UNIFORM BUILDING CODE

1982 EDITION

101943106

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.

Vertical lines in the margins indicate changes from the 1979 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. Deletion indicators (▶▶) are provided in the margin where a paragraph or item listing has been deleted.

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.

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 for the conservation and rehabilitation of housing compatible with the Uniform Building Code. Meets federal Workable Program requirements.

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.

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 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 considera-

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tion 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 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.

1982 Accumulative Supplement to the ICBO Plumbing Code. This supplement contains revisions to the 1979 ICBO Plumbing Code. It is styled so that cities and other jurisdictions can update the 1979 ICBO Plumbing Code by adopting the supplement by reference.

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

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.

Code for Energy Conservation in New Building Construction. This code sets forth minimum requirements for the design of new buildings and structures and additions to existing buildings by regulating their exterior envelopes and heating, ventilating, air-conditioning, service water heating, electrical distribution and illuminating systems and equipment for effective use of energy. It is promulgated by ICBO in collaboration with the other model code agencies and the National Conference of States on Building Codes and Standards (NCSBCS).

Recommended Provisions and Commentary for Existing High-rise Buildings. A booklet setting forth uniform guidelines for the building official to follow in regulating the retrofitting of existing high-rise buildings. The booklet also includes a commentary briefly explaining the conceptual basis of the provisions.

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.

Training Manual in Field Inspection of Buildings and Structures. 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 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.

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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.

Concrete Inspection 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.

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.

Installation and Operation of Solid-fuel-burning Appliances. A fully illustrated manual designed to provide information on the proper installation and operation of listed solid-fuel-burning appliances. Intended to supplement the detailed installation and operating instructions normally supplied with these types of appliances. An aid to building officials administering ICBO codes and standards and/or utilizing research reports.

Solar Systems Code Review Manual. A completely illustrated manual to facilitate approval of solar systems, from plan check to field inspection. Specifically addresses needs of building departments, and is equally valuable to all departments dealing with housing and commercial structures. Developed by California Building Officials, Inc., (CALBO) under contract with the California Energy Commission.

Solar Swimming Pool/Spa Code Review Manual. A completely illustrated manual to assist local officials in identifying, understanding and completing a code analysis of solar pool and spa heating systems presented for permit approval. Developed by the California Building Officials, Inc., (CALBO) under contract to the California Energy Commission.

You Can Build It! Sponsored by 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.

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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 GROUP:** Determine the occupancy group which the use of the building most nearly resembles. See the '01 sections of Chapters 6 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 exterior wall and wall opening requirements based on proximity to property lines. See Section 504 for buildings located on the same site.

   D. **FLOOR AREA:** Compute the 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, from grade, Section 408, and for the number of stories, Section 420. See Table No. 5-D for the allowable height and number of stories 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.

   F. **OCCUPANT LOAD:** Compute the occupant load of the building. See Section 3302 (a) and Table No. 33-A.

2. Verify compliance of the building with detailed occupancy requirements. See Chapters 6 through 12.

3. Verify compliance of the building with detailed type of construction requirements. See Chapters 17 through 22.

4. Verify compliance of the building with exit requirements. See Chapter 33.

5. Verify compliance of the building with detailed code regulations. See Chapters 29 through 43, Chapters 47 through 54, and Appendix.

6. Verify compliance of building with engineering regulations and requirements for materials of construction. See Chapters 23 through 29.

The following is a sample form for adoption of the Uniform Building Code and Uniform Building Code Standards.

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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)____ 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; 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 in the office of the ____(jurisdiction's keeper of records)____ and the ____(jurisdiction)____, being marked and designated as "Uniform Building Code," including Appendix Chapter _____ *(fill in the applicable appendix chapters; see Uniform Building Code Section 103, last paragraph)*, 1982 edition, and the "Uniform Building Code Standards," 1982 edition, published by the International Conference of Building Officials, be and the same is 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," 1982 edition, and the "Uniform Building Code Standards," 1982 edition, published by the International Conference of Building Officials, 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. That Ordinance No. _____ of ____(jurisdiction)____ entitled *(fill in here the complete title of the present building ordinance or ordinances in effect at the present time so that they will be repealed by definite mention)* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

Section 3. That the ____(jurisdiction's keeper of records)____ shall certify to the adoption of this ordinance and cause the same to be published.

Section 4. That if any section, subsection, sentence, clause or phrase of this ordinance is, for any reason, held to be unconstitutional, such decision shall not affect the validity 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 thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses and phrases be declared unconstitutional.

