIREMENTS

| Fixed Windows and Openable Windows Other Than Horizontal Sliding | | | | | |
|---|---|---|---|---|---|
| GLASS AREA | UP TO 6 SQ. FT. | 6 TO 14 SQ. FT. | 14 TO 32 SQ. FT. | 32 TO 50 SQ. FT. | OVER 50 SQ. FT. |
| 1. Minimum Frame Lap | 1/4" | 1/4" | 5/16" | 3/8" | 1/2" |
| 2. Minimum Glass Edge Clearance | 1/8" [1,2] | 1/8" [1,2] | 3/16" [1] | 1/4" | 1/4" [1] |
| 3. Continuous Glazing Rabbet and Glass Retainer [3]. | Required | | | | |
| 4. Resilient Setting Material [4] | Not Required | Required | | | |

| Sliding Doors and Horizontal Sliding Windows | | | | |
|---|---|---|---|---|
| GLASS AREA | UP TO 14 SQ. FT. | 14 TO 32 SQ. FT. | 32 TO 50 SQ. FT. | OVER 50 SQ. FT. |
| 5. Minimum Glass Frame Lap | 1/4" | 5/16" | 3/8" | 1/2" |
| 6. Minimum Glass Edge Clearance | 1/8" [2] | 3/16" | 1/4" | 1/4" |
| 7. Continuous Glazing Rabbet and Glass Retainer [3] | Required above third story | Required | | |
| 8. Resilient Setting Material [4] | Not Required | Required | | |

[1]Glass edge clearance in fixed openings shall be not less than required to provide for wind and earthquake drift.

[2]Glass edge clearance at all sides of pane shall be a minimum of 3/16 inch where height of glass exceeds 3 feet.

[3]Glass retainers such as metal, wood or vinyl face stops, glazing beads, gaskets, glazing clips and glazing channels shall be of sufficient strength and fixation to serve this purpose.

[4]Resilient setting material shall include preformed rubber or vinyl plastic gaskets or other materials which are proved to the satisfaction of the building official to remain resilient.

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# Chapter 55
# (SEE APPENDIX CHAPTER 55)



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# Chapter 56

# COVERED MALL BUILDINGS

**NOTE: This chapter has been relocated in its entirety from Appendix Chapter 7, Division I.**

## General

**Sec. 5601.** (a) **Purpose.** The purpose of this chapter is to establish minimum standards of safety for the construction and use of covered mall buildings having not more than three levels.

(b) **Scope.** The provisions of this chapter shall apply to buildings or structures defined herein as covered mall buildings.

This chapter does not apply to terminals for transportation facilities and lobbies of hotel, apartment and office buildings.

Covered mall buildings conforming with all other applicable provisions of this code are not required to comply with the provisions of this chapter.

(c) **Definitions.** For the purpose of this chapter, certain terms are defined as follows:

**ANCHOR STORE** is an exterior perimeter department store or major merchandising center having direct access to a covered mall building but having all required exits independent of a mall.

**COVERED MALL BUILDING** is a single building enclosing a number of tenants and occupancies such as retail stores, drinking and dining establishments, entertainment and amusement facilities, offices and other similar uses wherein two or more tenants have a main entrance into one or more malls.

**GROSS LEASABLE AREA** is the total floor area designed for tenant occupancy and exclusive use. The area of tenant occupancy is measured from the center lines of joint partitions to the outside of the tenant walls. All tenant areas, including areas used for storage, shall be included in calculating gross leasable area.

**MALL** is a roofed or covered common pedestrian area within a covered mall building which serves as access for two or more tenants and may have three levels that are open to each other.

(d) **Applicability of Other Provisions.** Except as specifically required by this chapter, covered mall buildings shall meet all applicable provisions of this code.

## Types of Construction and Required Yards for Unlimited Area

**Sec. 5602.** (a) **Type of Construction.** One- and two-level covered mall buildings may be of any type of construction permitted by this code. Three-level covered mall buildings shall be at least Type II One-hour construction.

Anchor stores and parking garages shall be limited in height and area in accordance with Sections 505, 506 and 507.

(b) **Required Yards for Unlimited Area.** Covered mall buildings may be of unlimited area, provided the covered mall building, attached anchor stores and



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parking garages are adjoined by public ways, streets or yards not less than 60 feet in width along all exterior walls.

**Special Provisions.**

**Sec. 5603.** (a) **Automatic Sprinkler Systems.** The covered mall building shall be provided with an automatic sprinkler system conforming to the provisions of U.B.C. Standard No. 38-1. In addition to these standards, the automatic sprinkler system shall comply with the following:

1. All automatic sprinkler system control valves shall be electrically supervised by an approved central, proprietary or remote station or a local alarm service which will give an audible signal at a constantly attended location.
2. The automatic sprinkler system shall be complete and operative throughout all occupied space in the covered mall building prior to occupancy of any of the tenant spaces. The level of protection provided for unoccupied tenant space shall be subject to the approval of the building official and fire department.
3. Sprinkler protection for the mall shall be independent from that provided for tenant spaces. However, tenant spaces may be supplied by the same system if they can be independently controlled.

The respective increases for area and height for covered mall buildings, including anchor stores, specified in Sections 506 and 507 of this code, shall be permitted.

(b) **Standpipes.** There shall be a Class I standpipe outlet connected to a system sized to deliver 250 gallons per minute at each of the following locations for fire department use:

1. Within the mall at the entrance to an exit passage or exit corridor.
2. At each floor level landing within enclosed stairways opening directly onto the mall and adjacent to principal exterior entrances to the mall.

Standpipes shall be installed in accordance with the requirements of Chapter 38 of this code.

**EXCEPTIONS:** 1. Risers and laterals of Class I standpipe systems not located within an enclosed stairway need not be protected by a degree of fire resistance equal to that required for vertical enclosures in the covered mall building.

2. Piping may be hydraulically sized.

Standpipes in covered mall buildings exceeding 50,000 square feet shall be charged with water. The source of water may be either by interconnection with the sprinkler system or may be connected with the domestic water supply by a minimum of 1-inch-diameter pipe. The domestic water supply connection shall be provided with an approved backflow device.

(c) **Smoke-control System.** 1. **Required.** A mechanically operated air-handling system shall be installed in covered mall buildings which will restrict the movement of smoke to the general area of fire origin and maintain the exiting system in a condition that is safe for exiting.

2. **General.** The smoke-control system shall be connected to both the sprinkler system and the smoke detector system and shall automatically operate when



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either the sprinkler system or smoke detector system is actuated. The smoke-control system shall go into operation immediately following actuation of the smoke detector. The smoke-control system shall also be capable of manual operation. A smoke detector shall be provided within the return-air portion of heating and cooling systems exceeding 10,000 cfm. The detector shall be installed ahead of any fresh-air intake. Smoke detectors shall also be provided on the tenant side at openings into the mall where open-type security grilles are used. The smoke-control system shall be as follows:

A. The smoke-control equipment for the mall shall be separate from that serving tenant spaces.

B. The covered mall building shall be compartmented into smoke-control zones. Except for openings between the mall and tenant spaces, smoke-control zones shall be separated from each other by construction having a fire-resistive time period of not less than one hour. Walls between tenant spaces used to separate smoke-control zones shall extend from the floor to the underside of the floor or roof above.

C. A smoke control zone shall coincide with the area of coverage of a single sprinkler supply. Within that sprinkler zone there may be one or more air-moving systems but no single smoke-control zone shall be larger than the sprinkler area.

D. When a fire occurs within a tenant sprinkler zone, that zone is to go to 100 percent exhaust and the supply air to that zone is to be shut down. All adjoining tenant areas are to go into normal operation. The mall itself shall go to 100 percent fresh air supply.

E. When a fire occurs within the mall, the mall smoke-control equipment shall go to 100 percent exhaust and the adjoining tenant spaces shall go into normal operation.

F. The mall smoke-control equipment shall be sized to provide a minimum of six air changes per hour for malls 600,000 cubic feet or less in volume and four air changes per hour for malls of greater size. The volume of the mall is measured from the entrance to tenant spaces and to a height of 12 feet above each pedestrian area.

G. Mall exhaust inlets shall be not less than 6 feet above the walking surface for each pedestrian level.

H. During those hours when the building air-conditioning systems are not operating, smoke detector or sprinkler systems shall be designed so the activation of either will transmit an alarm as required in Subsection (a), Item No. 1, of this section and shall activate the smoke-control system.

3. **Acceptance testing.** Before the smoke-control system is accepted by the building official, it shall be tested in his presence to confirm that the system is operating in compliance with the requirements of this subsection.

(d) **Fire Department Access to Equipment.** Rooms or areas containing controls for air-conditioning systems, automatic fire-extinguishing systems or other detection, suppression or control elements shall be identified for use by the fire department.



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(e) **Tenant Separation.** Each tenant space shall be separated from other tenant spaces by a wall having a fire-resistive rating of not less than one hour. The separation wall shall extend from the floor to the underside of the ceiling above. Except as required by other provisions of this code, the ceiling need not be a fire-resistive assembly. A separation is not required between any tenant space and a mall except for occupancy separations required by Section 5605 or for smoke-control purposes.

(f) **Public Address System.** Covered mall buildings exceeding 50,000 square feet in total floor area shall be provided with a public address system accessible for use by the fire department. Covered mall buildings of 50,000 square feet or less in total floor area, when provided with a public address system, shall have such system accessible for use by the fire department.

(g) **Plastic Panels and Plastic Signs.** Within every story or level and from sidewall to sidewall of each tenant space or mall, approved plastic panels and signs shall be limited as follows:

1. They shall not exceed 20 percent of the wall area facing the mall;
2. They shall not exceed a height of 36 inches except that if the sign is vertical then the height shall not exceed 96 inches and the width shall not exceed 36 inches;
3. They shall be located a minimum distance of 18 inches from adjacent tenants;

(h) **Lease Plan.** Each covered mall building owner shall provide both the building and fire departments with a lease plan showing the location of each occupancy and its exits after the Certificate of Occupancy has been issued. Such plans shall be kept current. No modifications or changes in occupancy or use shall be made from that shown on the lease plan without prior approval of the building official.

(i) **Mixed Type of Construction.** Openings between an anchor store of Type I, II-F.R. or II One-hour construction and the mall need not be protected.

(j) **Standby Power.** Covered mall buildings exceeding 50,000 square feet shall be provided with standby power systems which are capable of operating the public address system, the exit signs, emergency lighting, the smoke control activation system and the smoke control equipment from four adjacent zones acting simultaneously.

## Exits

**Sec. 5604.** (a) **General.** Each tenant space and the covered mall building shall be provided with exits as required by this section and Chapter 33 of this code. Where there is a conflict between the requirements of Chapter 33 and the requirements of this section, the requirements of this section shall apply.

(b) **Determination of Occupant Load.** The occupant load permitted in any individual tenant space in a covered mall building shall be determined as required by Section 3302 of this code. Exit requirements for individual tenant spaces shall be based on the occupant load thus determined.



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The occupant load permitted for the covered mall building, assuming all portions, including individual tenant spaces and the mall to be occupied at the same time, shall be determined by dividing the gross leasable area by 30 for covered mall buildings containing up to 150,000 square feet of gross leasable area, by 40 for covered mall buildings containing between 150,001 and 350,000 square feet of gross leasable area, and by 50 for covered mall buildings containing more than 350,000 square feet of gross leasable area. Exit requirements for the covered mall building shall be based on the occupant load thus determined.

The occupant load of anchor stores opening into the mall shall not be included in determining exit requirements for the mall.

(c) **Number of Exits.** When the distance of travel to the mall exceeds 75 feet within the public area of a tenant space or when the occupant load served by the exit to the mall exceeds 50, not less than two exits shall be provided. The occupant load of a public sales area shall be computed at 30 square feet per occupant. Occupant loads for other areas shall be computed in accordance with Table No. 33-A.

(d) **Arrangement of Exits.** Group A, Divisions 1, 2 and 2.1 Occupancies, other than drinking and dining establishments, shall be so located in the covered mall building that their entrance will be immediately adjacent to a principal entrance to the mall and shall have not less than one half of their required exits opening directly to the exterior of the covered mall building.

Required exits for anchor stores shall be provided independently from the mall exit system.

Malls shall not exit through anchor stores. Malls terminating at an anchor store where no other means of exit has been provided shall be considered as a dead-end mall.

(e) **Distance to Exits.** Within each individual tenant space in a covered mall building the maximum distance of travel from any point to an exterior exit door, horizontal exit, exit passageway, enclosed stairway or entrance to the mall shall not exceed 200 feet.

The maximum distance of travel from any point within a mall to an exterior exit door, horizontal exit, exit passageway or an enclosed stairway shall not exceed 200 feet.

(f) **Access to Exits.** Exits shall be so arranged that it is possible to go in either direction from any point in a mall to a separate exit, except for dead ends not exceeding a length equal to twice the width of the mall measured at the narrowest location within the dead-end portion of the mall.

The minimum width of exit from a mall shall be 66 inches.

When exit passageways are present to provide a secondary exit from a tenant space, doors to the exit passageway shall be one-hour fire doors. Such doors shall be self-closing and be so maintained or shall be automatic closing by smoke detector actuation.

Storage is prohibited in exit passageways which are also used for service to the tenants. Such exit passageways shall be posted with conspicuous signs so stating.



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(g) **Malls.** For the purpose of providing required egress, malls may be considered as corridors but need not comply with the requirements of Section 3305 (g) and (h) of this code when the width of mall is as specified in this section.

The minimum width of the mall shall be 20 feet. There shall be a minimum of 10 feet clear width to a height of 8 feet between any projection from a tenant space bordering the mall and the nearest kiosk, vending machine, bench, display or other obstruction to egress. The mall shall be sufficient to accommodate the occupant load immediately tributary thereto.

Malls which do not conform to the requirements of this section shall comply with the requirements of Section 3305 (g) and (h) of this code.

(h) **Security Grilles and Doors.** Horizontal sliding or vertical security grilles or doors which are a part of a required means of egress shall conform to the following:

1. They must remain secured in the full open position during the period of occupancy by the general public.
2. Doors or grilles shall not be brought to the closed position when there are more than 10 persons occupying spaces served by a single exit or 50 persons occupying spaces served by more than one exit.
3. The doors or grilles shall be openable from within without the use of any special knowledge or effort when the space is occupied.
4. When two or more exits are required, not more than one half of the exits may be equipped with horizontal sliding or vertical rolling grilles or doors.

## Occupancy

**Sec. 5605.** (a) **General.** Covered mall buildings shall be classified as Group B, Division 2 Occupancies and may contain accessory uses consisting of Groups A, E or R, Division 1 Occupancies. The area of individual accessory uses within a covered mall building shall not exceed three times the basic area permitted by Table No. 5-C of this code for the type of construction and the occupancy involved. The aggregate area of all accessory uses within a covered mall building shall not exceed 25 percent of the gross leasable area.

An attached garage for the storage of passenger vehicles having a capacity of not more than nine persons and open parking garages may be considered as separate buildings when they are separated from the covered mall building by an occupancy separation having a fire-endurance time period of at least two hours.

(b) **Mixed Occupancy.** Individual tenant spaces within a covered mall building which comprise a distinct "Occupancy," as described in Chapters 5, 6, 7, 8, 11 and 12 of this code, shall be separated from any other occupancy as specified in Section 503 (d) of this code.

**EXCEPTION:** A service ... which opens onto a mall need have no separa...

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# Chapters 57-59
# NO REQUIREMENTS



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# *Part XI*

# UNIFORM BUILDING CODE STANDARDS

## Chapter 60

## UNIFORM BUILDING CODE STANDARDS

### Scope

**Sec. 6001.** The U.B.C. Standards which are referred to in various parts of this code shall be the Uniform Building Code Standards, 1988 Edition, and are hereby declared to be a part of this code.

| U.B.C. STD. AND SEC. NO. | TITLE AND SOURCE |
|---|---|

**CHAPTER 4**

4-1; 415

Noncombustible Material Tests. Standard Method of Test E136-79 of the ASTM.*

**CHAPTER 6**

6-1; 608, 3903 (d)

Proscenium Curtains. Installation Standard of the International Conference of Building Officials.

**CHAPTER 17**

17-1; 1707 (a)

Kraft Waterproof Building Paper. Federal Specification UU-B-790a, February 5, 1968.

17-2; 1712 (b) 7

Test Method to Determine Potential Heat of Building Materials. Test Standard of the International Conference of Building Officials

17-3; 1712 (a)

Test Method for the Evaluation of Thermal Barriers. Standard of the International Conference of Building Officials

17-4; 1712 (b) 5

Fire Test Standard for Insulated Roof Deck Construction. Factory Mutual Standard and UL 1256 (January, 1985) of the Underwriters Laboratories Inc.

17-5; 1712 (c)

Room Fire Test Standard for Interior of Foam Plastic Systems. Test Standard of the International Conference of Building Officials.

*ANSI refers to American National Standards Institute.



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17-6; 1712

Method of Test for the Evaluation of Flammability Characteristics of Exterior, Nonload-bearing Wall Panel Assemblies Using Foam Plastic Insulation. Test Standard of the International Conference of Building Officials.

## CHAPTER 18

18-1; 1807 (i), App. 716

Fire Alarm and Standby Power Generating Systems for High-rise Buildings. Installation Standard of the International Conference of Building Officials.

## CHAPTER 24

24-1; 2402 (b) 4

Building Brick, Facing Brick and Hollow Brick. (Made from Clay or Shale.) Standard Specifications C62-58, C216-66 and C652-70 of the ASTM.

24-2; 2402 (b) 6

Calcium Silicate Face Brick (Sand-lime Brick). Standard Specification C73-75 of the ASTM.

24-3; 2402 (b) 5

Concrete Building Brick. Standard Specification C55-75 (1980) of the ASTM.

24-4; 2402 (b), Table No. 43-B

Hollow and Solid Load-bearing Concrete Masonry Units. Standard Specification C90-86 of the ASTM.

24-6; 2402 (b) 5

Nonload-bearing Concrete Masonry Units. Standard Specification C129-75 (1980) of the ASTM.

24-7; 2405 (c) 1

Sampling and Testing Concrete Masonry Units. Standard Methods C140-75 (1980) of the ASTM.

24-8; 2402 (b) 4

Structural Clay Load-bearing Wall Tile and Standard Methods of Sampling and Testing Structural Clay Tile. Standard Specification C34-70 and Standard Method C112-70 of the ASTM.

24-9; 2402 (b) 4

Structural Clay Nonload-bearing Tile. Standard Specification C56-70 of the ASTM.

24-13; 2402 (b) 6, 2405 (c) 1

Cast Stone. Specification ACI 704-44 of the American Concrete Institute.

24-14; 2402 (b) 6, 2405 (c) 1

Unburned Clay Masonry Units and Standard Methods of Sampling and



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Testing Unburned Clay Masonry Units. Test Standard of the International Conference of Building Officials.

24-15; 2402 (b) 10, 2404 (i)
Part I—Joint Reinforcement for Masonry. Specification Standard of the International Conference of Building Officials. Part II—Cold-drawn Steel Wire for Concrete Reinforcement. Standard Specification A82-85 of the ASTM.

24-16; 2402 (b) 2
Cement, Masonry. Standard Specification C91-83a of the ASTM.

24-17; 2402 (b) 3
Quicklime for Structural Purposes. Standard Specification C5-79 (1984) of the ASTM.

24-18; 2402 (b) 3
Hydrated Lime for Masonry Purposes. Standard Specifications C207-79 (1984) of the ASTM.

24-20; 2402 (b) 8
Mortar for Unit Masonry and Reinforced Masonry Other Than Gypsum. Standard Specifications C161-44T and C270-59T of the ASTM.

24-21; 2402 (b) 1, 2618 (q)
Aggregate for Masonry Mortar. Standard Specification C144-81 of the ASTM.

24-22; 2405 (c) 3
Field Tests Specimens for Mortar. Test Standard of the International Conference of Building Officials.

24-23; 2402 (b) 1
Aggregates for Grout. Standard Specification C404-76 (1981) of the ASTM.

24-24; 2405 (c) 1
Sampling and Testing Brick. Standard Methods C67-83 of the ASTM.

24-25; 2402 (b) 4
Glazed Structural Clay Facing Tile. Standard Specification C126-71 of the ASTM.

24-26; 2405 (c)
Test Method for Compressive Strength of Masonry Prisms. Standard Test Method E447-80 of the ASTM.

24-27; 24-3, 24-4 and 24-6
Standard Test Method for Drying Shrinkage of Concrete Block. Standard Test Method C426-70 (Reapproved 1982) of the ASTM.

24-28; 2402 (b) 9, 2403 (d)
Method of Sampling and Testing Grout. Standard Method C1019-84 of the ASTM.



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24-29; 2402 (b) 9

Grout for Masonry. Standard Specification C476-83 of the ASTM.

## CHAPTER 25

25-1; 2502 (a), Tables Nos. 25-A-1 and 25-A-2

Classification, Definition and Methods of Grading for All Species of Lumber. Standard Methods D245-70 and D2555-70 of the ASTM, Handbook No. 72 of the U.S. Department of Agriculture. American Softwood Lumber Standard PS20-70 and National Grading Rule for Dimension Lumber of the National Grading Rule Committee.

25-2; Tables Nos. 25-A-1, 25-A-2 and 25-R-2

Black Cottonwood, Coast Sitka Spruce, Douglas Fir-Larch (North), Eastern Hemlock-Tamarack (North), Eastern White Pine (North), Hem-Fir (North), Northern Aspen, Ponderosa Pine, Red Pine, Spruce-Pine-Fir, Western Cedars (North), and Western White Pine. Standard Grading Rules for Canadian Lumber, U.S. Edition (September, 1979).

25-3; Tables Nos. 25-A-1, 25-A-2 and 25-R-2

Douglas Fir (Coast Region), West Coast Hemlock, Western Red Cedar, White Fir and Sitka Spruce. Standard Grading Rules No. 16 (September, 1970) of the West Coast Lumber Inspection Bureau.

25-4; Tables Nos. 25-A-1, 25-A-2 and 25-R-2

Douglas Fir, Larch, Hem-Fir, Mountain Hemlock, Alpine Fir, Englemann Spruce, Lodgepole Pine, Ponderosa Pine, Sugar Pine, Idaho White Pine, Western Cedars, Western Hemlock and Aspen (Bigtooth Quaking). Standard Grading Rules (1981) of the Western Wood Products Association.

25-5; Tables Nos. 25-A-1 and 25-R-2

Eastern Woods, Eastern White Pine, Red Pine, Eastern Spruce, Balsam Fir, Aspen (Bigtooth Quaking), Eastern Hemlock and Tamarack. Grading Rules of the Northern Hardwood and Pine Manufacturers Association, Inc. (September 1, 1970).

25-6; Tables Nos. 25-A-1, 25-A-2 and 25-R-2

Southern Pine. Grading Rules, Southern Pine Inspection Bureau (September 1, 1970).

25-7; Tables Nos. 25-A-1 and 25-R-2

Redwood. Standard Specifications for Grades of California Redwood Lumber (November, 1970) of the Redwood Inspection Service.

25-8; Tables Nos. 25-A-1 and 25-R-2

Eastern Woods, Eastern Spruce, Balsam Fir, Eastern White Pine, Northern Pine, Eastern Hemlock-Tamarack and Northern White Cedar. Standard Grading Rules of the Northeastern Lumber Manufacturers Association, Inc. (September 1, 1970).

25-9; 2501 (e), 2502 (a), 2513 (a), 2513 (c), Tables Nos. 25-B, 25-J-1, 25-K-1, 25-S-2, and 47-J

Construction and Industrial Plywood. Product Standard PS 1-83 of the



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U.S. Department of Commerce, and National Bureau of Standards Calculation of Diaphragm Action, an Engineering Standard of the International Conference of Building Officials.

25-10; 2502 (a), 2511 (b), 2511 (f)

Structural Glued-laminated Timber. ANSI*/AITC Standard A190.1, 1983 and Standard Specification D3737-85 of the ASTM..

25-11; 2502 (a), 2511 (d) 5, Table No. 25-C-1.

Structural Glued-laminated Timbers, Softwood and Hardwood Species. Standard Specifications for Structural Glued-laminated Timber of Softwood Species (1986), American Institute of Timber Construction, and Standard Specifications for Hardwood Glued-laminated Timber (1985), American Institute of Timber Construction.

25-12; 2502 (a), 2505, 2516 (c), 2909 (a) 1, 3202

Division I—Preservative Treatment by Pressure Proeesses and Quality Control Standards. Standard Specifications C1-82, C2-82, C3-81, C4-81, C9-77, C23-77, C28-79 and M4-80 of the American Wood Preservers Association. Division II—Quality Control, CP-79, LP2-80, LP3-78, LP4-78, LP5-78, LP7-78, LP22-80, LP33-78, LP44-78, LP55-78, LP77-78 and FDN-80 of the American Wood Preservers Bureau.

25-13; 2504 (b)

Wood Poles. Specifications and Dimensions for Wood Poles. 05.1-1972 of the ANSI.*

25-14; 2504 (b), 2909 (a) 1

Round Timber Piles. Standard Specification D25-73 of the ASTM.

25-15; 2507 (a) 2

Spaced Columns. National Design Specification for Wood Construetion (1982), including the 1982 Supplement, National Forest Products Association.

25-17; 2504 (c) 3, 2510 (a), 2510 (b), 2510 (c), 2510 (d), 2510 (e), 2510 (h), 2513 (b) 1 and 2, 2516 (j) 1, 3203 (e) 4, Tables Nos. 25-F, 25-G, 25-H, 47-G and 47-H

Timber Conneetor Joints, Bolted Joints, Drift Bolts and Wood Serews, and Lag Screws; Metal Plate Connected Wood Truss Design; and Nails and Staples. National Design Specification for Wood Construction (1982), including the 1982 Supplement, National Forest Products Association; Design Specifications for Metal Plate Connected Wood Truss TPI-85, and Design Specification for Metal Plate Connected Parallel Chord Wood Trusses, PCT-80 of the Truss Plate Institute; and Federal Specifieation No. FF-N-105B, March 17, 1971.

25-18; 2512

Structural Glued Built-up Members—Plywood Components. Design and Fabrieation Specifications of American Plywood Assoeiation.

*ANSI refers to Ameriean National Standards Institute.



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25-19; 2517 (e) 2

Part I—Dry Use Adhesives with Protein Base, Casein Type, Standard Specification D3024-78 of the ASTM. Part II—Wet Use Adhesives. Standard Specification D2559-76 of the ASTM. Part III—Adhesives for Field Gluing Plywood to Wood Framing, Specification AFG-01 September 1974 of the American Plywood Association.

25-20

Test for Glue Joints in Laminated Wood Product. Standard Test Method D1101-81 of the ASTM, and AITC 200-83, American Institute of Timber Construction referenced in PS 56-73.

25-21; Tables Nos. 25-U-J-1, 25-U-J-6, 25-U-R-1, 25-U-R-2, 25-U-R-7, 25-U-R-8, 25-U-R-10, 25-U-R-11, 25-U-R-13 and 25-U-R-14

Span Tables for Joists and Rafters. Specification Standard of the International Conference of Building Officials.

25-22

Plank-and-Beam Framing. Wood Construction Data No. 4 (1970) of the National Forest Products Association.

25-23

Tests for Structural Glued-laminated Timber. Inspection Manual, AITC 200-86 of American Institute of Timber Construction, referenced in ANSI/AITC A190.1, 1983 of the ANSI [the basis for U.B.C. Standard No. 25-10 and Standard Methods of Testing D 905-49 (R81) of the ASTM.]

25-24; 2502 (a), 2514, 2516 (g) 4

Cellulosic Fiber Insulating Board (Fiberboard). Voluntary Product Standard PS 57-73, U.S. Department of Commerce, National Bureau of Standards.

25-25; 2502 (a), 2516 (g) 5, 2517 (f)

Mat-formed Wood Particleboard. American National Standard for Mat-formed Wood Particleboard, ANSI A208.1-1979.

25-26; 2502 (a), 2516 (g) 6

Hardboard Siding. American National Standard ANSI/AHA A135.6-1984.

25-27; 2504 (c) 9

Temperature Effects. National Design Specification for Wood Construction (1982), including the 1982 Supplement, National Forest Products Association.

25-28; 407.

Fire-retardant-treated Wood Tests on Durability and Hygroscopic Properties. Standard Test Methods D2891-81 and D3201-79 of the ASTM and Standards C20-83 and C27-83 of the American Wood Preservers Association.

25-29; 407, 2507 (c) 3

Fire-retardant-treated Wood. National Design Specification for Wood Construction Policy on Design Values for Fire-retardant-treated Lumber.



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## CHAPTER 26

26-1; 2402 (b) 2, 2603 (c), 2604 (e)

Portland Cement and Blended Hydraulic Cements. Standard Specifications C150-81 and C595-81a of the ASTM.

26-2; 2603 (d), Table No. 26-A-4, 2708 (d)

Concrete Aggregates. Standard Specification C33-81 of the ASTM.

26-3; 2602, 2603 (d), 2604 (b), 2708 (d), Table No. 27-C,

Lightweight Aggregates for Structural and Insulating Concrete: Standard Specifications C330-80 and C332-80 of the ASTM.

26-4; 2402 (b), 2603 (f) 2, 2603 (f) 3, 2625 (c) 6

Reinforcing Bars for Concrete. Standard Specifications A615-85, A616-85, A617-84, A706-84a, A767-M-85 and A775-M-84 of the ASTM.

26-5; 2603 (f) 2

Fabricated Deformed Steel Bar Mats. Standard Specification A184-84a of the ASTM.

26-6; 2603 (f) 2

Welded Steel Wire Fabric and Deformed Steel Wire. Standard Specifications A185-85, A496-85 and A497-79 of the ASTM.

26-7; 2603 (f) 4, 2909 (e) 2

Steel Wire, Strand and Bar for Prestressing. Standard Specifications A416-80, A421-80 and A722-75 of the ASTM.

26-8; 2603 (f) 1, 2603 (i), 2612 (p) 3, 2625 (c) 6

Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction. Structural Welding Code—Reinforcing Steel AWS D1.4-79 of the American Welding Society Inc.

26-9; 2603 (g)

Admixtures for Concrete. Standard Specifications C260-77, C494-80 and C618-80 of the ASTM.

26-10; 2604 (d) 3, 2604 (h) 2, 3 and 4

Concrete Tests. Part I—Making and Curing Concrete Test Specimens in the Laboratory. Part II—Making and Curing Test Specimens in the Field. Part III—Obtaining and Testing Drilled Cores and Sawed Beams of Concrete. Part IV—Compressive and Flexural Tests. Part V—Capping Cylindrical Concrete Specimens. Part VI—Sampling Fresh Concrete. Standard Methods C31-69 (1980), C39-80, C42-77, C78-75 (1978), C172-71 (1977), C192-81 and C617-76 (1979) of the ASTM.

26-12; 2602

Splitting Tensile Strength. Standard Test Method C496-71 (1979) of the ASTM.

26-13; 305 (e) Item 1, 2605 (b)

Ready-mixed Concrete. Standard Specification C94-81 of the ASTM.



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26-14; 2605 (b)

Concrete Made by Volumetric Batching and Continuous Mixing. Standard Specification C685-83 of the ASTM.

26-15; 2627 (a) and (c)

Mill Mixed Gypsum Concrete and Poured Gypsum Roof Diaphragms. Standard Specification C317-70 of the ASTM. Poured Gypsum Roof Diaphragms, based on reports of test programs by S.B. Barnes and Associates dated February, 1955; November, 1956; January, 1958; and February, 1962.

## CHAPTER 27

27-1; 2603 (f) 5, 2721 (b), 2909 (f) 1, 2909 (g) 1

Material Specifications for Structural Steel. Standard Specifications A27, A36, A48, A53, A148, A242, A252, A283, A307, A325, A336, A441, A446, A449, A490, A500, A501, A514, A529, A569, A570, A572, A588, A606, A607, A611, A618, A666, A690, A715 and A792 of the ASTM.

27-2; 2701 (b), 2719, 2720, 2721 (k)

Erection, Fabrication, Identification and Painting of Structural Steel. Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings of the American Institute of Steel Construction, Inc. (November 1, 1978).

27-3; 2702 (c), 2704, 2707 (a), 2712 (c), Table No. 27-A

Stress Variation or Stress Reversal Design. Specifications of the American Institute of Steel Construction, Inc. (November 1, 1978).

27-4; 2701 (b); 2715 (a)

Open Web Steel Joists. Standard Specifications for Open Web Steel Joists, H Series; K Series; Longspan Steel Joists, LH Series; Deep Longspan Steel Joists, DLH Series; and Joist Girders, 1978 (including 1986 revisions), of the Steel Joist Institute.

27-5; 2713 (a)

Structural Rivet Steel. Standard Specification A502-65 of the ASTM.

27-6; 2702 (e), 2714 (a), 2722 (a) and (f), Table No. 27-B

Structural Welding. Structural Welding Code—Steel ANSI/AWS D1.1-84 of the American Welding Society, Inc.

27-7; 2713 (a), Table No. 27-A

High-Strength Bolts. Specification for Structural Joints Using ASTM A325 or A490 Bolts. Approved by the Research Council on Structural Connections of the Engineering Foundation, November 18, 1985, and endorsed by the American Institute of Steel Construction and by Industrial Fasteners Institute.

27-9; 2701 (b); 3208 (b) 6

Specifications for the Design of Cold-formed Steel Structural Members. Based on Specifications of the American Iron and Steel Institute (1986).



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27-10; 2701 (b)

Specification for the Design of Cold-formed Stainless Steel Structural Members. Specification Manual, 1974 Edition, American Iron and Steel Institute.

27-11; 2724

Steel Storage Racks. Interim Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks, 1972, and Supplement No. 1 to the Specification, June 18, 1973, of the Rack Manufacturers Institute.

27-12; 2725

Structural Applications of Steel Cables for Buildings. Criteria for Structural Applications of Steel Cables for Buildings, 1973 Edition, and Standard Specifications A586-68 (1976), A603-70 (1974) and B6-70 of the ASTM.

27-13; 2714 (a), 2714 (j)

Welding Sheet Steel. Structured Welding Code—Sheet Steel ANSI/AWS D1.3-81 of the American Welding Society, Inc.

27-14; 2723

Load and Resistance Factor Design Specification for Structural Steel Buildings—1986. Specification of the American Institute of Steel Construction.

## CHAPTER 28

28-1; 2801 (a), 2802 (a), 2802 (b), 2803 (a), 2803 (b), 2803 (d), 2804 (c), 2804 (e), 2804 (f), Table No. 28-F

Standard for Aluminum Structures. Specifications for Aluminum Structures, Aluminum Association (November, 1967).

## CHAPTER 29

29-1; 2904 (a)

Soils Classification. Standard Method D2487-69 of the ASTM.

29-2; 2904 (b)

Expansion Index Test. Recommendation of the Los Angeles Section ASCE Soil Committee.

29-3; 2907 (a)

Treated Wood Foundation System. National Forest Products Association, Technical Report No. 7.

29-4; 2907 (e)

Design of Slab-on-grade Foundations to Resist the Effects of Expansive Soils. Part I—Design of Slab-on-ground Foundations based on design specification of the Wire Reinforcement Institute (August 1981). Part II—Design of Post-tensioned Slabs on Ground based on design specification of the Post-tensioning Institute.



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## CHAPTER 32

32-1; 1707 (a), 3208 (a)

Materials for Use in Construction of Built-up Roof Coverings. Standard Specification 55-A, 1978, of the Underwriters Laboratories Inc.

32-2; 3208 (a)

Roofing Asphalt and Coal Tar Bitumen. Standard Specifications D312-84 and D450-78 (1984) of the ASTM.

32-3; 3208 (b) 8

Class C Sheet Roofing and Shingles Made from Asphalt Organic Felt. Standard Specification 55-B, October 5, 1983, of the Underwriters Laboratories Inc.

32-4; 3208 (b) 6

Sheet Metals. Standard Specifications A245-62aT, A361-63T and B209-63 of the ASTM.

32-5; Tables Nos. 32-E and 32-F

Roofing Aggregates. Material Standard of the International Conference of Building Officials.

32-6; Tables Nos. 32-D-1 and 32-D-2

Corrosion-resistant Metals. Standard Specifications A219-58 and A239-41 of the ASTM.

32-7; 1712 (b) 5, 3202, Table No. 32-A, 5207 (a) 2

Test Standard for Determining the Fire Retardancy of Roof Covering Materials. Standard Specification 790 (December 15, 1978) of the Underwriters Laboratories Inc.

32-8; 3208 (b) 10

Wood Shakes. Part I—Wood Shakes (nonpreservative treated). Grading and Packing Rules for Red Cedar Shakes of the Red Cedar Shingle & Handsplit Shake Bureau, 1975. Part II—Wood Shakes (preservative treated). Based on Grading and Packing Rules for Treated Southern Pine Taper-sawn Shakes of the Red Cedar Shingle & Handsplit Shake Bureau, 1982.

32-9; 3208 (b) 2

Asbestos-cement Shingles. Standard Specification C222-60 of the ASTM.

32-10; 3208 (b) 9

Slate Shingles. Standard Specification C406-57T of the ASTM.

32-11; 3208 (b) 11

Wood Shingles. Standards of the Red Cedar Shingle & Handsplit Shake Bureau and Material Standard of the International Conference of Building Officials.

32-12; 3208 (b) 5

Roofing Tile. Test Standard of the International Conference of Building Officials.



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32-13; Tables Nos. 32-D-1 and 32-D-2

Wire. Standard Specifications B134-62, B211-63 and B250-62 of the ASTM.

32-14; 3206 (a), (d)

Automatic Smoke and Heat Vents. Standard of the International Conference of Building Officials.

## CHAPTER 33

33-1; 3304 (h)

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33-2; 3306 (q)

Stairway Identification. Specification Standard of the International Conference of Building Officials.

33-3; App. 111 (a)

Exit Ladder Device. Test Standard of the International Conference of Building Officials.

33-4; 3304 (d)

Panic Hardware. Standard 305, July 30, 1979, of the Underwriters Laboratories Inc.

## CHAPTER 35

35-1; App. 3501 (b), App. 3501 (d)

Laboratory Determination of Airborne Sound Transmission Class (STC). Standard Method E90-83 and Standard Classification E413-73 (1980) of the ASTM.

35-2; App. 3501 (c); App. 3501 (d); App. 3501 (g)

Impact Sound Insulation. Standard Method E492-77 of the ASTM.

35-3; App. 3501 (d), 3501 (f)

Airborne Sound Insulation Field Test. Standard Test Method E336-67T of the ASTM.

## CHAPTER 37

37-1; 3702

Fireclay Refractories. Standard Specification C27-60 of the ASTM.

## CHAPTER 38

38-1; 1807 (c), 3801 (d), 3802 (g), 5603 (g), App. 1108 (b)

Design Installation and Acceptance of Automatic Fire Sprinkler Systems.

38-2; 3801 (d), 3805 (a)

Standpipe Systems. Installation Standard of the International Conference of Building Officials.



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47-16

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70-2; App. 7010 (e)

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# APPENDIX

## Chapter 1
## Division I
## LIFE-SAFETY REQUIREMENTS FOR EXISTING BUILDINGS OTHER THAN HIGH-RISE BUILDINGS

### General

**Sec. 110.** (a) **Purpose.** The purpose of this division is to provide a reasonable degree of safety to persons occupying existing buildings by providing for alterations to such existing buildings which do not conform with the minimum requirements of this code.

**EXCEPTION:** Group R, Division 3, Group M; and high-rise occupancies.

(b) **Effective Date.** Within 18 months after the effective date of this division, plans for compliance shall be submitted and approved, and within 18 months thereafter the work shall be completed or the building shall be vacated until made to conform.

### Exits

**Sec. 111.** (a) **Number of Exits.** Every floor above the first story used for human occupancy shall have access to at least two separate exits, one of which may be an exterior fire escape complying with Subsection (d) of this section. Subject to the approval of the building official, an approved ladder device may be used in lieu of a fire escape when the construction feature or location of the building on the property make the installation of a fire escape impracticable.

**EXCEPTION:** In all occupancies, second stories with an occupant load of 10 or less may have one exit.

An exit ladder device when used in lieu of a fire escape shall conform with U.B.C. Standard No. 33-3 and the following:

1. Serves an occupant load of 10 or less or a single dwelling unit or guest room.
2. The building does not exceed three stories in height.
3. The access is adjacent to an opening as specified for emergency egress or rescue or from a balcony.
4. Shall not pass in front of any building opening below the unit being served.
5. The availability of activating the device for the ladder is accessible only from the opening or balcony served.
6. So installed that it will not cause a person using it to be within 6 feet of exposed electrical wiring.

(b) **Stair Construction.** All required stairs shall have a minimum run of 9 inches and a maximum rise of 8 inches and shall have a minimum width of 30 inches exclusive of handrails. Every stairway shall have at least one handrail. A



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landing having a minimum 30-inch run in the direction of travel shall be provided at each point of access to the stairway.

**EXCEPTION:** Fire escapes as provided for in this section.

Exterior stairs shall be of noncombustible construction.

**EXCEPTION:** On buildings of Types III, IV and V, provided the exterior stairs are constructed of wood not less than 2-inch nominal thickness.

(c) **Corridors.** Corridors of Groups A, B, E, I, H and R, Division 1 Occupancies serving as an exit for an occupant load of 30 or more shall have walls and ceilings of not less than one-hour fire-resistive construction as required by this code. Existing walls surfaced with wood lath and plaster in good condition or 1/2-inch gypsum wallboard or openings with fixed wired glass set in steel frames are permitted for corridor walls and ceilings and occupancy separations when approved. Doors opening into such corridors shall be protected by 20-minute fire assemblies or solid wood doors not less than 1 3/4 inches thick. Where the existing frame will not accommodate the 1 3/4-inch-thick door, a 1 3/8-inch-thick solid bonded wood core door or equivalent insulated steel door shall be permitted. Doors shall be self-closing or automatic-closing by smoke detection. Transoms and openings other than doors from corridors to rooms shall comply with Section 3305 (h) of this code or shall be covered with a minimum of 3/4-inch plywood or 1/2-inch gypsum wallboard or equivalent material on the room side.

**EXCEPTION:** Existing corridor walls, ceilings and opening protection not in compliance with the above may be continued when such buildings are protected with an approved automatic sprinkler system throughout. Such sprinkler system may be supplied from the domestic water system if it is of adequate volume and pressure.

(d) **Fire Escapes.** 1. Existing fire escapes which in the opinion of the building official comply with the intent of this section may be used as one of the required exits. The location and anchorage of fire escapes shall be of approved design and construction.

2. Fire escapes shall comply with the following:

Access from a corridor shall not be through an intervening room.

All openings within 10 feet shall be proteeted by three-fourths-hour fire assemblies. When located within a recess or vestibule, adjacent enclosure walls shall be of not less than one-hour fire-resistive construction.

Egress from the building shall be by a clear opening having a minimum dimension of not less than 29 inches. Such openings shall be openable from the inside without the use of a key or special knowledge or effort. The sill of an opening giving access shall be not more than 30 inches above the floor of the building or balcony.

Fire escape stairways and balconies shall support the dead load plus a live load of not less than 100 pounds per square foot and shall be provided with a top and intermediate handrail on each side. The pitch of the stairway shall not exceed 60 degrees with a minimum width of 18 inches. Treads shall be not less than 4 inches in width and the rise between treads shall not exceed 10 inches. All stair and



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balcony railings shall support a horizontal force of not less than 50 pounds per lineal foot of railing.

Balconies shall be not less than 44 inches in width with no floor opening other than the stairway opening greater than 5/8 inch in width. Stairway openings in such balconies shall be not less than 22 inches by 44 inches. The balustrade of each balcony shall be not less than 36 inches high with not more than 9 inches between balusters.

Fire escapes shall extend to the roof or provide an approved gooseneck ladder between the top floor landing and the roof when serving buildings four or more stories in height having roofs with less than 4:12 slope. Fire escape ladders shall be designed and connected to the building to withstand a horizontal force of 100 pounds per lineal foot; each rung shall support a concentrated load of 500 pounds placed anywhere on the rung. All ladders shall be at least 15 inches wide, located within 12 inches of the building and shall be placed flatwise relative to the face of the building. Ladder rungs shall be 3/4 inch in diameter and shall be located 12 inches on center. Openings for roof access ladders through cornices and similar projections shall have minimum dimensions of 30 inches by 33 inches.

The lowest balcony shall be not more than 18 feet from the ground. Fire escapes shall extend to the ground or be provided with counterbalanced stairs reaching to the ground.

Fire escapes shall not take the place of stairways required by the codes under which the building was constructed.

Fire escapes shall be kept clear and unobstructed at all times and maintained in good working order.

(e) **Exit and Fire Escape Signs.** Exit signs shall be provided as required by this code.

**EXCEPTION:** The use of existing exit signs may be continued when approved by the building official.

All doors or windows providing access to a fire escape shall be provided with fire escape signs.

## Enclosure of Vertical Shafts

**Sec. 112.** Interior vertical shafts, including but not limited to stairways, elevator hoistways, service and utility shafts, shall be enclosed by a minimum of one-hour fire-resistive construction. All openings into such shafts shall be protected with one-hour fire assemblies which shall be maintained self closing or be automatic closing by smoke detection. All other openings shall be fire protected in an approved manner. Existing fusible link-type automatic door closing devices may be permitted if the fusible link rating does not exceed 135°F.

**EXCEPTIONS:** 1. In other than Group I Occupancies, an enclosure will not be required for openings serving only one adjacent floor.

2. Stairways need not be enclosed in a continuous vertical shaft if each story is separated from other stories by one-hour fire-resistive construction or approved wired glass set in steel frames. In addition, all exit corridors shall be sprinklered and the openings between the corridor and occupant space have at least one sprinkler



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head above the openings on the tenant side. The sprinkler system may be supplied from the domestic water supply if of adequate volume and pressure.

3. Vertical openings need not be protected if the building is protected by an approved automatic sprinkler system.

## Basement Access or Sprinkler Protection

**Sec. 113.** An approved automatic sprinkler system shall be provided in basements or stories exceeding 1500 square feet in area and not having a minimum of 20 square feet of opening entirely above the adjoining ground level in each 50 lineal feet or fraction thereof of exterior wall on at least one side of the building. Openings shall have a minimum clear dimension of 30 inches.

If any portion of a basement is located more than 75 feet from required openings, the basement shall be provided with an approved automatic sprinkler system throughout.

## Standpipes

**Sec. 114.** Any buildings over four stories in height shall be provided with an approved Class I or Class III standpipe system.

## Smoke Detectors

**Sec. 115.** 1. **General.** Dwelling units and hotel or lodging house guest rooms that are used for sleeping purposes shall be provided with smoke detectors. Detectors shall be installed in accordance with the approved manufacturer's instructions.

2. **Power source.** Smoke detectors may be battery operated or may receive their primary power from the building wiring when such wiring is served from a commercial source. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection.

3. **Location within dwelling units.** In dwelling units, detectors shall be mounted on the ceiling or wall at a point centrally located in the corridor or area giving access to each separate sleeping area. Where sleeping rooms are on an upper level, the detector shall be placed at the center of the ceiling directly above the stairway. Detectors shall also be installed in the basement of dwelling units having a stairway which opens from the basement into the dwelling. Detectors shall sound an alarm audible in all sleeping areas of the dwelling unit in which they are located.

4. **Location in efficiency dwelling units and hotels.** In efficiency dwelling units, hotel suites and in hotel sleeping rooms, detectors shall be located on the ceiling or wall of the main room or hotel sleeping room. When sleeping rooms within an efficiency dwelling unit or hotel suite are on an upper level, the detector shall be placed at the center of the ceiling directly above the stairway. When actuated, the detector shall sound an alarm audible within the sleeping area of the dwelling unit, hotel suite or sleeping room in which it is located.

## Separation of Occupancies

**Sec. 116.** Occupancy separations shall be provided as specified in Section 503 of this code. When approved by the building official, existing wood lath and



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plaster in good condition or 1/2-inch gypsum wallboard may be acceptable where one-hour occupancy separations are required.

# Division II
# LIFE-SAFETY REQUIREMENTS FOR EXISTING HIGH-RISE BUILDINGS

## Scope

**Sec. 120.** These provisions apply to existing high-rise buildings constructed prior to the adoption of this division and which house Group B, Division 2 offices or Group R, Division 1 Occupancies, each having floors used for human occupancy located more than 75 feet above the lowest level of fire department vehicle access.

## General

**Sec. 121.** Existing high-rise buildings as specified in Section 120 shall be modified to conform with not less than the minimum provisions specified in Table No. A-1-A and as further enumerated within this division.

The provisions of this division shall not be construed to allow the elimination of fire protection systems or a reduction in the level of fire safety provided in buildings constructed in conformance with previously adopted codes.

## Compliance Data

**Sec. 122.** After adoption of this division, the building official shall duly notify the owners whose buildings are subject to the provisions of this division. Upon receipt of such notice, the owner shall, subject to the following time limits, take necessary actions to comply with the provisions of this division.

Plans and specifications for the necessary alterations shall be filed with the building official within the time period established by the local jurisdiction after the date of owner notification. Work on the required alterations to the building shall commence within 30 months of the date of owner notification and such work shall be completed within five years from the date of owner notification.

The building official shall grant necessary extensions of time when it can be shown that the specified time periods are not physically practical or pose an undue hardship. The granting of an extension of time for compliance shall be based upon the showing of good cause and subject to the filing of an acceptable systematic progressive plan of correction with the building official.

## Authority of the Building Official

**Sec. 123.** For the purpose of applying the provisions of this division, the building official shall have the authority to consider alternative approaches and grant necessary deviations from this division as follows:

A. Allow alternate materials or methods of compliance if such alternate materials or methods of compliance will provide levels of fire and life safety equal to or greater than those specifically set forth in this division.



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B. Waive specific individual requirements if it can be shown that such requirements are not physically possible or practical and that a practical alternative cannot be provided.

## Appeals Board

**Sec. 124.** Appeals of the determinations of the building official in applying the provisions of this code may be made by an appeal directed to the Board of Appeals as established by Section 204 of this code.

## Specific Provisions and Alternates

**Sec. 125.** (a) **Specific Provisions.** The following provisions shall apply when required by Table No. A-1-A.

1. **Type of construction.** Buildings classified as Type II-N, III-N or V-N construction shall be equipped with an approved automatic sprinkler system installed in accordance with U.B.C. Standard No. 38-1.

**EXCEPTION:** Installation of meters or backflow preventers for the connection to the water works system need not be provided unless required by other regulations of the authority having jurisdiction.

2. **Automatic sprinklers.** All required exit corridors, stairwells, elevator lobbies, public assembly areas occupied by 100 or more persons and commercial kitchens shall be protected by an approved automatic sprinkler system meeting the design criteria of U.B.C. Standard No. 38-1. A minimum of one sprinkler shall be provided on the room side of every corridor opening.

**EXCEPTION:** Sprinkler may be omitted in stairwells of noncombustible construction.

3. **Fire department communication system.** When it is determined by test that the portable fire department communication equipment is ineffective, a communication system acceptable to the fire department shall be installed within the existing high-rise building to permit emergency communication between fire-suppression personnel.

4. **Single-station smoke detectors.** Single-station smoke detectors shall be installed within all dwelling units or guest rooms in accordance with the manufacturer's installation instructions. In dwelling units, the detector shall be mounted on the ceiling or wall at a point centrally located in the corridor or area giving access to each separate sleeping area. When sleeping rooms are located on an upper level, the detector shall be installed at the center of the ceiling directly above the stairway within the unit. In efficiency dwelling units, hotel suites and in hotel guest rooms, detectors shall be located on the ceiling or wall of the main room or hotel sleeping room. When actuated, the detector shall provide an audible alarm in the sleeping area of the dwelling unit, hotel suite or guest room in which it is located.

Such detectors may be battery operated.

5. **Manual fire alarm system.** An approved manual fire alarm system connected to a central, proprietary or remote station service, or an approved manual



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fire alarm system which will provide an audible signal at a constantly attended location, shall be provided.

6. **Occupant voice notification system.** An approved occupant voice notification system shall be provided. Such system shall provide communication from a location acceptable to the fire department and shall permit voice notification to at least all normally occupied areas of the building.

The occupant voice notification system may be combined with a fire alarm system, provided the combined system has been approved and listed for such use. The sounding of a fire alarm signal in any given area or floor shall not prohibit voice communication to other areas or floors. Combination systems shall be designed to permit voice transmission to override the fire alarm signal, but the fire alarm shall not terminate in less than 3 minutes.

7. **Vertical shaft enclosures.** Openings through two or more floors except mezzanine floors, which contain a stairway or elevator, shall be provided with vertical shaft enclosure protection as specified herein. Such floor openings, when not enclosed by existing shaft enclosure construction, shall be protected by one-hour fire-resistive-rated shaft enclosure construction. For floor openings which are enclosed by existing shaft enclosure construction having fire-resistive capabilities similar to wood lath and plaster in good condition, 1/2-inch gypsum wallboard or approved 1/4-inch-thick wired glass is acceptable. Wired glass set in a steel frame may be installed in existing shaft enclosure walls but shall be rendered inoperative and be fixed in a closed position.

Openings through two or more floors for other than stairways or elevators, such as openings provided for piping, ducts, gas vents, dumbwaiters, and rubbish and linen chutes, shall be provided with vertical shaft enclosure protection as specified for stairways and elevators.

> **EXCEPTION:** Openings for piping, ducts, gas vents, dumbwaiters and rubbish and linen chutes of copper or ferrous construction are permitted without a shaft enclosure, provided the floor openings are effectively fire-stopped at each floor level.

8. **Shaft enclosure opening protection.** Openings other than those provided for elevator doors in new vertical shaft enclosures constructed of one-hour fire-resistive construction shall be equipped with approved fire assemblies having a fire-protection rating of not less than one hour. Openings other than those provided for elevator doors in existing vertical shaft enclosures shall be equipped with approved 20-minute-rated fire assemblies, 1 3/4-inch solid wood doors or the equivalent thereto. Doors shall be either self-closing or automatic closing and automatic latching.

All elevators on all floors shall open into elevator lobbies which are separated from the remainder of the building as is required for corridor construction in the Building Code, unless the building is protected throughout by a sprinkler system.

9. **Manual shutoff of HVAC systems.** Heating, ventilating and air conditioning systems shall be equipped with manual shutoff controls installed at an approved location when required by the fire department.



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10. **Automatic elevator recall system.** Elevators shall be equipped with an approved automatic recall system as required by Section 1807 (h) 2.

11. **Unlocked stairway doors.** Exit doors into exit stairway enclosures shall be maintained unlocked from the stairway side on at least every fifth floor level. All unlocked doors shall bear a sign stating ACCESS ONTO FLOOR THIS LEVEL.

Stairway doors may be locked, subject to the following conditions:

A. Stairway doors which are to be locked from the stairway side shall have the capability of being unlocked simultaneously without unlatching upon a signal from an approved location.

B. A telephone or other two-way communications system connected to an approved emergency service which operates continuously shall be provided at not less than every fifth floor in each required stairway.

12. **Stair shaft ventilation.** Stair shaft enclosures which extend to the roof shall be provided with an approved manually openable hatch to the exterior having an area not less than 16 square feet with a minimum dimension of 2 feet.

**EXCEPTIONS:** 1. Stair shaft enclosures complying with the requirements for smokeproof enclosures.

2. Stair shaft enclosures pressurized as required for mechanically operated smokeproof enclosures to a minimum of 0.15- and a maximum of 0.50-inch water column.

13. **Elevator shaft ventilation.** Elevator shaft enclosures which extend to the roof shall be vented to the outside with vents whose area shall be not less than 3 1/2 percent of the area of the elevator shaft, with a minimum of 3 square feet per elevator.

**EXCEPTION:** Where energy conservation or hoistway pressurization requires that the vents be normally closed, automatic venting by actuation of an elevator lobby detector or power failure may be accepted.

14. **Posting of elevators.** A permanent sign shall be installed in each elevator cab adjacent to the floor status indicator and at each elevator call station on each floor reading IN FIRE EMERGENCY, DO NOT USE ELEVATOR—USE EXIT STAIRS, or similar verbiage approved by the building official.

**EXCEPTION:** Sign may be omitted at the main entrance floor-level call station.

15. **Exit Stairways.** All high-rise buildings shall have a minimum of two approved exit stairways.

16. **Exit corridor construction.** Corridors serving as an exit for an occupant load of 30 or more shall have walls and ceilings of not less than one-hour fire-resistive construction as required by this code. Existing walls may be surfaced with wood lath and plaster in good condition or 1/2-inch gypsum wallboard for corridor walls and ceilings and occupancy separations when approved.

17. **Exit corridor openings.** Openings in corridor walls and ceilings shall be protected by not less than 1 3/8-inch solid-bonded wood-core doors, approved 1/4-inch-thick wired glass, approved fire dampers conforming to U.B.C. Standard



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No. 43-7, or by equivalent protection in lieu of any of these items. Transoms shall be fixed closed and covered with 1/2-inch Type X gypsum wallboard or equivalent material installed on both sides of the opening.

18. **Exit corridor door closers.** Exit doors into corridors shall be equipped with self-closing devices or shall be automatic closing by actuation of a smoke detector. When spring hinges are used as the closing device, not less than two such hinges shall be installed on each door leaf.

19. **Exit corridor dead ends.** The length of dead end corridors serving an occupant load of more than 30 shall not exceed 20 feet.

20. **Interior finish.** The interior finish in exit corridors, exit stairways and extensions thereof shall conform to the provisions of Chapter 42 of this code.

21. **Exit stairway illumination.** When the building is occupied, exit stairways shall be illuminated with lights having an intensity of not less than 1 footcandle at the floor level. Such lighting shall be equipped with an independent alternate source of power such as a battery pack or on-site generator.

22. **Exit corridor illumination.** When the building is occupied, exit corridors shall be illuminated with lights having an intensity of not less than 1 footcandle at the floor level. Such lighting shall be equipped with an independent alternate source of power such as a battery pack or on site generator.

23. **Exit stairway exit signs.** The location of exit stairways shall be clearly indicated by illuminated exit signs. Such exit signs shall be equipped with an independent alternate source of power such as a battery pack or on-site generator or shall be of an approved self-illuminating type.

24. **Exitway exit signs.** Illuminated exit signs shall be provided in all exitways and located in such a manner as to clearly indicate the direction of egress. Such exit signs shall be equipped with an independent alternate source of power such as a battery pack or on-site generator or shall be of an approved self-illuminating type.

25. **Emergency plan.** The management for all buildings shall establish and maintain a written fire- and life-safety emergency plan which has been approved by the chief. The chief shall develop written criteria and guidelines upon which all plans shall be based.

26. **Posting of emergency plan and exit plans.** Copies of the emergency plan and exiting plans (including elevator and stairway placarding) shall be posted in locations approved by the chief.

27. **Fire drills.** The management of all buildings shall conduct fire drills for their staff and employees at least every 120 days. The fire department must be advised of such drills at least 24 hours in advance. A written record of each drill shall be maintained in the building management office and made available to the fire department for review.

(b) **Sprinkler Alternatives.** The requirements of Table No. A-1-A may be modified as specified by the following for existing high-rise buildings of Type I, II-F.R., II One-hour, III One-hour, IV or V One-hour construction when an



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approved automatic sprinkler system is installed throughout the building in accordance with U.B.C. Standard No. 38-1:

Item 5—Manual fire warning system shall not be required.

Item 6—Occupant voice notification system shall not be required; however, if the building is equipped with a public address system, the public address system shall be available for use as an occupant voice notification system.

Item 7—Vertical shaft enclosures may be of nonrated construction for required exit stairway enclosures. Vertical shaft enclosures of openings in floors provided for elevators, escalators and supplemental stairways shall not be required, provided such openings are protected by an approved curtain board and water curtain system.

Item 8—Protection of openings in vertical shaft enclosures may be nonrated but shall be not less than a 1 3/4-inch solid-wood door or the equivalent thereto. Closing and latching hardware shall be provided.

Item 10—An automatic elevator recall system shall not be required.

Item 12—Stair shaft ventilation shall not be required.

Item 16—Existing corridor construction need not be altered.

Item 17—Door openings into exit corridors may be protected by assemblies other than those specified in Section 125 (a), provided an effective smoke barrier is maintained. Closing and latching hardware shall be provided. Protection of duct penetrations is not required.

Item 19—The length of existing exit corridor dead ends shall not be limited.

Item 20—Interior finish in exitways may be reduced by one classification but shall not be less than Class III.

Installation of meters or backflow preventers for the connection to the water works system need not be provided unless required by other regulations of the authority having jurisdiction.



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## TABLE NO. A-1-A—OCCUPANCY CLASSIFICATION AND USE[1]

| ITEM REQUIRED | GROUP R, DIVISION 1 | | | | | | GROUP B, DIVISION 2 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Apartment | | | Hotel | | | Office | | |
| | Height Zones[2] | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1. Automatic sprinklers in buildings of Type II-N, III-N or V-N construction. See Section 125 (a) 1. | R | R | — | R | R | — | R | R | — |
| 2. Automatic sprinklers in corridors, stairways, elevator lobbies, public assembly areas, kitchens and at doors opening to corridors. See Section 125 (a) 2. | R | R | R | R | R | R | R | R | R |
| 3. Fire department communication system or radios. See Section 125 (a) 3. | R | R | R | R | R | R | R | R | R |
| 4. Single-station smoke detectors. See Section 125 (a) 4. | R | R | R | R | R | R | NR | NR | NR |
| 5. Manual fire warning system. See Section 125 (a) 5. | R | R | R | R | R | R | R | R | R |
| 6. Occupant voice notification system. See Section 125 (a) 6. | NR | R | R | NR | R | R | NR | NR | NR |
| 7. Vertical shaft enclosure walls of one-hour fire resistance. See Seetion 125 (a) 7. | R | R | R | R | R | R | R | R | R |
| 8. Protection of openings in vertical shaft enelosures by 20-minute-rated assemblies. See Section 125 (a) 8. | R | R | R | R | R | R | R | R | R |
| 9. Manual shutoff of HVAC systems. See Section 125 (a) 9. | R | R | R | R | R | R | R | R | R |
| 10. Automatic elevator recall system. See Section 125 (a) 10. | R | R | R | R | R | R | R | R | R |

(Continued)





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## TABLE NO. A-1-A—OCCUPANCY CLASSIFICATION AND USE[1]—(Continued)

| ITEM REQUIRED | GROUP R, DIVISION 1 | | | | | | GROUP B, DIVISION 2 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Apartment | | | Hotel | | | Office | | |
| | Height Zones[2] | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 11. Unlocked stairway doors every fifth floor. See Section 125 (a) 11. | R | R | R | R | R | R | NR | R | R |
| 12. Stair shaft ventilation. See Section 125 (a) 12. | R | R | R | R | R | R | R | R | R |
| 13. Elevator shaft ventilation. See Section 125 (a) 13. | R | R | R | R | R | R | R | R | R |
| 14. Posting of elevators as not intended for exiting purposes. See Section 125 (a) 14. | R | R | R | R | R | R | R | R | R |
| 15. Minimum of two exit stairways. See Section 125 (a) 15. | R | R | R | R | R | R | R | R | R |
| 16. Exit corridor wall construction. See Section 125 (a) 16. | R | R | R | R | R | R | R | R | R |
| 17. Protected exit corridor openings with 20-minute-rated assemblies or 1¾-inch solid wood door. See Section 125 (a) 17. | R | R | R | R | R | R | NR | NR | NR |
| 18. Exit corridor doors equipped with self-closing devices. See Section 125 (a) 18. | R | R | R | R | R | R | NR | NR | NR |
| 19. Exit corridor dead ends limited to 20 feet maximum. See Section 125 (a) 19. | R | R | R | R | R | R | NR | NR | NR |
| 20. Interior finish controlled in exit corridors, exit stairways and extensions thereof. See Section 125 (a) 20. | R | R | R | R | R | R | R | R | R |
| 21. Exit stairway illumination. See Section 125 (a) 21. | R | R | R | R | R | R | R | R | R |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22. Exit corridor illumination. See Section 125 (a) 22. | R | R | R | R | R | R | NR | NR | NR |
| 23. Exit stairway exit signs. See Section 125 (a) 23. | R | R | R | R | R | R | R | R | R |
| 24. Exitway exit signs. See Section 125 (a) 24. | R | R | R | R | R | R | R | R | R |
| 25. Emergency planning. See Section 125 (a) 25. | R | R | R | R | R | R | R | R | R |
| 26. Posting of emergency instructions. See Section 125 (a) 26. | R | R | R | R | R | R | R | R | R |
| 27. Fire drills. See Section 125 (a) 27. | NR | NR | NR | R | R | R | NR | NR | NR |

[1]R indicates provisions are required.
NR indicates provisions are not required.

[2]Height zones are established based on a building having a floor as measured to the top of the floor surface used for human occupancy located within the ranges of heights above the lowest level of the fire department vehicle access in accordanee with the following:

- Height Zone No. 1: More than 75 feet but not in excess of 149 feet.
- Height Zone No. 2: More than 149 feet but not in excess of 399 feet.
- Height Zone No. 3: More than 399 feet.





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# Chapter 7
# AVIATION CONTROL TOWERS

**NOTE: The provision for covered mall buildings have been relocated to Chapter 56.**

## General

**Sec. 711.** The provisions of this appendix apply exclusively to aviation control towers not exceeding 1,500 square feet per floor. Such buildings shall be classified as Group B, Division 2 Occupancies and shall be used only for the following uses:

1. Airport traffic control cab.
2. Electrical and mechanical equipment rooms.
3. Airport terminal radar and electronics rooms.
4. Office spaces incidental to the tower operation.
5. Lounges for employees, including restrooms.

## Construction, Height and Allowable Area

**Sec. 712.** Buildings or portions of buildings constructed under the provisions of this chapter shall be either Type I-F.R., Type II-F.R., Type II One-hour, Type II-N or Type III One-hour construction. The height of the building or parts thereof shall not exceed the limitations specified in Table No. A-7-A and the area of such buildings shall not exceed 1,500 square feet on any floor.

## Exit Facilities

**Sec. 713.** A single stairway may be used for exiting in towers of any height, provided the occupant load per floor does not exceed 15. Access to the stairway and the elevator shall be separated from each other a distance apart equal to no less than one half of the length of the maximum overall diagonal dimension of the area served measured in a straight line. The exit stairway and elevator hoistway may be located in a common shaft enclosure, provided they are separated from each other by a four-hour separation having no openings. Such stairway shall be constructed to comply with the requirements for smokeproof enclosures as specified in Section 3310. Stairways, however, need not extend to the roof as specified in Section 3306 (o). The provisions of Sections 1807 and 1907 do not apply.

## Fire Alarms

**Sec. 714.** Smoke detectors shall be installed in all occupied levels. These devices shall be part of an approved fire alarm system having audible alarms mounted in all occupied levels.

## Access for Handicapped

**Sec. 715.** Aviation control towers need not be accessible to the handicapped as specified in the provisions of Chapters 17 and 33.



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## Standby Power and Emergency Generation Systems

**Sec. 716.** A standby power generation system conforming to U.B.C. Standard No. 18-1 shall be installed in aviation control towers over 65 feet in height and shall provide power to the following equipment:

1. Smokeproof enclosure, mechanical equipment and lighting.
2. Elevator operational power.
3. Smoke-detection systems.

**TABLE NO. A-7-A—MAXIMUM HEIGHT OF AVIATION CONTROL TOWERS (In Feet)**

| TYPES OF CONSTRUCTION | | | | |
|---|---|---|---|---|
| I-F.R. | II-F.R. | II One-hour | III One-hour | II-N |
| Unlimited | 240 | 100 | 65 | 85 |



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# Chapter 11

# AGRICULTURAL BUILDINGS

## Scope

**Sec. 1107.** The provisions of this appendix shall apply exclusively to agricultural buildings. Such buildings shall be classified as a Group M, Division 3 Occupancy and shall include the following uses:

1. Storage, livestock and poultry.
2. Milking barns.
3. Shade structures.
4. Horticultural structures (greenhouse and crop protection).

## Construction, Height and Allowable Area

**Sec. 1108.** (a) **General.** Buildings classed as a Group M, Division 3 Occupancy shall be of one of the types of construction specified in this code and shall not exceed the area or height limits specified in Sections 505, 506 and 507 and Table No. A-11-A.

(b) **Special Provisions.** The area of a Group M, Division 3 Occupancy in a one-story building shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet in width, regardless of the type of construction.

The area of a two-story Group M, Division 3 Occupancy shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet in width and is provided with an approved automatic sprinkler system throughout, conforming to U.B.C. Standard No. 38-1.

Buildings using plastics shall comply with Type V-N construction. Plastics shall be approved plastics as defined in Chapter 4 and regulated by Chapter 52. For foam plastic, see Section 1712.

**EXCEPTIONS:** 1. When used as skylights or roofs, the areas of plastic skylights shall not be limited.

2. Except where designs must consider snow loads, plastics less than 20 mils thick may be used without regard to structural considerations. The structural frame of the building, however, shall comply.

## Occupancy Separations

**Sec. 1109.** Occupancy separations shall be as specified in Section 503 and Table No. A-11-B.

## Exterior Walls and Openings

**Sec. 1110.** Except where Table No. 17-A requires greater protection, exterior walls of agricultural buildings shall be not less than one-hour fire-resistive construction when less than 20 feet from property line.

Openings in exterior walls of agricultural buildings which are less than 20 feet from property lines shall be protected by fire assemblies having a fire-protection rating of not less than three-fourths hour.



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## Exit Facilities

**Sec. 1111.** Exit facilities shall be as specified in Chapter 33.

**EXCEPTIONS:** 1. The maximum distance of travel from any point in the building to an exterior exit door, horizontal exit, exit passageway or an enclosed stairway shall not exceed 300 feet.

2. One exit is required for each 15,000 square feet of floor area and fraction thereof.

3. Exit openings shall be not less than 2 feet 6 inches by 6 feet 8 inches.



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## TABLE NO. A-11-A—BASIC ALLOWABLE AREA FOR A GROUP M, DIVISION 3 OCCUPANCY, ONE STORY IN HEIGHT AND MAXIMUM HEIGHT OF SUCH OCCUPANCY

| I | II | | | III and IV | | V | |
|---|---|---|---|---|---|---|---|
| | F-R | One-Hour | N | One-Hour or Type IV | N | One-Hour | N |
| **ALLOWABLE AREA[1]** | | | | | | | |
| Unlimited | 60,000 | 27,100 | 18,000 | 27,100 | 18,000 | 21,100 | 12,000[1] |
| **MAXIMUM HEIGHT IN STORIES[2]** | | | | | | | |
| Unlimited | 12 | 4 | 2 | 4 | 2 | 3 | 2 |

[1]See Section 1108 for unlimited area under certain conditions.

[2]For maximum height in feet, see Chapter 5, Table No. 5-D.

## TABLE NO. A-11-B—REQUIRED SEPARATIONS BETWEEN GROUP M, DIVISION 3 AND OTHER OCCUPANCIES
**(In Hours)**

| Occupancy | A | E | I | H[1] | B-1 | B-2 | B-3 | B-4 | R-1 | R-3 | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rating | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | N |

[1]See Chapter 9 for Group H, Division 1 Occupancies.



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# Chapter 12
# Division I
# REQUIREMENTS FOR GROUP R, DIVISION 3 OCCUPANCIES

## General

**Sec. 1221.** (a) **Purpose.** The purpose of this division is to provide minimum standards for the protection of life, limb, health, property, environment and for the safety and welfare of the consumer, general public and the owners and occupants of Group R, Division 3 Occupancies regulated by this code.

(b) **Scope.** The provisions of this division apply to the construction, prefabrication, alteration, repair, use, occupancy and maintenance of one- or two-family dwellings not more than three stories in height and their accessory structures.

## One and Two Family Dwelling Code Adopted

**Sec. 1222.** Buildings regulated by this division shall be designed and constructed to comply with the requirements of the One and Two Family Dwelling Code, 1986 edition, promulgated jointly by the International Conference of Building Officials; the Building Officials and Code Administrators International, Inc., and the Southern Building Code Congress International, Inc.

# Division II
# REQUIREMENTS FOR GROUP R, DIVISION 4 OCCUPANCIES

**This is a new division.**

## General

**Sec. 1223.** (a) **Purpose.** The purpose of this division is to provide minimum standards of safety for group care facilities.

(b) **Scope.** 1. **General.** The provisions of this division shall apply to buildings or portions thereof that are to be used for Group R, Division 4 Occupancies.

2. **Applicability of other provisions.** Except as specifically required by this division, Group R, Division 4 Occupancies shall meet all applicable provisions of this code.

(c) **Definitions.** For the purpose of this division, certain terms are defined as follows:

**GROUP R, DIVISION 4 OCCUPANCIES** shall be residential group care facilities for ambulatory, nonrestrained persons who may have a mental or physical impairment (each accommodating more than five and not more than 16 clients or residents, excluding staff).

**AMBULATORY PERSONS** are those capable of achieving mobility sufficient to exit without the assistance of another person.



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## Construction, Height and Allowable Area

**Sec. 1224.** (a) **General.** Buildings or portions of buildings classified as Group R, Division 4 may be constructed of any materials allowed by this code, shall not exceed two stories in height nor be located above the second story in any building, and shall not exceed 3,000 square feet in floor area per story except as provided in Sections 505, 506 and 507.

(b) **Special Provisions.** Group R, Division 4 Occupancies having more than 3,000 square feet of floor area above the first story shall be of not less than one-hour fire-resistive construction throughout.

(c) **Mixed Occupancies.** Group R, Division 4 Occupancies shall be separated from Group H Occupancies by a four-hour fire-resistive occupancy separation and shall be separated from all other occupancies by a one-hour fire-resistive occupancy separation.

**EXCEPTIONS:** 1. An occupancy separation need not be provided between a Group R, Division 4 Occupancy and a carport having no enclosed uses above, provided the carport is entirely open on two or more sides.

2. In the one-hour occupancy separation between a Group R, Division 4 and Group M, Division 1 Occupancy, the separation may be limited to the installation of materials approved for one-hour fire-resistive construction on the garage side and a self-closing, tight-fitting solid-wood door 1 3/8 inch in thickness will be permitted in lieu of a one-hour fire assembly. Fire dampers need not be installed in air ducts passing through the wall, floor or ceiling separating a Group R, Division 4 Occupancy from a Group M, Division 1 Occupancy, provided such ducts within the Group M Occupancy are constructed of steel having a thickness not less than 0.019 inch (No. 26 galvanized sheet gauge) and have no openings into the Group M Occupancy.

## Location on Property

**Sec. 1225.** Exterior walls located less than 3 feet from property lines shall be of one-hour fire-resistive construction. Openings shall not be permitted in exterior walls located less than 3 feet from property lines. For other requirements, see Section 504 and Part IV.

## Exits and Emergency Escapes

**Sec. 1226.** (a) **General.** Group R, Division 4 Occupancies shall be provided with exits as required by this section and Chapter 33 of this code.

(b) **Exits Required.** 1. **Number of exits.** Every story, basement or portion thereof housing a Group R, Division 4 Occupancy shall have not less than two exits.

**EXCEPTIONS:** 1. Basements used exclusively for the service of the building may have one exit. For the purpose of this exception, storage rooms, laundry rooms, maintenance offices and similar uses shall not be considered as providing service to the building.

2. Storage rooms, laundry rooms and maintenance offices not exceeding 300 square feet in floor area may be provided with only one exit.

2. **Distance to exits.** The maximum travel distance specified in Chapter 33 shall be reduced by 50 percent.



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(c) **Corridor Width.** Corridors shall be not less than 36 inches in width.

(d) **Stairways.** Stairways shall be constructed as required by Section 3306 of this code.

**EXCEPTION:** In buildings that are converted to a Group R, Division 4 Occupancy, existing stairways may have an 8-inch maximum rise, 9-inch minimum run and may be 30 inches in width.

(e) **Emergency Exit Illumination.** In the event of power failure, exit illumination shall be automatically provided from an emergency system. Emergency systems shall be supplied from storage batteries or an on site generator set and the system shall be installed in accordance with the requirements of the Electrical Code.

(f) **Emergency Escape.** Every sleeping room shall be provided with emergency escape or rescue facilities as required by Section 1204 of this code.

## Light, Ventilation and Sanitation

**Sec. 1227.** Light, ventilation and sanitation shall be as specified in Section 1205.

## Yards and Courts

**Sec. 1228.** Yards and courts shall be as specified in Section 1206.

## Room Dimensions

**Sec. 1229.** Room dimensions shall be as specified in Section 1207.

**Sec. 1230.** No requirements.

## Shaft Enclosures

**Sec. 1231.** Exits shall be enclosed as specified in Chapter 33.

Elevator shafts, vent shafts, dumbwaiter shafts, clothes chutes and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 1706.

## Fire-warning Systems

**Sec. 1232. Fire-warning Systems.** Basements, attached garages and all rooms in a Group R, Division 4 Occupancy shall be provided with smoke detectors except that kitchens and mechanical rooms shall be provided with approved heat detectors in lieu of smoke detectors. All detectors shall be installed in accordance with approved manufacturer's instructions. Detectors shall be mounted in an approved central location on the ceiling or wall of each room or space.

**EXCEPTION:** Detectors may be omitted in bathrooms and closets.

All detectors shall be connected to a sounding device or other detectors to provide an alarm which will be audible throughout the Group R, Division 4 Occupancy. Required detectors shall receive their primary power from the building wiring. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection.



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### Heating

**Sec. 1233.** All habitable rooms shall be provided with heating facilities capable of maintaining a room temperature of 70°F. at a point 3 feet above the floor.

### Special Hazards

**Sec. 1234.** (a) **Heating Equipment.** All heating equipment shall be permanently installed. Chimneys and heating apparatus shall conform to the requirements of Chapter 37 of this code and the Mechanical Code.

(b) **Flammable Liquids.** The storage and handling of gasoline, fuel oil or other flammable liquids shall be in accordance with the Fire Code.



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# Chapter 23
# Division I
# SNOW LOAD DESIGN

**NOTE: This division has been revised in its entirety.**

## General

**Sec. 2315.** Buildings, structures and portions thereof shall be designed and constructed to sustain all dead loads plus live loads as provided by Table No. 23-C or snow loads as defined in this division where such snow loads will result in larger members or connections.

## Notations

**Sec. 2316.**

$a$ = Roof slope expressed in degrees.

$B$ = Width of projection measured parallel to ridge, ft. Minimum assumed width shall be 1 foot.

$C_e$ = Snow exposure factor (see Table No. A-23-S).

$C_s$ = Slope reduction factor.

$C_v$ = Valley design coefficient (see Figure No. A-11).

$D$ = Density of snow, pounds per cubic foot (pcf) (refer to Formula 21-2).

$F_s$ = Ice splitter horizontal load, lbs.

$F_v$ = Ice splitter snow weight, lbs.

$h_b$ = Height of balanced snow load on lower roof or deck, ft.

$h_d$ = Maximum height of drift surcharge, ft. (refer to Formula 21-1).

$h_g$ = Depth of ground snow (as determined by the building official), ft.

$h_r$ = Difference in height between the upper and lower roof or deck, ft.

$I$ = Importance faetor (see Table No. A-23-T).

$L$ = Horizontal distance between projection and ridge, ft.

$P_f$ = Minimum roof snow load, pounds per square foot (psf).

$P_g$ = Basic ground snow load, pounds per square foot (psf).

$P_m$ = Maximum intensity of the load at the height change, pounds per square foot (psf).

$S$ = Horizontal separation between adjacent structures, ft. (see Figure No. A-7).

$W_b$ = Horizontal dimension in feet of upper roof normal to the line of change in roof level, but not less than 50 feet, nor greater than 500 feet.

$W_d$ = Width of drift, base of triangular drift load, ft.

$X$ = Vertical component of roof slope (rise), ft.

$Y$ = Horizontal component of roof slope (run), ft.



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## Ground Snow Loads

**Sec. 2317.** The ground snow load, $P_g$, to be used in the determination of design snow loads for buildings and other structures shall be as shown in Figures Nos. A-5-A, A-5-B and A-5-C. For the hatched areas in Figure No. A-5-A, the basic ground snow loads shall be determined by the building official. The ground snow load, $P_g$ may be adjusted by the building official when a registered engineer or architect submits data substantiating the adjustments.

## Roof Snow Loads

**Sec. 2318.** The value of roof (or other member) snow load, $P_f$, shall be determined by the following formula:

$$P_f = C_e I P_g \quad \text{.....(18-1)}$$

where $C_e$ is given in Table No. A-23-S and $I$ is given in Table No. A-23-T.

The roof snow load shall be assumed to act vertically upon the area projected upon a horizontal plane. The horizontal projection of inclined walls as defined in Section 424 need not be considered in snow load design.

Roof snow loads between 20 pounds per square foot and 70 pounds per square foot may be multiplied by $C_s$ given in the formula:

$$C_s = 1 - \frac{(a - 30)}{40} \text{ for unobstructed slippery surfaces} \quad \text{.....(18-2A)}$$

$$C_s = 1 - \frac{(a - 45)}{25} \text{ for all other surfaces.} \quad \text{.....(18-2B)}$$

Roof snow loads greater than 70 pounds per square foot may be reduced for each degree of slope over 20 degrees by $R_s$, as determined by the following formula:

$$R_s = \frac{P_f}{40} - \frac{1}{2} \quad \text{.....(18-2C)}$$

Where $R_s$ = snow reduction in pounds per square foot per degree of roof slope over 20 degrees.

The following conditions must be met before using Formulas (18-2A), (18-2B) and (18-2C):

1. The height of all eaves exceeds $h_g$, and;
2. There are no obstructions adjacent to the structure for a distance $h_g$ measured from the eave normal to the ridge line.

   Where the eave height is less than $h_g$ but greater than $h_g/2$, and the above condition is met, the roof snow load may be reduced by 50 percent of the reductions allowed by the applicable formula (18-2A), (18-2B) or (18-2C).
3. If $P_g$ is 20 pounds per square foot or less, design roof snow load must not be



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less than $P_g$. If $P_g$ exceeds 20 pounds per square foot, design roof snow load must not be less than 20 pounds per square foot.

4. Reduced roof loads where $P_g$ exceeds 70 pounds per square foot shall not be less than those obtained through use of Formula (18-2A) for $P_g$ equal to 70 pounds per square foot.

Where the eave height is less than $h_g$ but greater than $h_g/2$ and conditions 1 and 3 above are met, the roof snow load may be multiplied by $C_s$ determined from the formula:

$$C_s = 1 - \frac{(a - 30)}{80} \quad \text{.....(18-2D)}$$

## Unbalanced Snow Loads, Gable Roofs

**Sec. 2319.** (a) **General.** In addition to the balanced load condition, unbalanced loading shall be considered for gable roofs in accordance with this section:

(b) **Single-gable Roofs.** Single-gable roofs with slopes greater than 1/2:12 and less than 3:12 shall be designed to sustain a uniformly distributed load of 0.5 $P_f$ acting on one slope and 1.0 $P_f$ on the opposite slope. Roofs with slopes greater than 3:12 shall be designed to sustain a uniformly distributed load equal to 1.25 $P_f$ applied to one slope only.

(c) **Multiple-gable Roofs.** 1. **With parallel ridge lines.** For multiple-gable roofs with parallel ridge lines having slopes exeeeding 2:12, the roof snow load shall be increased from one-half the applicable uniform roof load at the ridge ($0.5P_f$) to three times the uniform load at the valley (3.0 $P_f$).

2. **With nonparallel ridge lines.** Structural members at roof valleys where the slope is 3:12 or greater shall be designed for $P_f$ times $C_v$ and the distribution of loads is as shown in Figures Nos. A-13 and A-14 where $C_v$ shall be determined from Figure No. A-12.

## Special Eave Requirements

**Sec. 2320.** Eave overhanging roof structures shall be designed to sustain a uniformly distributed load of 2.0 $P_f$, or as determined by the building official, to account for ice dams and snow accumulation as shown in Figure No. A-11. Heat strips or other exposed heat methods may not be used in lieu of this design criterion. For shingle or shake roofs, hot or cold underlayment roofing is required on all roofs from the building edge for a distance of 5 feet or to the ridge, whichever is less. All building exits under down-slope eaves shall be protected from sliding snow and ice.

## Drift Loads on Lower Roofs, Decks and Roof Projections

**Sec. 2321.** (a) **General.** Multilevel roofs, lower roofs and decks of adjacent structures and roofs adjacent to projections shall be designed in accordance with this section.

(b) **Drift Loads for Lower Roofs.** The drift load on lower roofs or decks shall



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be taken as the triangular loading surcharge superimposed on the minimum roof snow load, $P_f$, (see Figures Nos. A-6, A-7, A-8 and A-10).

The height of the drift $h_d$ shall be determined by the following formula:

$$h_d = \sqrt{\frac{W_b P_f}{8D}} \quad \text{(21-1)}$$

except that $h_d$ need not exceed $(h_r - h_b)$ and $P_f$ is evaluated on the basis of the upper roof.

For the purpose of evaluating the height of snow drift, ground and roof snow, the snow density $D$ shall be calculated from the formula:

$$D = 0.24 P_g + 9.0 \leq 40 \text{ pcf} \quad \text{(21-2)}$$

The width of the drift $W_d$ in feet shall be taken as the smaller of $4h_d$ or $4(h_r - h_b)$. Drift loads need only be considered when:

$$\frac{h_r - h_b}{h_b} > 0.2 \quad \text{(21-3)}$$

**WHERE:**

$$h_b = \frac{P_f}{D}$$

where $P_f$ is evaluated on the basis of the lower roof. The maximum intensity, $P_m$, of the snow load at the high point of the drift shall be determined from the formula:

$$P_m = D(h_d + h_b) \quad \text{(21-4)}$$

except that $P_m$ need not exceed $Dh_r$.

(c) **Roof of an Adjacent Lower Structure.** Drifts may occur on lower roofs of structures sited within 20 feet of a higher structure as depicted in Figure No. A-7. The height of the surcharge on the lower structure shall be taken as $h_d$ multiplied by (20-$S$)/20 to account for the horizontal separation between structures, $S$, in feet.

(d) **Sliding Snow.** Lower roofs which are located below roofs having a slope greater than 2:12 shall be designed for an increase in drift height of $0.4h_d$, except that the total drift surcharge ($1.4h_d$) shall not exceed the height of the roof above the uniform snow depth ($h_r - h_b$). Sliding snow need not be considered if the lower roof is separated a distance, $S$, greater than $h_r$ or 20 feet as shown in Figures Nos. A-7 and A-8.

(e) **Roof Projections.** Mechanical equipment, penthouses, parapets and other projections above the roof can produce drifting as depicted in Figure No. A-9. Such drift loads shall be calculated on all sides of projections having horizontal dimensions exceeding 15 feet. The value of $W_b$ shall be taken as the maximum distance from the projection to the edges of the roof, or 50 feet, whichever is less.



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(f) **Intersecting Drifts.** When one snow drift intersects another at an angle as depicted in Figure No. A-10, the maximum unit pressure of the drift shall be taken as the greater of the two individual drifts, but not the sum of the two. The total load on the area of intersection is increased, however, simply beeause of the assumed geometry of the interseeting drifts.

### Rain on Snow

**Sec. 2322.** In geographie areas where intense rains may add to the roof snow load, the building official may require the use of an additional rain on snow surcharge of 5 pounds per square foot. This surcharge may be disregarded where roof slopes exceed 1/2 inch in 12 inches or where the basic ground snow load, $P_g$, exceeds 50 lbs./ft.$^2$. See Section 2305 (f) for ponding.

### Deflections

**Sec. 2323.** For roof slopes less than 1/2 inch in 12 inches, the deflection of any structural member shall not exceed L/180 evaluated on the basis of roof snow loads plus $K$ times dead load, where $K$ is defined in Table No. 23-D.

### Impact Loads

**Sec. 2324.** Whenever $P_g$ exceeds 70 pounds per square foot, structures which could be subjected to impact loads (snow unloading from a higher roof) shall be designed for impact loading. Drift loads and impact loads need not be considered cumulatively. Positive connections shall be provided for all members subject to impact loads.

### Vertical Obstructions

**Sec. 2325.** Whenever $P_g$ exceeds 70 pounds per square foot, roof projections which could be subjected to sliding ice or snow shall be protected with ice splitters or crickets, or shall be designed for these forces. These conditions apply whenever the roof slope is 3:12 or greater (except those projections within 36 inches of the ridge). All ice splitters shall be constructed the full width of the projection base (see Figure No. A-15).

Ice splitters shall be designed for a horizontal force $F_s$ and the resultant moment produced from $F_s$ being applied at midheight of the splitter given by

$$F_s = \frac{F_v X}{\sqrt{X^2 + Y^2}} \qquad (25\text{-}1)$$

**WHERE:**

$$F_v = L(0.5L + B)P_f$$

The projection width, $B$, shall not exceed 6 feet where the roof slope is greater than 2:12 unless approved by the building official. Chimneys and similar projections at or near the eave of a roof shall have footings and roof/wall ties designed to resist the force of the sliding snow. Cross-grain bending of wood ledgers and edge nailing of plywood shall not be considered to resist such forces. Snow melting equipment shall not be considered to reduce the required design loads.



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## TABLE NO. A-23-S—SNOW EXPOSURE COEFFICIENT ($C_e$)[1,2]

| | |
|---|---|
| 1. Roofs located in generally open terrain extending one-half mile or more from the structure. | 0.6 |
| 2. Structures located in densely forested or sheltered areas. | 0.9 |
| 3. All other structures. | 0.7 |

[1]The building official may determine this coefficient for specific structures with special local conditions. For Alaska, Arizona and Hawaii, the coefficient shall be determined by the building official.

[2]For roofs at or near grade with slopes less than 3:12 or decks at or near grade, $C_e = 1.0$.

## TABLE NO. A-23-T—VALUES FOR OCCUPANCY IMPORTANCE FACTOR *I*

| TYPE OF OCCUPANCY | *I* SNOW |
|---|---|
| 1. Essential facilities.[1] | 1.15 |
| 2. Any building where the primary occupancy is for assembly use for more than 300 persons (in one room). | 1.15 |
| 3. Agricultural buildings and other miscellaneous structures. | 0.9 |
| 4. All others. | 1.0 |

[1]See Section 2312 (k) for definition and additional requirements for essential facilities.



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In these areas extreme local variations in snow loads preclude mapping at this scale; ground snow load, $P_g$, shall be established by the building official.

The zoned value is not appropriate for certain geographic settings, such as high country, in these areas; ground snow load, $P_g$, shall be established by the building official.

In these areas ground snow load, $P_g$, shall be established by the building official.

Those areas shown as zero, 5 and 10 are for information only.

**FIGURE NO. A-5-A—GROUND SNOW LOAD, $P_g$, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR WESTERN UNITED STATES (Pounds per square foot)**



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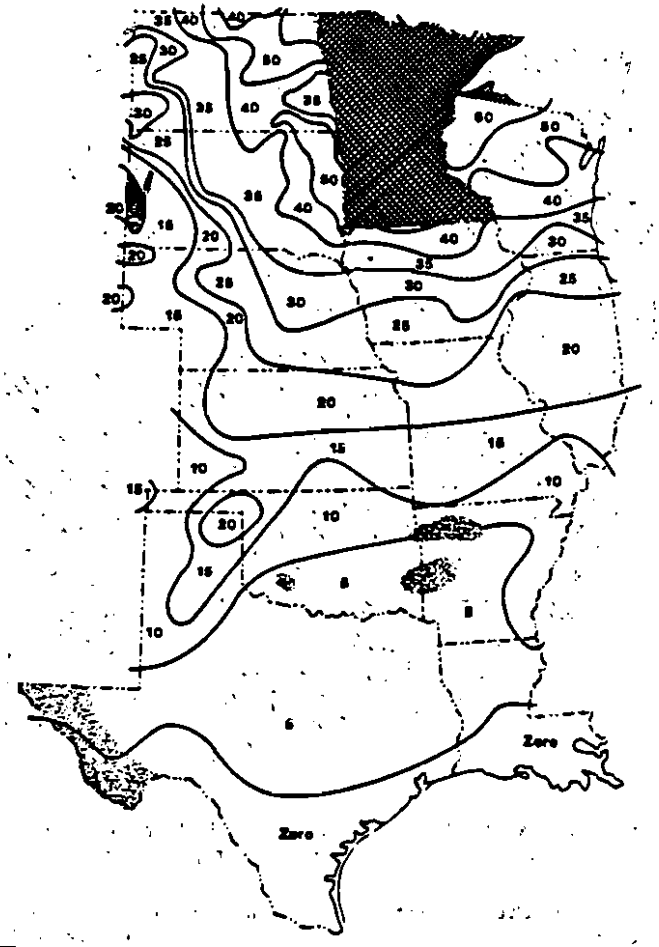


Those areas shown as zero, 5 and 10 are for information only.

In these areas extreme local variations in snow loads preclude mapping at this scale; ground snow load, $P_g$, shall be established by the building official.

The zoned value is not appropriate for certain geographic settings, such as high country, in these areas; ground snow load, $P_g$, shall be established by the building official.

**FIGURE NO. A-5-B—GROUND SNOW LOAD, $P_g$, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR THE CENTRAL UNITED STATES (Pounds per square foot)**



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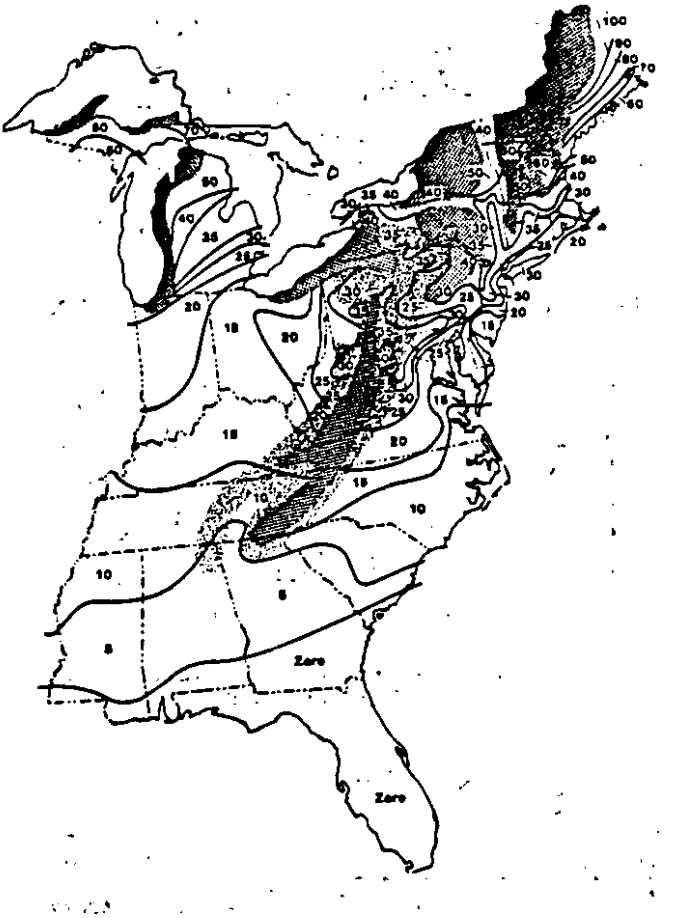


Those areas shown as zero, 5 and 10 are for information only.

In these areas extreme local variations in snow loads preclude mapping at this scale; ground snow load, $P_g$, shall be established by the building official.

The zoned value is not appropriate for certain geographic settings, such as high country, in these areas; ground snow load, $P_g$, shall be established by the building official.

**FIGURE NO. A-5-C—GROUND SNOW LOAD, $P_g$, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR THE EASTERN UNITED STATES (Pounds per square foot)**



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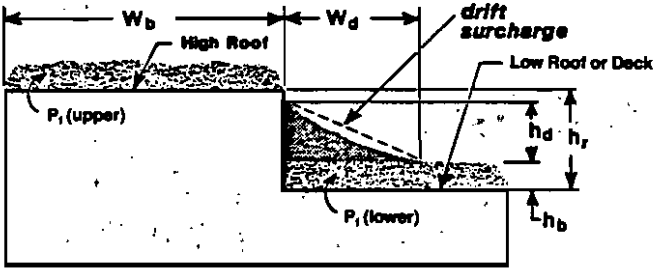


FIGURE NO. A-6—DRIFTING SNOW ON LOW ROOFS AND DECKS

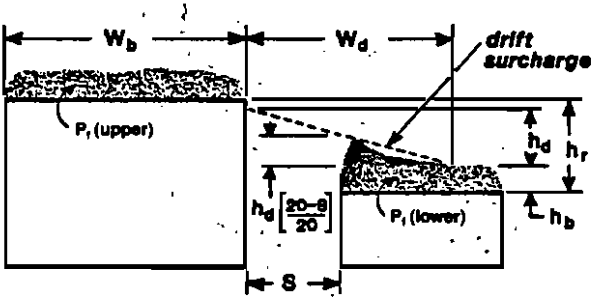


FIGURE NO. A-7—DRIFTING SNOW ONTO ADJACENT LOW STRUCTURES

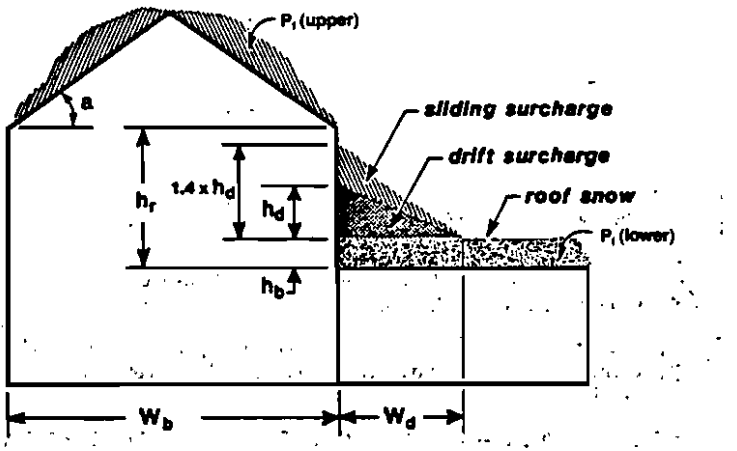


FIGURE NO. A-8—ADDITIONAL SURCHARGE DUE TO SLIDING SNOW



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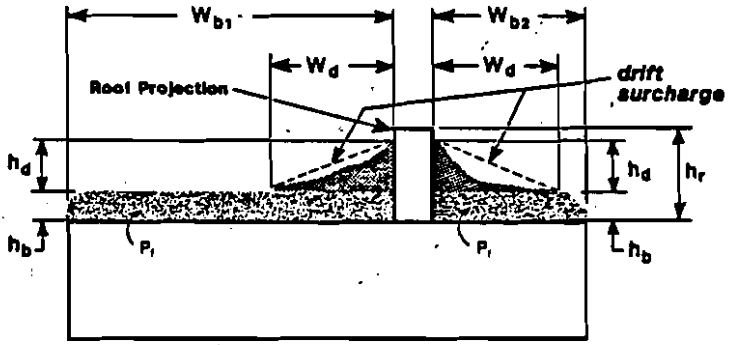


FIGURE NO. A-9—SNOW DRIFTING AT ROOF PROJECTIONS

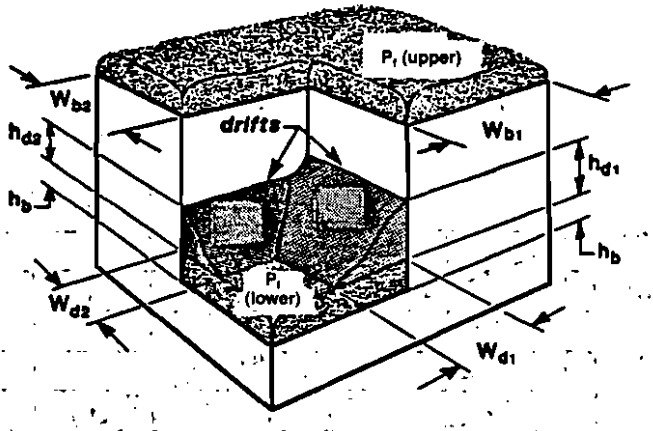


FIGURE NO. A-10—INTERSECTING SNOW DRIFTS

**NOTE:**

$$h_{d1} = \sqrt{\frac{W_{b1} P_f}{8D}}$$

$$h_{d1} = \sqrt{\frac{W_{b2} P_f}{8D}}$$

$P_f$ is evaluated on the basis of upper roof



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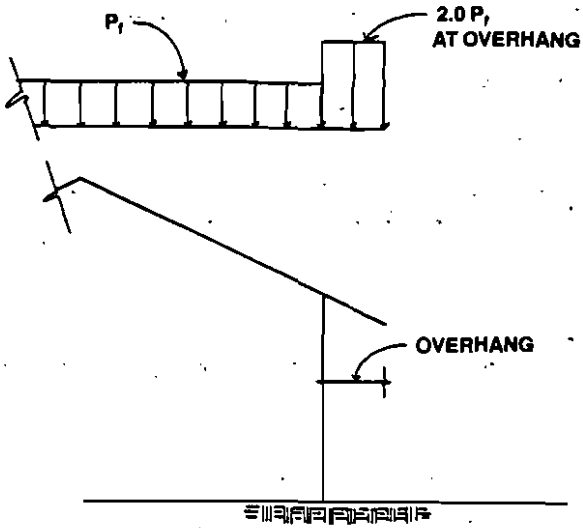


FIGURE NO. A-11—OVERHANG LOADS

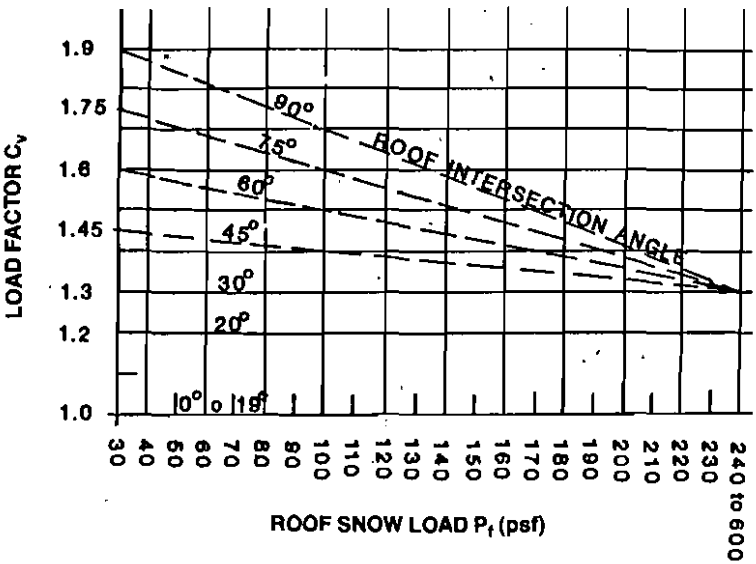


FIGURE NO. A-12—VALLEY COEFFICIENT, $C_v$



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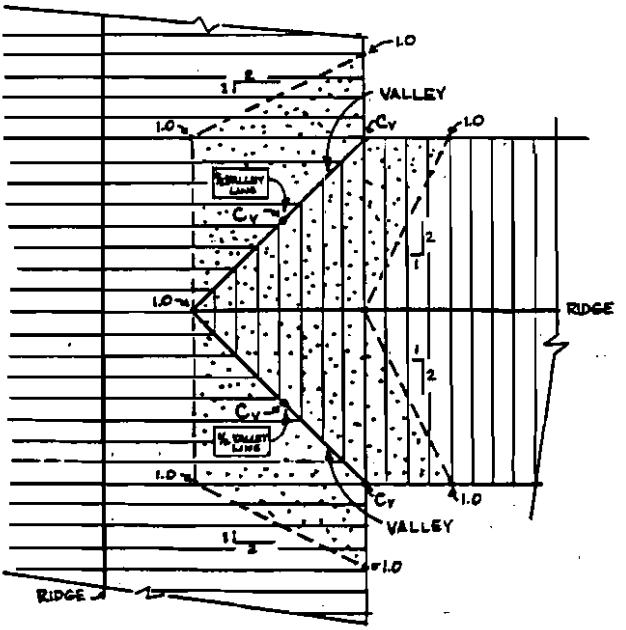


DENOTES INCREASED LOAD AREA:

1. Load is constant on lines connecting points noted 1.0.
2. Load is constant on lines connecting points noted $C_v$.
3. Load varies linearly between 1.0 & $C_v$.

**FIGURE NO. A-13—VALLEY DESIGN COEFFICIENTS $C_v$**



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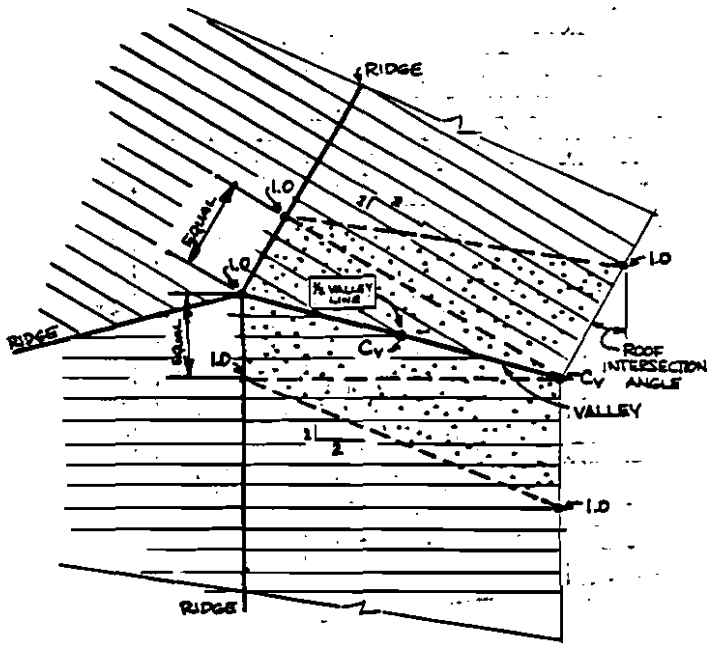


DENOTES INCREASED LOAD AREA:

1. Load is constant on lines connecting points noted 1.0.
2. Load is constant on lines connecting points noted $C_v$.
3. Load varies linearly between 1.0 & $C_v$.

**FIGURE NO. A-14—VALLEY DESIGN COEFFICIENTS $C_v$**



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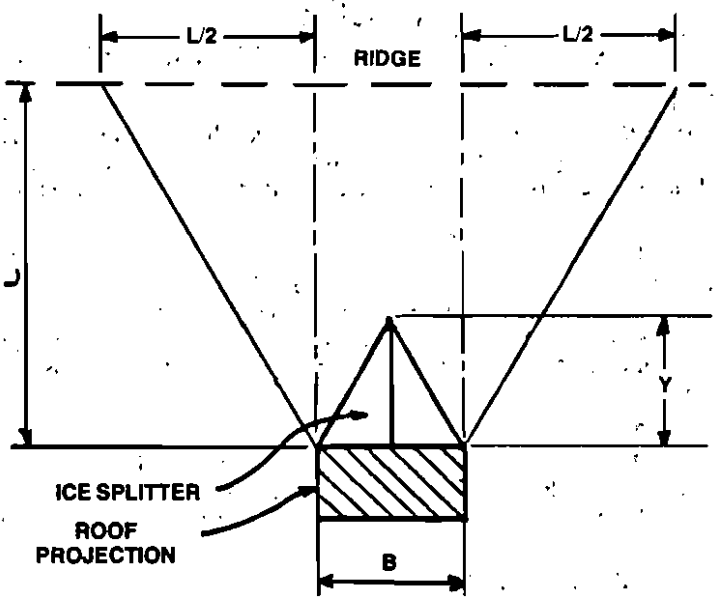


FIGURE NO. A-15—ICE SPLITTER—PLAN VIEW



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# Division II
# EARTHQUAKE RECORDING INSTRUMENTATION

## General

**Sec. 2326.** In Seismic Zones No. 3 and No. 4 every building over six stories in height with an aggregate floor area of 60,000 square feet or more, and every building over 10 stories in height regardless of floor area, shall be provided with not less than three approved recording accelerographs.

## Location

**Sec. 2327.** The instruments shall be located in the basement, midportion, and near the top of the building. Each instrument shall be located so that access is maintained at all times and is unobstructed by room contents. A sign stating "Maintain Clear Access to This Instrument" shall be posted in a conspicuous location.

## Maintenance

**Sec. 2328.** Maintenance and service of the instruments shall be provided by the owner of the building, subject to the approval of the building official. Data produced by the instruments shall be made available to the building official upon his request.

## Instrumentation of Existing Buildings

**Sec. 2329.** All owners of existing structures selected by the jurisdiction authorities shall provide accessible space for the installation of appropriate earthquake-recording instruments. Location of said instruments shall be determined by the jurisdiction authorities. The jurisdiction authorities shall make arrangements to provide, maintain and service the instruments. Data shall be the property of the jurisdiction, but copies of individual records shall be made available to the public upon request and the payment of an appropriate fee.

## SEISMIC ZONE TABULATION
## For Areas Outside the United States

| Location | Seismic Zone |
|---|---|
| ASIA | |
| Turkey | |
| Ankara | 2 |
| Karamursel | 3 |
| ATLANTIC OCEAN AREA | |
| Azores | 2 |
| Bermuda | 1 |
| CARIBBEAN SEA | |
| Bahama Islands | 1 |
| Canal Zone | 2 |
| Leeward Islands | 3 |
| Puerto Rico | 3 |
| Trinidad Island | 2 |
| NORTH AMERICA | |
| Greenland | 1 |
| Iceland | |
| Keflavik | 3 |

| Location | Seismic Zone |
|---|---|
| PACIFIC OCEAN AREA | |
| Caroline Island | |
| Koror, Paulau | 2 |
| Ponape | 0 |
| Johnston Island | 1 |
| Kwajalein | 1 |
| Mariana Islands | |
| Guam | 3 |
| Saipan | 3 |
| Tinian | 3 |
| Marcus Island | 1 |
| Okinawa | 3 |
| Philippine Islands | 3 |
| Samoa Islands | 3 |
| Wake Island | 0 |



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# Chapter 26

# PROTECTION OF RESIDENTIAL CONCRETE EXPOSED TO FREEZING AND THAWING

**NOTE: New appendix chapter.**

## General

**Sec. 2628.** (a) **Purpose.** The purpose of this appendix is to provide minimum standards for the protection of residential concrete exposed to freezing and thawing conditions.

(b) **Scope.** The provisions of this appendix apply to concrete used in buildings of Group R and Group M Occupancies which are three stories or less in height.

(c) **Special Provisions.** Normal-weight aggregate concrete used in buildings of Group R and Group M Occupancies three stories or less in height which are subject to deicer chemicals or freezing and thawing conditions as determined from Figure No. A-26-1 shall comply with the requirements of Table No. A-26-A.

**TABLE NO. A-26-A**
**MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE[1]**

| TYPE OR LOCATION OF CONCRETE CONSTRUCTION | MINIMUM SPECIFIED COMPRESSIVE STRENGTH[2] ($f'_c$) | | |
|---|---|---|---|
| | Weathering Potential[3] | | |
| | Negligible | Moderate | Severe |
| Basement walls and foundations not exposed to the weather | 2,500 | 2,500 | 2,500[4] |
| Basement slabs and interior slabs on grade, except garage floor slabs | 2,500 | 2,500 | 2,500[4] |
| Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather | 2,500 | 3,000[5] | 3,000[5] |
| Porches, carport slabs and steps exposed to the weather, and garage floor slabs | 2,500 | 3,000[5] | 3,500[5] |

[1]Increases in compressive strength above those used in the design shall not cause implementation of the special inspection provisions of Section 306 (a) 1.

[2]At 28 days psi.

[3]See Figure No. A-26-1 for weathering potential.

[4]Concrete in these locations which may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with Footnote 5.

[5]Concrete shall be air entrained. Total air content (percent by volume of concrete) shall be not less than 5 percent nor more than 7 percent.



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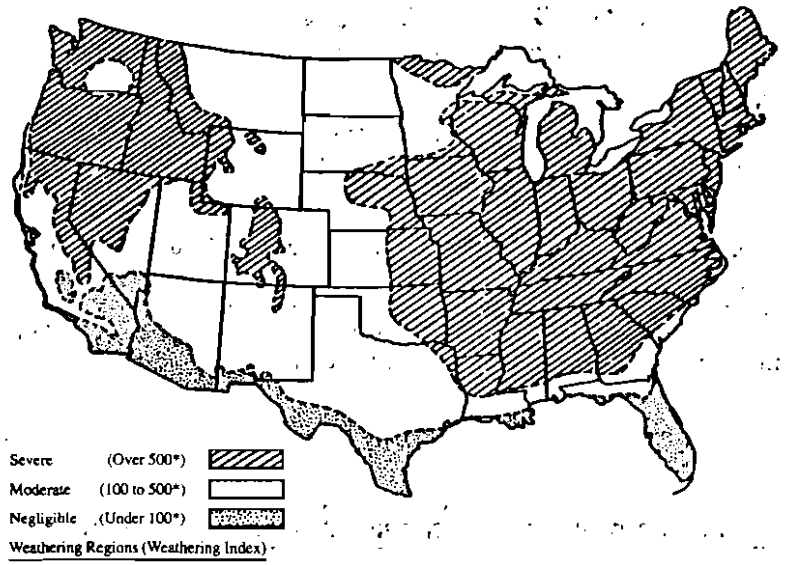
## WEATHERING PROBABILITY MAP FOR CONCRETE




*Index in day-inches, multiply by 25.4 to convert to day-mm

**FIGURE NO. A-26-1**

**Notes:**

1. Lines defining areas are approximate only. Local conditions may be more or less severe than indicated by the region classification.
2. Data needed to determine the weathering index for any locality may be found or estimated from the tables of Local Climatological Data, published by the Weather Bureau, U.S. Department of Commerce.
3. The weathering index for any locality is the product of the average annual number of freezing-cycle days and the average annual winter rainfall in inches, defined as follows:

   A freezing-cycle day is any day during which the air temperature passes either above or below 32°F. The average number of freezing-cycle days in a year may be taken to equal the difference between the mean number of days during which the minimum temperature was 32°F. or below and the mean number of days during which the maximum temperature was 32°F. or below.

   Winter rainfall is the sum, in inches, of the mean monthly corrected precipitation (rainfall) occurring during the period between and including the normal date of the first killing frost in the fall and the normal date of the last killing frost in the spring. The winter rainfall for any period is equal to the total precipitation less one tenth of the total fall of snow, sleet and hail. Rainfall for a portion of a month is prorated.

   The map indicates general areas of the United States in which concrete is subject to severe, moderate and mild weathering. The severe weathering region has a weathering index greater than 500. The moderate weathering region has a weathering index of 100 to 500. The mild weathering region has a weathering index of less than 100.



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# Chapter 32
# RE-ROOFING

**NOTE: This chapter has been revised in its entirety.**

## General

**Sec. 3209.** All re-roofing shall conform to the applicable provisions of Chapter 32 of this code.

Roofing materials and methods of application shall comply with the U.B.C. Standards or shall follow manufacturer's installation requirements when approved by the building official.

## Inspections

**Sec. 3210.** New roof coverings shall not be applied without first obtaining an inspection by the building official and written approval from the building official. A final inspection and approval shall be obtained from the building official when the re-roofing is complete. The pre-roofing inspection shall pay particular attention to evidence of accumulation of water. Where extensive ponding of water is apparent, an analysis of the roof structure for compliance with Section 3207 shall be made and corrective measures, such as relocation of roof drains or scuppers, resloping of the roof or structural changes, shall be made.

An inspection covering the above-listed topics prepared by a special inspector may be accepted in lieu of the preinspection by the building official.

## Built-up Roofs

**Sec. 3211.** (a) **General.** Built-up roof covering shall be completely removed before applying the new roof covering. New roofing conforming to Section 3203 shall be applied except that when the new roof is to be applied directly to a nailable deck which has residual bitumen adhering to it, a rosin-sized or other dry sheet shall be installed prior to the installation of the new roof system.

**EXCEPTION:** The building official may allow existing roof coverings to remain when inspection or other evidence reveals all of the following:

1. That the roof structure is sufficient to sustain the weight of the additional dead load of the roof covering.
2. There is not more than one existing roof covering on the structure.
3. The existing roof covering is securely attached to the deck.
4. The roof deck is structurally sound.
5. The existing insulation is not water soaked.

(b) **Preparation of Roof and Application of New Covering.** 1. **General.** When re-roofing without removal of existing roof coverings is permitted by the building official and when the conditions specified in the exceptions to Subsection (a) above have been met, the re-roofing shall be accomplished in accordance with this section.

2. **Over gravel-surfaced roof coverings.** Over gravel-surfaced roof coverings, the roof shall be cleaned of all loose gravel and debris. All blisters, buckles



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and other irregularities shall be cut and made smooth and secure. Minimum 3/8-inch insulation board shall be nailed or securely cemented to the existing roofing with hot bitumen over which a new roof complying with Section 3203 shall be installed. When insulation board is to be attached with hot bitumen, the existing surface shall be primed.

Alternatively, on nailable decks only, all existing gravel shall be spudded off to provide a smooth surface. All blisters, buckles and other irregularities shall be cut and made smooth and secure. A rosin-sized or other dry sheet shall be installed and a base sheet as defined in the code shall be mechanically fastened in place. New roofing conforming to Section 3203 shall be applied.

3. **Over smooth or cap-sheet surface.** Over smooth or cap-sheet surfaced roof coverings, all blisters, buckles and other irregularities shall be cut and made smooth and secure. In the case of non-nailable decks, a base sheet shall be spot cemented to the existing roofing. New roofing conforming to Section 3203 shall be applied.

In the case of nailable decks, a base sheet shall be nailed in place. In those cases where residual materials may cause the new base sheet to adhere to the old roof, a rosin-sized dry or other sheet shall be installed under the base sheet. New roofing conforming to Section 3203 shall be applied.

(c) **Construction Details.** 1. **Flashings and edgings.** Vent flashings, metal edgings, drain outlets, metal counterflashing and collars shall be removed and cleaned. Rusted metal shall be replaced. Metal shall be primed with cutback primer prior to installation. Collars and flanges shall be flashed per the roofing manufacturer's instructions.

2. **Intersecting walls.** All concrete and masonry walls shall be completely cleaned and primed to receive new flashing. All vertical walls, other than concrete or masonry, shall have the surface finish material removed to a height of approximately 6 inches above the deck new roof surface to receive new roofing and flashing. All rotted wood shall be replaced with new materials. Surface finish material shall be replaced.

3. **Parapets.** Parapets of area separation walls shall have noncombustible faces, including counterflashing and coping materials.

**EXCEPTION:** Combustible roofing may extend 7 inches above the roof surface.

4. **Cant strips.** Where space permits, cant strips shall be installed at all angles. All angles shall be flashed with at least two more layers than in the new roof with an exposed finish layer of inorganic felt or mineral surfaced cap sheet.

## Shingles and Shakes

**Sec. 3212.** (a) **General.** Based on inspection of the existing roofing, the building official may permit the recovering of existing shingle or shake roofing in accordance with the provisions of this section.

(b) **Asphalt Shingle Application.** Not more than two overlays of asphalt shingles shall be applied over an existing asphalt shingle roof.



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Not more than two overlays of asphalt shingle roofing shall be applied over wood shingles. Asphalt shingles applied over wood shingles shall have an overlay underlayment of not less than Type 30 nonperforated felt.

On structures with a slope of 2:12 or greater and having no more than one existing built-up roof, one overlay of asphalt shingles may be applied, provided (1) If the built-up roof has a gravel surface, the gravel must first be spudded off to provide a smooth surface. All blisters and irregularities shall be cut and made smooth and secure and an underlayment of not less than Type 30 nonperforated felt shall be installed. (2) If the built-up roof has a smooth or cap-sheet surface, all blisters and irregularities shall be cut and made smooth and secure and an underlayment of not less than Type 30 nonperforated felt shall be installed.

(c) **Wood Shake Application.** Not more than one overlay of wood shakes shall be applied over an existing asphalt shingle or wood shingle roof (with one layer of 18-inch, Type 30 nonperforated felt interlaced between each layer of shakes).

(d) **Wood Shingle Application.** Not more than one overlay of wood shingles shall be applied over existing wood shingles.

(e) **Application Over Shakes.** New roof covering shall not be applied over an existing shake roof.

(f) **Flashing and Edgings.** Rusted or damaged flashing, vent caps and metal edgings shall be replaced with new materials as necessary.

### Tile

**Sec. 3213.** Tile roofs may be applied over existing roof coverings when approved by the building official. Such installations shall be substantiated by structural data indicating that the existing or modified roof framing system is adequate to support the additional tile roof covering.

Existing tile roofing shall be removed and cleaned. Damaged or rusted flashing and cracked or broken tile shall be replaced. Tile shall be applied in accordance with the requirements of Section 3208 (b) 5 (application of clay or concrete tile) and in conformance with the original manufacturer's specifications.

> **EXCEPTION:** When the original manufacturer's specifications are no longer available, the tile may be reinstalled to match the prior installation except that clay and terra-cotta hips and ridge tile shall be reinstalled with portland cement mortar.

### Metal Roofing

**Sec. 3214.** Reroofing with metal roofing shall be in accordance with the original manufacturer's specifications or when the original manufacturer's specifications are no longer available as required by Section 3208 (b) 6.

### Other Roofings

**Sec. 3215.** Re-roofing with systems not covered elsewhere in Chapter 32 or this appendix, such as, but not limited to, those that are fluid applied, foamed in place or applied as nonasphaltic sheets, shall be done with materials and procedures approved by the building official.



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# Chapter 35
# SOUND TRANSMISSION CONTROL

## Sound Transmission Control

**Sec. 3501.** (a) **General.** In Group R Occupancies, wall and floor-ceiling assemblies separating dwelling units or guest rooms from each other and from public space such as interior corridors and service areas shall provide airborne sound insulation for walls, and both airborne and impact sound insulation for floor-ceiling assemblies.

(b) **Airborne Sound Insulation.** All such separating walls and floor-ceiling assemblies shall provide an airborne sound insulation equal to that required to meet a Sound Transmission Class (STC) of 50 (45 if field tested) as defined in U.B.C. Standard No. 35-1.

Penetrations or openings in construction assemblies for piping, electrical devices, recessed cabinets, bathtubs, soffits, or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings.

Entrance doors from interior corridors together with their perimeter seals shall have a laboratory-tested Sound Transmission Class (STC) rating of not less than 26 and such perimeter seals shall be maintained in good operating condition.

(c) **Impact Sound Insulation.** All separating floor-ceiling assemblies between separate units or guest rooms shall provide impact sound insulation equal to that required to meet an Impact Insulation Class (IIC) of 50 (45 if field tested) as defined in U.B.C. Standard No. 35-2. Floor coverings may be included in the assembly to obtain the required ratings and must be retained as a permanent part of the assembly and may be replaced only by other floor covering that provides the same sound insulation required above.

(d) **Tested Assemblies.** Field or laboratory tested wall or floor-ceiling designs having an STC or IIC of 50 or more as determined by U.B.C. Standard No. 35-1, 35-2 or 35-3 may be used without additional field testing when, in the opinion of the building official, the tested design has not been compromised by flanking paths. Tests may be required by the building official when evidence of compromised separations is noted.

(e) **Field Testing and Certification.** Field testing, when required, shall be done under the supervision of a professional acoustician who shall be experienced in the field of acoustical testing and engineering and who shall forward certified test results to the building official that minimum sound insulation requirements stated above have been met.

(f) **Airborne Sound Insulation Field Tests.** When required, airborne sound insulation shall be determined according to the applicable Field Airborne Sound Transmission Loss Test procedures of U.B.C. Standard No. 35-3. All sound transmitted from the source room to the receiving room shall be considered to be transmitted through the test partition.

(g) **Impact Sound Insulation Field Test.** When required, impact sound insulation shall be determined in accordance with U.B.C. Standard No. 35-2.



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## Sound Transmission Control Systems.

**Sec. 3502.** Generic systems as listed in the Fire Resistance Design Manual, October, 1984, Eleventh Edition, as published by the Gypsum Association may be accepted where a laboratory test indicates that the requirements of Section 3501 are met by the system.



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# Chapter 38
# BASEMENT PIPE INLETS

## Basement Pipe Inlets

**Sec. 3807.** (a) **General.** All basement pipe inlets shall be installed in accordance with requirements of this section.

(b) **Where Required.** Basement pipe inlets shall be installed in the first floor of every store, warehouse or factory having basements.

**EXCEPTIONS:** 1. Where the basement is equipped with an automatic sprinkler system as specified in Section 3802.

2. Where the basement is used for the storage of permanent archives or valuables such as safe deposit vaults or similar uses adversely affected by water.

(c) **Location.** The location of basement pipe inlets shall be as required by the fire department.

(d) **Detailed Requirements.** All basement pipe inlets shall be of cast iron, steel, brass or bronze with lids of cast brass or bronze.

The basement pipe inlet shall consist of a sleeve not less than 8 inches inside diameter extending through the floor and terminating flush with or through the basement ceiling and shall have a top flange recessed with an inside shoulder to receive the lid. The top flange shall be installed flush with finish floor surface. The lid shall be a solid casting and have a lift recessed in the top. This lid shall be provided with a cast-in sign reading: "FIRE DEPARTMENT ONLY, DO NOT COVER." The lid shall be installed in such a manner to permit its easy removal from the flange shoulder.



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# Chapter 49
# PATIO COVERS

## Patio Covers Defined

**Sec. 4901.** Patio covers are one-story structures not exceeding 12 feet in height. Enclosure walls may have any configuration, provided the open area of the longer wall and one additional wall is equal to at least 65 percent of the area below a minimum of 6 feet 8 inches of each wall, measured from the floor. Openings may be enclosed with insect screening or plastic that is readily removable translucent or transparent plastic not more than 0.125 inch in thickness.

Patio covers may be detached or attached to other buildings as accessories to Group M, Group R, Division 3, or to single dwelling units in Group R, Division 1 Occupancies. Patio covers shall be used only for recreational, outdoor living purposes and not as carports, garages, storage rooms or habitable rooms.

## Design Loads

**Sec. 4902.** Patio covers shall be designed and constructed to sustain, within the stress limits of this code, all dead loads plus a minimum vertical live load of 10 pounds per square foot exeept that snow loads shall be used where such snow loads exceed this minimum. Such covers shall be designed to resist the minimum horizontal wind loads set forth in this code, except that where less than 12 feet high the horizontal wind load shall be as indicated in Table No. 49-A. In addition, they shall be designed to support a minimum wind uplift equal to the horizontal wind load acting vertical upward normal to the roof surface, except that for structures not more than 10 feet above grade the uplift may be three fourths of the horizontal wind load. When enclosed with insect screening or plastic that is readily removable translucent or transparent plastic not more than 0.125 inch in thickness, wind loads shall be applied to the structure, assuming it is fully enclosed.

## Light and Ventilation

**Sec. 4903.** Windows required for light and ventilation may open into a patio structure conforming to Section 4901.

## Footings

**Sec. 4904.** A patio cover may be supported on a concrete slab on grade without footings, provided the slab is not less than 3½ inches thick and further provided that the columns do not support live and dead loads in excess of 750 pounds per column.

**TABLE NO. 49-A—DESIGN WIND PRESSURES FOR PATIO COVERS[1]**

| HEIGHT ZONE IN FEET | WIND SPEED—MAP AREAS (Miles Per Hour) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 70 | 80 | 90 | 100 | 110 | 120 | 130 |
| Less than 12 | 10 | 13 | 15 | 19 | 23 | 27 | 32 |

[1]See Figure No. 1 in Chapter 23 for Basic Wind Speeds.



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# Chapter 51

# ELEVATORS, DUMBWAITERS, ESCALATORS AND MOVING WALKS

## Purpose

**Sec. 5107.** The purpose of this appendix is to safeguard life, limb, property and public welfare by establishing minimum requirements regulating the design, construction, alteration, operation and maintenance of elevators, dumbwaiters, escalators and moving walks and by establishing procedures by which these requirements may be enforced.

## Scope

**Sec. 5108.** This appendix shall apply to new and existing installations of elevators, dumbwaiters, escalators and moving walks, requiring permits therefore and providing for the inspection and maintenance of such conveyances.

## Definitions

**Sec. 5109.** For purposes of this appendix, certain terms are defined as follows:

**ANSI CODE** is the ANSI/ASME A17.1 Code—1984 with Supplements A17.1a-1985, A17.1b-1985, A17.1c-1986; A17.1d-1986 and A17.1e-1987 Safety Code for Elevators and Escalators, an American National Standard published by the American Society of Mechanical Engineers.

## Permits—Certificates of Inspection

**Sec. 5110.** (a) **Permits Required.** It shall be unlawful to hereafter install any new elevator, moving walk, escalator or dumbwaiter, or to make major alterations to any existing elevator, dumbwaiter, escalator or moving walk as defined in Part XII of the ANSI code, without having first obtained a permit for such installation from the building official. Permits shall not be required for maintenance or minor alterations.

(b) **Certificates of Inspection Required.** It shall be unlawful to operate any elevator, dumbwaiter, escalator or moving walk without a current Certificate of Inspection issued by the building official. Such certificate shall be issued upon payment of prescribed fees and the presentation of a valid inspection report indicating that the conveyance is safe and that the inspections and tests have been performed in accordance with Part X of the ANSI Code. Certificates shall not be issued when the conveyance is posted as unsafe pursuant to Section 5114.

**EXCEPTION:** Certificates of Inspection shall not be required for conveyances within a dwelling unit.

(c) **Application for Permits.** Application for a permit to install shall be made on forms provided by the building official, and the permit shall be issued to an owner upon payment of the permit fees specified in this section.

(d) **Application for Certificates of Inspection.** Application for a Certificate of Inspection shall be made by the owner of an elevator, dumbwaiter, escalator or moving walk. Applications shall be accompanied by an inspection report as



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described in Section 5113. Fees for Certificates of Inspection shall be as specified in this section.

(e) **Fees.** A fee for each permit or Certificate of Inspection shall be paid to the building official as follows:

New Installations:

Passenger or freight elevator, escalator, moving walk:

Up to and including $40,000 of valuation—$55.00

Over $40,000 of valuation—$55.00 plus $1.00 for each $1,000 or fraction thereof over $40,000

Dumbwaiter or private residence elevator:

Up to and including $10,000 of valuation—$15.00

Over $10,000 of valuation—$15.00 plus $1.00 for each $1,000 or fraction thereof over $10,000

Major Alterations:

Fees for major alterations shall be as set forth in Table No. 3-A.

Installation fees include charges for the first year's annual inspection fee and charges for electrical equipment on the conveyance side of the disconnect switch.

Annual Certificates of Inspection:

| | |
|---|---|
| For each elevator | $25.00 |
| For each escalator or moving walk | $15.00 |
| For each commercial dumbwaiter | $10.00 |

(Each escalator or moving walk unit powered by one motor shall be considered as a separate escalator or moving walk.)

## ANSI Code Adopted

**Sec. 5111.** All new elevators, dumbwaiters, escalators and moving walks and major alterations to such conveyances and the installation thereof shall conform to the requirements of the American National Standard Institute ANSI/ASME A17.1-1984 Safety Code for Elevators and Escalators, including Supplements A17.1a-1985, A17.1b-1985, A17.1c-1986, A17.1d-1986 and A17.1e-1987, published by the American Society of Mechanical Engineers.

## Design

**Sec. 5112.** For detailed design, construction and installation requirements, see Chapter 23 and the appropriate requirements of the ANSI Code.

In Seismic Zones Nos. 3 and 4, elevators shall conform to Appendix F of the ANSI Code.

## Requirements for Operation and Maintenance

**Sec. 5113.** (a) **General.** The owner shall be responsible for the safe operation and maintenance of each elevator, dumbwaiter, escalator or moving walk installation and shall cause periodic inspections, tests and maintenance to be made on such conveyances as required in this section.



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(b) **Periodic Inspections and Tests.** Routine and periodic inspections and tests shall be made as required by Part X of the ANSI Code.

(c) **Alterations, Repairs and Maintenance.** Alterations, repairs and maintenance shall be made as required by Part XII of the ANSI Code.

(d) **Inspection Costs.** All costs of such inspections and tests shall be paid by the owner.

(e) **Inspection Reports.** After each required inspection, a full and correct report of such inspection shall be filed with the building official.

## Unsafe Conditions

**Sec. 5114.** When an inspection reveals an unsafe condition, the inspector shall immediately file with the owner and the building official a full and true report of such inspection and such unsafe condition. If the building official finds that the unsafe condition endangers human life, he shall cause to be placed on such elevator, escalator or moving walk, in a conspicuous place, a notice stating that such conveyance is unsafe. The owner shall see to it that such notiee of unsafe condition is legibly maintained where placed by the building official. The building official shall also issue an order in writing to the owner requiring the repairs or alterations to be made to such conveyance which are necessary to render it safe and may order the operation thereof discontinued until the repairs or alterations are made or the unsafe conditions are removed. A posted notice of unsafe conditions shall be removed only by the building official when he is satisfied that the unsafe conditions have been corrected.



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# Chapter 53

# ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION

## General

**Sec. 5301.** (a) **Purpose.** The purpose of this appendix is to regulate the design and construction of the exterior envelopes and selection of heating, ventilating and air-conditioning, service water heating, electrical distribution and illuminating systems and equipment required for the purpose of effective conservation of energy within a building or structure governed by this code.

(b) **Model Energy Code Adopted.** In order to comply with the purpose of this appendix, buildings shall be designed to comply with the requirements of the Model Energy Code promulgated jointly by the International Conference of Building Officials (ICBO); the Southern Building Code Congress International, Inc. (SBCCI); the Building Officials and Code Administrators International, Inc. (BOCA); and the National Conference of States on Building Codes and Standards, Inc. (NCSBCS); dated 1986.



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# Chapter 55
# MEMBRANE STRUCTURES

## General

**Sec. 5501.** (a) **Purpose.** The purpose of this appendix is to establish minimum standards of safety for the construction and use of air-supported, air-inflated and membrane-covered cable or frame structures, collectively known as membrane structures.

(b) **Scope.** The provisions of this appendix shall apply to membrane structures erected for a period of 180 days or longer. Those erected for a shorter period of time shall comply with applicable provisions of the Uniform Fire Code.

> **EXCEPTION:** Water storage facilities, water clarifiers, water treatment plants, sewer plants, aquaculture pond covers, residential and agricultural greenhouses and similar facilities not used for human occupancy need meet only the requirements of Section 5502 (b) and Section 5505.

(c) **Definitions.** For the purpose of this appendix, certain terms are defined as follows:

**AIR-INFLATED STRUCTURE** is a building where the shape of the structure is maintained by air pressurization of cells or tubes to form a barrel vault over the usable area. Occupants of such a structure do not occupy the pressurized area used to support the structure.

**AIR-SUPPORTED STRUCTURE** is a building wherein the shape of the structure is attained by air pressure and occupants of the structure are within the elevated pressure area. Air-supported structures are of two basic types:

1. **Single skin**—Where there is only the single outer skin and the air pressure is directly against that skin.
2. **Double skin**—Similar to a single skin, but with an attached liner which is separated from the outer skin and provides an air space which serves for insulation, acoustic, aesthetic or similar purposes.

A cable-restrained air-supported structure is one in which the uplift is resisted by cables or webbing which are anchored to either foundations or dead men. Reinforcing cable or webbing may be attached by various methods to the membrane or may be an integral part of the membrane. This is not a cable-supported structure.

**CABLE STRUCTURE** is a nonpressurized structure in which a mast and cable system provides support and tension to the membrane weather barrier and the membrane imparts structural stability to the structure.

**FRAME-COVERED STRUCTURE** is a nonpressurized building wherein the structure is composed of a rigid framework to support tensioned membrane which provides the weather barrier.

**MEMBRANE** is a thin, flexible, impervious material capable of being supported by an air pressure of 1.5 inches of water column.



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**NONCOMBUSTIBLE MEMBRANE STRUCTURE** is a membrane structure in which the membrane and all component parts of the structure are noncombustible as defined by Section 415.

**TENT** is any structure, enclosure or shelter constructed of canvas or pliable material supported by any manner except by air or the contents it protects.

## Type of Construction and General Requirements

**Sec. 5502.** (a) **General.** Membrane structures shall be classified as Type V-N construction, except that noncombustible membrane structures may be classified as Type II-N construction.

**EXCEPTION:** A noncombustible membrane structure used exclusively as a roof and located more than 25 feet above any floor, balcony or gallery is deemed to comply with the roof construction requirements for Type I and Type II fire-resistant construction, provided that such a structure complies with the requirements of this section.

(b) **Membrane Material.** Membranes shall be either noncombustible as defined by Section 415, or flame retardant conforming to U.B.C. Standard No. 55-1.

**EXCEPTION:** Plastic less than 20-mil thickness used in greenhouses and for aquaculture pond covers need not be flame retardant.

(c) **Applicability of Other Provisions.** Except as specifically otherwise required by this section, membrane structures shall meet all applicable provisions of this code. Roof coverings shall be fire retardant.

**EXCEPTION:** Roof coverings for Group M, Division 1 Occupancies not exceeding 1000 square feet in area need not be fire retardant.

(d) **Allowable Floor Areas.** The area of a membrane structure shall not exceed the limits set forth in Table No. 5-C, except as provided in Section 506.

(e) **Maximum Height.** Membrane structures shall not exceed one story nor shall they exceed the height limits in feet set forth in Table No. 5-D.

**EXCEPTION:** Noncombustible membrane structures serving as roof only.

## Inflation Systems

**Sec. 5503.** (a) **General.** Air-supported and air-inflated structures shall be provided with primary and auxiliary inflation systems to meet the minimum requirements of this section.

(b) **Equipment Requirements.** The inflation system shall consist of one or more blowers and shall include provisions for automatic control to maintain the required inflation pressures. The system shall be so designed as to prevent overpressurization of the system.

In addition to the primary inflation system, in buildings exceeding 1500 square feet in area, there shall be provided an auxiliary inflation system with sufficient capacity to maintain the inflation of the structure in case of primary system failure.

The auxiliary inflation system shall operate automatically if there is a loss of internal pressure or should the primary blower system become inoperative.



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Blower equipment shall meet the following requirements:

1. Blowers shall be powered by continuous rated motors at the maximum power required for any flow condition as required by the structural design.
2. Blowers shall be provided with inlet screens, belt guards and other protective devices as may be required by the building official to provide protection from injury.
3. Blowers shall be housed within a weather-protecting structure.
4. Blowers shall be equipped with back draft check dampers to minimize air loss when inoperative.
5. Blower inlets shall be located to provide protection from air contamination. Location of inlets shall be approved by the building official.

(c) **Emergency Power.** Whenever an auxiliary inflation system is required, an approved standby power generating system shall be provided. The system shall be equipped with a suitable means for automatically starting the generator set upon failure of the normal electrical service and for automatic transfer and operation of all the required electrical functions at full power within 60 seconds of such normal service failure. Standby power shall be capable of operating independently for a minimum of four hours.

## Section Provisions

**Sec. 5504.** A system capable of supporting the membrane in the event of deflation shall be provided in all air-supported and air-inflated structures having an occupant load of more than 50 or when covering a swimming pool regardless of occupant load. Such system shall maintain the membrane at least 7 feet above the floor, seating area or surface of the water.

**EXCEPTION:** Membrane structures used as a roof for Type I or Type II fire-resistant construction must be maintained not less than 25 feet above floor or seating areas.

## Engineering Design

**Sec. 5505.** All membrane structures shall be structurally designed in accordance with criteria approved by the building official and developed by an engineer or architect licensed by the state to practice as such.



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# Chapter 57

# REGULATIONS GOVERNING FALLOUT SHELTERS

## Purpose

**Sec. 5701.** The purpose of this appendix is to establish minimum criteria which must be met before a building or building space can be constructed, occupied, used or designated a fallout shelter.

## Scope

**Sec. 5702.** The scope of this appendix extends to building spaces designated for use as fallout shelters including periods of drill and instruction for this purpose.

## Definitions

**Sec. 5703. FALLOUT SHELTER** is any room, structure or space designated as such and providing its occupants with protection at a minimum protection factor of 40 from gamma radiation from fallout from a nuclear explosion as determined by a qualified fallout shelter analyst certified by the Office of Civil Defense. Area used for storage of shelter supplies need not have a protection factor of 40.

**DUAL-USE FALLOUT SHELTER** is a fallout shelter having a normal, routine use and occupancy as well as an emergency use as a fallout shelter.

**SINGLE-PURPOSE FALLOUT SHELTER** is a fallout shelter having no use or occupancy except as a fallout shelter.

**PROTECTION FACTOR** is a factor used to express the relation between the amount of fallout gamma radiation that would be received by an unprotected person and the amount that would be received by one in a shelter.

**UNIT OF EGRESS WIDTH** is 22 inches.

## Occupancy Requirements

**Sec. 5704.** (a) **General.** Nothing in these regulations shall be construed as preventing the dual use or multiple use of normal occupancy space as fallout shelter space, providing the minimum requirements for each use are met.

(b) **Mixed Occupancy.** The occupancy classification shall be determined by the normal use of the building. When a normal-use space is designed to have an emergency use as a fallout shelter in addition to the normal use, the most restrictive requirements for all such uses shall be met.

(c) **Occupancy Separation.** No occupancy separation is required between that portion designated as a fallout shelter and the remainder of the building.

(d) **Space and Ventilation.** A minimum of 10 square feet of net floor area shall be provided per shelter occupant. Partitions, columns and area for storage of federal shelter supplies also may be included in net area. A minimum of 65 cubic feet of volume shall be provided per shelter occupant. A minimum of 3 cubic feet of fresh air per minute per person shall be provided.

In addition, the shelter shall have a ventilating rate sufficient to maintain a daily



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average effective temperature of not more than 82°F. for at least 90 percent of the days of the year.

(e) **Illumination.** No special lighting levels are required.

(f) **Hazards.** Hazardous utility lines such as steam, gas and oil shall not be located in or near the shelter unless provision is made to control such lines by valving or other approved means.

### Exits

**Sec. 5705.** There shall be no fewer than two widely spaced exits from a fallout shelter, leading directly to other spaces of the building or outdoors. Exits from the fallout shelter shall aggregate at least one unit of egress width for every 200 shelter occupants. In no case shall a single exit be less than 24 inches wide.

### Flame-spread Index of Interior Surfaces

**Sec. 5706.** Interior surfaces of single-purpose fallout shelters shall have a flame-spread index not exceeding 200.

### Minimum Design Loads

**Sec. 5707.** (a) **Dual-use Fallout Shelters.** In the case of dual-use fallout shelters, design live load required for the normal use shall govern, except that concentrated loads shall be considered.

(b) **Single-purpose Fallout Shelters.** Minimum live loads for floor design in single-purpose fallout shelters shall be 40 pounds per square foot except that concentrated loads shall be considered.

### Sanitation

**Sec. 5708.** Toilets, either flush-type operating from the normal water supply system, or chemical or other types, shall be provided on the basis of one toilet per 50 fallout shelter occupants. Fifty percent of the toilets may be provided outside the fallout shelter area. Empty water containers may be considered as fulfilling this requirement.



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# Chapter 70
# EXCAVATION AND GRADING

## Purpose

**Sec. 7001.** The purpose of this appendix is to safeguard life, limb, property and the public welfare by regulating grading on private property.

## Scope

**Sec. 7002.** This appendix sets forth rules and regulations to control excavation, grading and earthwork construction, including fills and embankments; establishes the administrative procedure for issuance of permits; and provides for approval of plans and inspection of grading construction.

## Permits Required

**Sec. 7003.** No person shall do any grading without first having obtained a grading permit from the building official except for the following:

1. Grading in an isolated, self-contained area if there is no danger apparent to private or public property.

2. An excavation below finished grade for basements and footings of a building, retaining wall or other structure authorized by a valid building permit. This shall not exempt any fill made with the material from such excavation nor exempt any excavation having an unsupported height greater than 5 feet after the completion of such structure.

3. Cemetery graves.

4. Refuse disposal sites controlled by other regulations.

5. Excavations for wells or tunnels or utilities.

6. Mining, quarrying, excavating, processing, stockpiling of rock, sand, gravel, aggregate or clay where established and provided for by law, provided such operations do not affect the lateral support or increase the stresses in or pressure upon any adjacent or contiguous property.

7. Exploratory excavations under the direction of soil engineers or engineering geologists.

8. An excavation which (a) is less than 2 feet in depth, or (b) which does not create a cut slope greater than 5 feet in height and steeper than one and one-half horizontal to one vertical.

9. A fill less than 1 foot in depth and placed on natural terrain with a slope flatter than five horizontal to one vertical, or less than 3 feet in depth, not intended to support structures, which does not exceed 50 cubic yards on any one lot and does not obstruct a drainage course.

## Hazards

**Sec. 7004.** Whenever the building official determines that any existing excavation or embankment or fill on private property has become a hazard to life and limb, or endangers property, or adversely affects the safety, use or stability of a public way or drainage channel, the owner of the property upon which the excavation or fill is located, or other person or agent in control of said property,



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upon receipt of notice in writing from the building official, shall within the period specified therein repair or eliminate such excavation or embankment so as to eliminate the hazard and be in conformance with the requirements of this code.

### Definitions

**Sec. 7005.** For the purposes of this appendix the definitions listed hereunder shall be eonstrued as specified in this section.

**APPROVAL** shall mean the proposed work or completed work conforms to this chapter in the opinion of the building official.

**AS-GRADED** is the extent of surface conditions on completion of grading.

**BEDROCK** is in-place solid rock.

**BENCH** is a relatively level step excavated into earth material on which fill is to bc placed.

**BORROW** is earth material acquired from an off-site location for use in grading on a site.

**CIVIL ENGINEER** is a professional engineer registered in the state to practice in the field of civil works.

**CIVIL ENGINEERING** is the application of the knowledge of the forces of nature, principles of mechanics and the properties of materials to the evaluation, design and construction of civil works for the beneficial uses of mankind.

**COMPACTION** is the densification of a fill by mechanical means.

**EARTH MATERIAL** is any rock, natural soil or fill and/or any combination thereof.

**ENGINEERING GEOLOGIST** is a geologist experienced and knowledgeable in engineering geology.

**ENGINEERING GEOLOGY** is the application of geologic knowledge and principles in the investigation and evaluation of naturally occurring rock and soil for use in the design of civil works.

**EROSION** is the wearing away of the ground surface as a result of the movement of wind, water and/or ice.

**EXCAVATION** is the mechanical removal of earth material.

**FILL** is a deposit of earth material placed by artificial means.

**GEOTECHNICAL ENGINEER.** See Soils Engineer.

**GRADE** is the vertical loeation of the ground surface.

**Existing Grade** is the grade prior to grading.

**Rough Grade** is the stage at which the grade approximately conforms to the approved plan.

**Finish Grade** is the final grade of the site which conforms to the approved plan.

**GRADING** is any excavating or filling or combination thereof.

**KEY** is a designed compacted fill placed in a trench excavated in earth material beneath the toe of a proposed fill slope.



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**SITE** is any lot or parcel of land or contiguous combination thereof, under the same ownership, where grading is performed or permitted.

**SLOPE** is an inclined ground surface the inclination of which is expressed as a ratio of horizontal distance to vertical distance.

**SOIL** is naturally occurring superficial deposits overlying bed rock.

**SOILS ENGINEER (GEOTECHNICAL ENGINEER)** is an engineer experienced and knowledgeable in the practice of soils engineering (geotechnical) engineering.

**SOILS ENGINEERING (GEOTECHNICAL ENGINEERING)** is the application of the principles of soils mechanics in the investigation, evaluation and design of civil works involving the use of earth materials and the inspection and/or testing of the construction thereof.

**TERRACE** is a relatively level step constructed in the face of a graded slope surface for drainage and maintenance purposes.

## Grading Permit Requirements

**Sec. 7006.** (a) **Permits Required.** Except as exempted in Section 7003 of this code, no person shall do any grading without first obtaining a grading permit from the building official. A separate permit shall be required for each site, and may cover both excavations and fills.

(b) **Application.** The provisions of Section 302 (a) are applicable to grading and in addition the application shall state the estimated quantities of work involved.

(c) **Plans and Specifications.** When required by the building official, each application for a grading permit shall be accompanied by two sets of plans and specifications, and supporting data consisting of a soils engineering report and engineering geology report. The plans and specifications shall be prepared and signed by a civil engineer when required by the building official.

(d) **Information on Plans and in Specifications.** Plans shall be drawn to scale upon substantial paper or cloth and shall be of sufficient clarity to indicate the nature and extent of the work proposed and show in detail that they will conform to the provisions of this code and all relevant laws, ordinances, rules and regulations. The first sheet of each set of plans shall give the location of the work and the name and address of the owner and the person by whom they were prepared.

The plans shall include the following information:

1. General vicinity of the proposed site.

2. Property limits and accurate contours of existing ground and details of terrain and area drainage.

3. Limiting dimensions, elevations or finish contours to be achieved by the grading, and proposed drainage channels and related construction.

4. Detailed plans of all surface and subsurface drainage devices, walls, cribbing, dams and other protective devices to be constructed with, or as a part of, the proposed work together with a map showing the drainage area and the estimated runoff of the area served by any drains.



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5. Location of any buildings or structures on the property where the work is to be performed and the location of any buildings or structures on land of adjacent owners which are within 15 feet of the property or which may be affected by the proposed grading operations.

Specifications shall contain information covering construction and material requirements.

(e) **Soils Engineering Report.** The soils engineering report required by Subsection (c) shall include data regarding the nature, distribution and strength of existing soils, conclusions and recommendations for grading procedures and design criteria for corrective measures, including buttress fills, when necessary, and opinions and recommendations covering adequacy of sites to be developed by the proposed grading, including the stability of slopes.

Recommendations included in the report and approved by the building official shall be incorporated in the grading plans or specifications.

(f) **Engineering Geology Report.** The engineering geology report required by Subsection (c) shall include an adequate description of the geology of the site, conclusions and recommendations regarding the effect of geologic conditions on the proposed development, and opinions and recommendations covering the adequacy of sites to be developed by the proposed grading.

Recommendations included in the report and approved by the building official shall be incorporated in the grading plans or specifications.

(g) **Issuance.** The provisions of Section 303 are applicable to grading permits. The building official may require that grading operations and project designs be modified if delays occur which incur weather-generated problems not considered at the time the permit was issued.

## Grading Fees

**Sec. 7007.** (a) **General.** Fees shall be assessed in accordance with the provisions of this section or shall be as set forth in the fee schedule adopted by the jurisdiction.

(b) **Plan Review Fees.** When a plan or other data are required to be submitted, a plan review fee shall be paid at the time of submitting plans and specifications for review. Said plan review fee shall be as set forth in Table No. 70-A. Separate plan review fees shall apply to retaining walls or major drainage structures as required elsewhere in this code: For excavation and fill on the same site, the fee shall be based on the volume of excavation or fill, whichever is greater.

(c) **Grading Permit Fees.** A fee for each grading permit shall be paid to the building official as set forth in Table No. 70-B. Separate permits and fees shall apply to retaining walls or major drainage structures as required elsewhere in this code. There shall be no separate charge for standard terrace drains and similar facilities.



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## TABLE NO. 70-A—GRADING PLAN REVIEW FEES[1]

| | |
|---|---|
| 50 cubic yards or less | No fee |
| 51 to 100 cubic yards | $15.00 |
| 101 to 1000 cubic yards | 22.50 |
| 1001 to 10,000 cubic yards | 30.00 |

10,001 to 100,000 cubic yards—$30.00 for the first 10,000 cubic yards, plus $15.00 for each additional 10,000 yards or fraction thereof.

100,001 to 200,000 cubic yards—$165.00 for the first 100,000 cubic yards, plus $9.00 for each additional 10,000 cubic yards or fraction thereof.

200,001 cubic yards or more—$255.00 for the first 200,000 cubic yards, plus $4.50 for each additional 10,000 cubic yards or fraction thereof.

**Other Fees:**

Additional plan review required by changes, additions or revisions to approved plans ..... $30.00 per hour*
(minimum charge—one-half hour)

*Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.

## TABLE NO. 70-B—GRADING PERMIT FEES[1]

| | |
|---|---|
| 50 cubic yards or less | $15.00 |
| 51 to 100 cubic yards | 22.50 |

101 to 1000 cubic yards—$22.50 for the first 100 cubic yards plus $10.50 for each additional 100 cubic yards or fraction thereof.

1001 to 10,000 cubic yards—$117.00 for the first 1,000 cubic yards, plus $9.00 for each additional 1,000 cubic yards or fraction thereof.

10,001 to 100,000 cubic yards—$198.00 for the first 10,000 cubic yards, plus $40.50 for each additional 10,000 cubic yards or fraction thereof.

100,001 cubic yards or more—$562.50 for the first 100,000 cubic yards, plus $22.50 for each additional 10,000 cubic yards or fraction thereof.

**Other Inspections and Fees:**

1. Inspections outside of normal business hours ..... $30.00 per hour[2]
   (minimum charge—two hours)
2. Reinspection fees assessed under provisions of Section 305 (g) ..... $30.00 per hour[2]
3. Inspections for which no fee is specifically indicated ..... $30.00 per hour[2]
   (minimum charge—one-half hour)

[1]The fee for a grading permit authorizing additional work to that under a valid permit shall be the difference between the fee paid for the original permit and the fee shown for the entire project.

[2]Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.



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## Bonds

**Sec. 7008.** The building official may require bonds in such form and amounts as may be deemed necessary to assure that the work, if not completed in accordance with the approved plans and specifications, will be corrected to eliminate hazardous conditions.

In lieu of a surety bond the applicant may file a cash bond or instrument of credit with the building official in an amount equal to that which would be required in the surety bond.

## Cuts

**Sec. 7009.** (a) **General.** Unless otherwise recommended in the approved soils engineering and/or engineering geology report, cuts shall conform to the provisions of this section.

In the absence of an approved soils engineering report, these provisions may be waived for minor cuts not intended to support structures.

(b) **Slope.** The slope of cut surfaces shall be no steeper than is safe for the intended use and shall be no steeper than 2 horizontal to 1 vertical unless the owner furnishes a soils engineering or an engineering geology report, or both, stating that the site has been investigated and giving an opinion that a cut at a steeper slope will be stable and not create a hazard to public or private property.

(c) **Drainage and Terracing.** Drainage and terracing shall be provided as required by Section 7012.

## Fills

**Sec. 7010.** (a) **General.** Unless otherwise recommended in the approved soils engineering report, fills shall conform to the provisions of this section.

In the absence of an approved soils engineering report these provisions may be waived for minor fills not intended to support structures.

(b) **Fill Location.** Fill slopes shall not be constructed on natural slopes steeper than two to one.

(c) **Preparation of Ground.** The ground surface shall be prepared to receive fill by removing vegetation, noncomplying fill, topsoil and other unsuitable materials scarifying to provide a bond with the new fill and, where slopes are steeper than five to one and the height is greater than 5 feet, by benching into sound bedrock or other competent material as determined by the soils engineer. The bench under the toe of a fill on a slope steeper than five to one shall be at least 10 feet wide. The area beyond the toe of fill shall be sloped for sheet overflow or a paved drain shall be provided. When fill is to be placed over a cut, the bench under the toe of fill shall be at least 10 feet wide but the cut shall be made before placing the fill and acceptance by the soils engineer or engineering geologist or both as a suitable foundation for fill.

(d) **Fill Material.** Detrimental amounts of organic material shall not be permitted in fills. Except as permitted by the building official, no rock or similar



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irreducible material with a maximum dimension greater than 12 inches shall be buried or placed in fills.

**EXCEPTION:** The building official may permit placement of larger rock when the soils engineer properly devises a method of placement, continuously inspects its placement and approves the fill stability. The following conditions shall also apply:

A. Prior to issuance of the grading permit, potential rock disposal areas shall be delineated on the grading plan.

B. Rock sizes greater than 12 inches in maximum dimension shall be 10 feet or more below grade, measured vertically.

C. Rocks shall be placed so as to assure filling of all voids with fines.

(e) **Compaction.** All fills shall be compacted to a minimum of 90 percent of maximum density as determined by U.B.C. Standard No. 70-1. In-place density shall be determined in accordance with U.B.C. Standard No. 70-2, 70-3, 70-4 or 70-5.

(f) **Slope.** The slope of fill surfaces shall be no steeper than is safe for the intended use. Fill slopes shall be no steeper than two horizontal to one vertical.

(g) **Drainage and Terracing.** Drainage and terracing shall be provided and the area above fill slopes and the surfaces of terraces shall be graded and paved as required by Section 7012.

## Setbacks

**Sec. 7011.** (a) **General.** Cut and fill slopes shall be set back from site boundaries in accordance with this section. Setback dimensions shall be horizontal distances measured perpendicular to the site boundary. Setback dimensions shall be a shown in Figure No. 70-1.

(b) **Top of Cut Slope.** The top of cut slopes shall be made not nearer to a site boundary line than one fifth of the vertical height of cut with a minimum of 2 feet and a maximum of 10 feet. The setback may need to be increased for any required interceptor drains.

(c) **Toe of Fill Slope.** The toe of fill slope shall be made not nearer to the site boundary line than one-half the height of the slope with a minimum of 2 feet and a maximum of 20 feet. Where a fill slope is to be located near the site boundary and the adjacent off-site property is developed, special precautions shall be incorporated in the work as the building official deems necessary to protect the adjoining property from damage as a result of such grading. These precautions may include but are not limited to:

1. Additional setbacks.
2. Provision for retaining or slough walls.
3. Mechanical or chemical treatment of the fill slope surface to minimize erosion.
4. Provisions for the control of surface waters.

(d) **Modification of Slope Location.** The building official may approve alternate setbacks. The building official may require an investigation and recommendation by a qualified engineer or engineering geologist to demonstrate that the intent of this section has been satisfied.



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## Drainage and Terracing

**Sec. 7012.** (a) **General.** Unless otherwise indicated on the approved grading plan, drainage facilities and terracing shall conform to the provisions of this section for cut or fill slopes steeper than 3 horizontal to 1 vertical.

(b) **Terrace.** Terraces at least 6 feet in width shall be established at not more than 30-foot vertical intervals on all cut or fill slopes to control surface drainage and debris except that where only one terrace is required, it shall be at midheight. For cut or fill slopes greater than 60 feet and up to 120 feet in vertical height, one terrace at approximately midheight shall be 12 feet in width. Terrace widths and spacing for cut and fill slopes greater than 120 feet in height shall be designed by the civil engineer and approved by the building official. Suitable access shall be provided to permit proper cleaning and maintenance.

Swales or ditches on terraces shall have a minimum gradient of 5 percent and must be paved with reinforced concrete not less than 3 inches in thickness or an approved equal paving. They shall have a minimum depth at the deepest point of 1 foot and a minimum paved width of 5 feet.

A single run of swale or ditch shall not collect runoff from a tributary area exceeding 13,500 square feet (projected) without discharging into a down drain.

(c) **Subsurface Drainage.** Cut and fill slopes shall be provided with subsurface drainage as necessary for stability.

(d) **Disposal.** All drainage facilities shall be designed to carry waters to the nearest practicable drainage way approved by the building official and/or other appropriate jurisdiction as a safe place to deposit such waters. Erosion of ground in the area of discharge shall be prevented by installation of nonerosive downdrains or other devices.

Building pads shall have a drainage gradient of 2 percent toward approved drainage facilities, unless waived by the building official.

**EXCEPTION:** The gradient from the building pad may be 1 percent if all of the following conditions exist throughout the permit area:

A. No proposed fills are greater than 10 feet in maximum depth.

B. No proposed finish cut or fill slope faces have a vertical height in excess of 10 feet.

C. No existing slope faces, which have a slope face steeper than 10 horizontally to 1 vertically, have a vertical height in excess of 10 feet.

(e) **Interceptor Drains.** Paved interceptor drains shall be installed along the top of all cut slopes where the tributary drainage area above slopes towards the cut and has a drainage path greater than 40 feet measured horizontally. Interceptor drains shall be paved with a minimum of 3 inches of concrete or gunite and reinforced. They shall have a minimum depth of 12 inches and a minimum paved width of 30 inches measured horizontally across the drain. The slope of drain shall be approved by the building official.

## Erosion Control

**Sec. 7013.** (a) **Slopes.** The faces of cut and fill slopes shall be prepared and maintained to control against erosion. This control may consist of effective



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planting. The protection for the slopes shall be installed as soon as practicable and prior to calling for final approval. Where cut slopes are not subject to erosion due to the erosion-resistant character of the materials, such protection may be omitted.

(b) **Other Devices.** Where necessary, check dams, cribbing, riprap or other devices or methods shall be employed to control erosion and provide safety.

## Grading Inspection

**Sec. 7014.** (a) **General.** All grading operations for which a permit is required shall be subject to inspection by the building official. When required by the building official, special inspection of grading operations and special testing shall be performed in accordance with the provisions of Section 306 and Subsection 7014 (c).

(b) **Grading Designation.** All grading in excess of 5000 cubic yards shall be performed in accordance with the approved grading plan prepared by a civil engineer, and shall be designated as "engineered grading." Grading involving less than 5000 cubic yards shall be designated "regular grading" unless the permittee, with the approval of the building official, chooses to have the grading performed as "engineered grading."

(c) **Engineered Grading Requirements.** For engineered grading, it shall be the responsibility of the civil engineer who prepares the approved grading plan to incorporate all recommendations from the soils engineering and engineering geology reports into the grading plan. He also shall be responsible for the professional inspection and approval of the grading within his area of technical specialty. This responsibility shall include, but need not be limited to, inspection and approval as to the establishment of line, grade and drainage of the development area. The civil engineer shall act as the coordinating agent in the event the need arises for liaison between the other professionals, the contractor and the building official. The civil engineer also shall be responsible for the preparation of revised plans and the submission of as-graded grading plans upon completion of the work. The grading contractor shall submit in a form prescribed by the building official a statement of compliance to said as-built plan.

Soils engineering and engineering geology reports shall be required as specified in Section 7006. During grading all necessary reports, compaction data and soil engineering and engineering geology recommendations shall be submitted to the civil engineer and the building official by the soils engineer and the engineering geologist.

The soils engineer's area of responsibility shall include, but need not be limited to, the professional inspection and approval concerning the preparation of ground to receive fills, testing for required compaction, stability of all finish slopes and the design of buttress fills, where required, incorporating data supplied by the engineering geologist.

The engineering geologist's area of responsibility shall include, but need not be limited to, professional inspection and approval of the adequacy of natural ground for receiving fills and the stability of cut slopes with respect to geological matters and the need for subdrains or other groundwater drainage devices. He shall report his findings to the soils engineer and the civil engineer for engineering analysis.



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The building official shall inspect the project at the various stages of the work requiring approval to determine that adequate control is being exercised by the professional consultants.

(d) **Regular Grading Requirements.** The building official may require inspection and testing by an approved testing agency.

The testing agency's responsibility shall include, but need not be limited to, approval concerning the inspection of cleared areas and benches to receive fill, and the compaction of fills.

When the building official has cause to believe that geologic factors may be involved the grading operation will be required to conform to "engineered grading" requirements.

(e) **Notification of Noncompliance.** If, in the course of fulfilling his responsibility under this chapter, the civil engineer, the soils engineer, the engineering geologist or the testing agency finds that the work is not being done in conformance with this chapter or the approved grading plans, the discrepancies shall be reported immediately in writing to the person in charge of the grading work and to the building official. Recommendations for corrective measures, if necessary, shall be submitted.

(f) **Transfer of Responsibility for Approval.** If the civil engineer, the soils engineer, the engineering geologist or the testing agency of record is changed during the course of the work, the work shall be stopped until the replacement has agreed to accept the responsibility within the area of his technical competence for approval upon completion of the work.

## Completion of Work

**Sec. 7015.** (a) **Final Reports.** Upon completion of the rough grading work and at the final completion of the work the building official may require the following reports and drawings and supplements thereto:

1. An as-graded grading plan prepared by the civil engineer including original ground surface elevations, as-graded ground surface elevations, lot drainage patterns and locations and elevations of all surface and subsurface drainage facilities. He shall state that to the best of his knowledge the work was done in accordance with the final approved grading plan.

2. A soils-grading report prepared by the soils engineer, including locations and elevations of field density tests, summaries of field and laboratory tests and other substantiating data and comments on any changes made during grading and their effect on the recommendations made in the soils engineering investigation report. He shall render a finding as to the adequacy of the site for the intended use.

3. A geologic grading report prepared by the engineering geologist, including a final description of the geology of the site and any new information disclosed during the grading and the effect of same on recommendations incorporated in the approved grading plan. He shall render a finding as to the adequacy of the site for the intended use as affected by geologic factors.

(b) **Notification of Completion.** The permittee or his agent shall notify the building official when the grading operation is ready for final inspection. Final approval shall not be given until all work, including installation of all drainage



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facilities and their protective devices, and all erosion-control measures have been completed in accordance with the final approved grading plan and the required reports have been submitted.

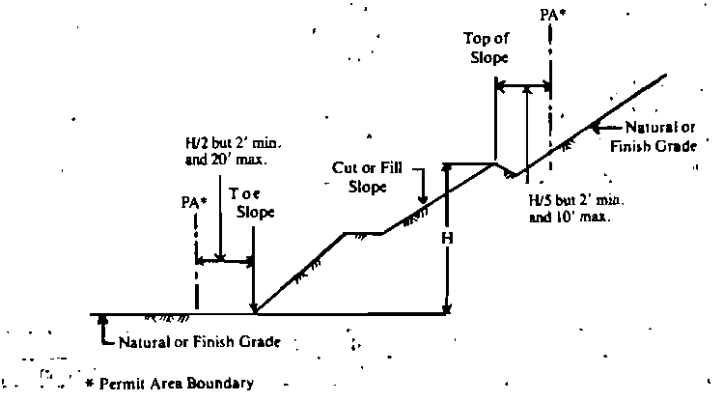


Figure No. 70-1



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# UNIT CONVERSION TABLES

## SI SYMBOLS AND PREFIXES

| BASE UNITS | | |
|---|---|---|
| Quantity | Unit | Symbol |
| Length | Meter | m |
| Mass | Kilogram | kg |
| Time | Second | s |
| Electric current | Ampere | A |
| Thermodynamic temperature | Kelvin | K |
| Amount of substance | Mole | mol |
| Luminous intensity | Candela | cd |

| SI SUPPLEMENTARY UNITS | | |
|---|---|---|
| Quantity | Unit | Symbol |
| Plane angle | Radian | rad |
| Solid angle | Steradian | sr |

| SI PREFIXES | | |
|---|---|---|
| Multiplication Factor | Prefix | Symbol |
| $1\,000\,000\,000\,000\,000\,000 = 10^{18}$ | exa | E |
| $1\,000\,000\,000\,000\,000 = 10^{15}$ | peta | P |
| $1\,000\,000\,000\,000 = 10^{12}$ | tera | T |
| $1\,000\,000\,000 = 10^{9}$ | giga | G |
| $1\,000\,000 = 10^{6}$ | mega | M |
| $1\,000 = 10^{3}$ | kilo | k |
| $100 = 10^{2}$ | hecto | h |
| $10 = 10^{1}$ | deka | da |
| $0.1 = 10^{-1}$ | deci | d |
| $0.01 = 10^{-2}$ | centi | c |
| $0.001 = 10^{-3}$ | milli | m |
| $0.000\,001 = 10^{-6}$ | micro | μ |
| $0.000\,000\,001 = 10^{-9}$ | nano | n |
| $0.000\,000\,000\,001 = 10^{-12}$ | pico | p |
| $0.000\,000\,000\,000\,001 = 10^{-15}$ | femto | f |
| $0.000\,000\,000\,000\,000\,001 = 10^{-18}$ | atto | a |



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## SI SYMBOLS AND PREFIXES—(Continued)

| SI DERIVED UNIT WITH SPECIAL NAMES | | | |
|---|---|---|---|
| **Quantity** | **Unit** | **Symbol** | **Formula** |
| Frequency (of a periodic phenomenon) | hertz | Hz | 1/s |
| Force | newton | N | kg•m/s² |
| Pressure, stress | pascal | Pa | N/m² |
| Energy, work, quantity of heat | joule | J | N•m |
| Power, radiant flux | watt | W | J/s |
| Quantity of electricity, electric charge | coulomb | C | A•s |
| Electric potential, potential difference, electromotive force | volt | V | W/A |
| Capacitance | farad | F | C/V |
| Electric resistance | ohm | Ω | V/A |
| Conductance | siemens | S | A/V |
| Magnetic flux | weber | Wb | V•s |
| Magnetic flux density | tesla | T | Wb/m² |
| Inductance | henry | H | Wb/A |
| Luminous flux | lumen | lm | cd•sr |
| Illuminance | lux | lx | lm/m² |
| Activity (of radionuclides) | becquerel | Bq | 1/s |
| Absorbed dose | gray | Gy | J/kg |

## CONVERSION FACTORS

| To convert | to | multiply by |
|---|---|---|
| **LENGTH** | | |
| 1 mile (U.S. statute) | km | 1.609 344 |
| 1 yd | m | 0.9144 |
| 1 ft | m | 0.3048 |
| | mm | 304.8 |
| 1 in | mm | 25.4 |
| **AREA** | | |
| 1 mile² (U.S. statute) | km² | 2.589 99 |
| 1 acre (U.S. survey) | ha | 0.404 687 |
| | m² | 4046.87 |
| 1 yd² | m² | 0.836 127 |
| 1 ft² | m² | 0.092 903 |
| 1 in² | mm² | 645.16 |
| **VOLUME, MODULUS OF SECTION** | | |
| 1 acre ft | m³ | 1233.49 |
| 1 yd³ | m³ | 0.764 555 |
| 100 board ft | m³ | 0.235 974 |
| 1 ft³ | m³ | 0.028 316 8 |
| | L (dm³) | 28.3168 |
| 1 in³ | mm³ | 16 387.1 |
| | mL (cm³) | 16.3871 |
| 1 barrel (42 U.S. gallons) | m³ | .158 987 |

*(Continued)*



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## CONVERSION FACTORS—(Continued)

| To convert | to | multiply by |
|---|---|---|
| **(FLUID) CAPACITY** | | |
| 1 gal (U.S. liquid)** | L* | 3.785 41 |
| 1 qt (U.S. liquid) | mL | 946.353 |
| 1 pt (U.S. liquid) | mL | 473.177 |
| 1 fl oz (U.S.) | mL | 29.5735 |
| 1 gal (U.S. liquid) | $m^3$ | 0.003 785 |
| **1 gallon (UK) approx. 1.2 gal (U.S.) | | |
| *1 liter approx. 0.001 cubic meters | | |
| **SECOND MOMENT OF AREA** | | |
| 1 $in^4$ | $mm^4$ | 416 231 |
| | $m^4$ | $0.416\ 231 \times 10^{-6}$ |
| **PLANE ANGLE** | | |
| 1° (degree) | rad | 0.017 453 3 |
| | mrad | 17.4533 |
| 1′ (minute) | urad | 290.888 |
| 1″ (second) | urad | 4.848 14 |
| **VELOCITY, SPEED** | | |
| 1 ft/s | m/s | 0.3048 |
| 1 mile/h | km/h | 1.609 344 |
| | m/s | 0.447 04 |
| **VOLUME RATE OF FLOW** | | |
| 1 $ft^3/s$ | $m^3/s$ | 0.028 316 8 |
| 1 $ft^3/min$ | L/s | 0.471 947 |
| 1 gal/min | L/s | 0.063 090 2 |
| 1 gal/min | $m^3/min$ | 0.0038 |
| 1 gal/h | mL/s | 1.051 50 |
| 1 million gal/d | L/s | 43.8126 |
| 1 acre ft/s | $m^3/s$ | 1233.49 |
| **TEMPERATURE INTERVAL** | | |
| 1°F | °C or K | 0.555 556 |
| | | 5/9°C = 5/9 K |
| **EQUIVALENT TEMPERATURE ($t_{oc} = T_k - 273.15$)** | | |
| $t_{oF}$ | | $9/5\ t_{oc} + 32$ |
| **MASS** | | |
| 1 ton (short***) | metric ton | 0.907 185 |
| | kg | 907.185 |
| 1 lb | kg | 0.453 592 |
| 1 oz | g | 28.3495 |
| ***1 long ton (2240 lb) | kg | 1016.05 |
| **MASS PER UNIT AREA** | | |
| 1 $lb/ft^2$ | $kg/m^2$ | 4.882 43 |
| 1 $oz/yd^2$ | $g/m^2$ | 33.9057 |
| 1 $oz/ft^2$ | $g/m^2$ | 305.152 |



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## CONVERSION FACTORS—(Continued)

| To convert | to | multiply by |
|---|---|---|
| **DENSITY (MASS PER UNIT VOLUME)** | | |
| 1 lb/ft³ | kg/m³ | 16.0185 |
| 1 lb/yd³ | kg/m³ | 0.593 276 |
| 1 ton/yd³ | t/m³ | 1.186 55 |
| **FORCE** | | |
| 1 tonf (ton-force) | kN | 8.896 44 |
| 1 kip (1000 lbf) | kN | 4.448 22 |
| 1 lbf (pound-force) | N | 4.448 22 |
| **MOMENT OF FORCE, TORQUE** | | |
| 1 lbf•ft | N•m | 1.355 82 |
| 1 lbf•in | N•m | 0.112 985 |
| 1 tonf•ft | kN•m | 2.711 64 |
| 1 kip•ft | kN•m | 1.355 82 |
| **FORCE PER UNIT LENGTH** | | |
| 1 lbf/ft | N/m | 14.5939 |
| 1 lbf/in | N/m | 175.127 |
| 1 tonf/ft | kN/m | 29.187 8 |
| **PRESSURE, STRESS, MODULUS OF ELASTICITY (FORCE PER UNIT AREA) (1 Pa = 1 N/m²)** | | |
| 1 tonf/in² | MPa | 13.7895 |
| 1 tonf/ft² | kPa | 95.7605 |
| 1 kip/in² | MPa | 6.894 76 |
| 1 lbf/in² | kPa | 6.894 76 |
| 1 lbf/ft² | Pa | 47.8803 |
| Atmosphere | kPa | 101.3250 |
| 1 inch mercury | kPa | 3.376 85 |
| 1 foot (water column at 32°F.) | kPa | 2.988 98 |
| **WORK, ENERGY, HEAT (1J = 1N-m = 1W-s)** | | |
| 1 kWh (550 ft•lbf/s) | Mj | 3.6 |
| 1 Btu (Int. Table) | kJ | 1.055 06 |
| | J | 1055.06 |
| 1 ft•lbf | J | 1.355 82 |
| **COEFFICIENT OF HEAT TRANSFER** | | |
| 1 Btu/(ft2•h•°F) | W/(m²•K) | 5.678 26 |
| **THERMAL CONDUCTIVITY** | | |
| 1 Btu/(ft•h•°F) | W/(m•K) | 1.730 73 |
| **ILLUMINANCE** | | |
| 1 lm/ft² (footcandle) | lx (lux) | 10.7639 |
| **LUMINANCE** | | |
| 1 cd/ft² | cd/m² | 10.7639 |
| 1 foot lambert | cd/m² | 3.426 26 |
| 1 lambert | kcd/m² | 3.183 01 |



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