Section 5. That this ordinance shall be and is hereby declared to be in full force and effect, from after ____(time period)____ from this date of final passage and approval.

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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	$kg \cdot m/s^2$
Pressure, stress	pascal	Pa	N/m^2
Energy, work, quantity of heat	joule	J	$N \cdot m$
Power, radiant flux	watt	W	J/s
Quantity of electricity, electric charge	coulomb	C	$A \cdot s$
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	$V \cdot s$
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	$cd \cdot sr$
Illuminance	lux	lx	lm/m^2
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	1.609 347
1 yd	m	0.9144
1 ft	m	0.3048
	mm	304.8
1 in	mm	25.4
AREA		
1 $mile^2$ (U.S. statute)	km^2	2.589 99
1 acre (U.S. survey)	ha	0.404 687
	m^2	4046.87
1 yd^2	m^2	0.836 127
1 ft^2	m^2	0.092 903
1 in^2	mm^2	645.16
VOLUME, MODULUS OF SECTION		
1 acre ft	m^3	1233.49
1 yd^3	m^3	0.764 555
100 board ft	m^3	0.235 974
1 ft^3	m^3	0.028 316 8
	L (dm^3)	28.3168
1 in^3	mm^3	16 387.1
	mL (cm^3)	16.3871
1 barrel (42 U.S. gallons)	m^3	.158 987

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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 ($t_c = T_k - 273.15$)		
$t_{°F}$		$9/5\ t_{°c} + 32$
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/ft^3	kg/m^3	16.0185
1 lb/yd^3	kg/m^3	0.593 276
1 ton/yd^3	t/m^3	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/m^2)		
1 tonf/in^2	MPa	13.7895
1 tonf/ft^2	kPa	95.7605
1 kip/in^2	MPa	6.894 76
1 lbf/in^2	kPa	6.894 76
1 lbf/ft^2	Pa	47.8803
Atmosphere	kPa	101.3250
1 inch mercury	kPa	3.376 85
1 foot (water column @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/(ft^2·h·°F)	W/(m^2·K)	5.678 26
THERMAL CONDUCTIVITY		
1 Btu/(ft·h·°F)	W/(m·K)	1.730 73
ILLUMINANCE		
1 lm/ft^2 (footcandle)	lx (lux)	10.7639
LUMINANCE		
1 cd/ft^2	cd/m^2	10.7639
1 foot lambert	cd/m^2	3.426 26
1 lambert	kcd/m^2	3.183 01

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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.

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.

Additions, alterations, repairs and changes of use or occupancy in all buildings and structures shall comply with the provisions for new buildings and structures except as otherwise provided in Sections 104, 307 and 502 of this code.

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, alterations or repairs shall not cause an existing building or structure to become unsafe or overloaded. Any building so altered, which involves a change

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in use or occupancy, shall not exeeed 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.

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.

EXCEPTION: 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 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.

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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.

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.

(b) **Deputies.** In accordance with prescribed procedures and with the approval of the appointing authority, the building official may appoint a chief plans examiner, a chief building inspector and other related technical officers and inspectors and other employees as shall be authorized from time to time.

(c) **Right of Entry.** Whenever necessary 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.

When the building official or his authorized representative shall have first obtained a proper inspection warrant or other remedy provided by law to secure entry, no owner or occupant or any other persons having charge, care or control of any building or premises shall fail or neglect, after proper request is made as herein provided, to promptly permit entry therein by the building official or his authorized representative for the purpose of inspection and examination pursuant to this code.

(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 code is being used contrary to the provisions of this code, the building official may order such use discontinued and the structure, or portion thereof, vacated by notice served on any person causing such use to be continued.

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Such person shall discontinue the use within the time prescribed by the building 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 this code shall be defended by legal counsel provided by this jurisdiction until final termination of such proceedings.

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 certificates of inspection 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, obsoleseence, 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. In order to determine the suitability of alternate materials and methods of construction and to provide for reasonable interpretations 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. The building official shall be an ex officio member and

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shall act as secretary of the board. The Board of Appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt reasonable rules and regulations for conducting its investigations and shall render all decisions and findings in writing to the building official with a duplicate copy to the appellant.

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.** It shall be unlawful for any person, firm or corporation to erect, construct, enlarge, alter, repair, move, improve, remove, convert or demolish any building or structure regulated by this code, except as specified in Subsection (b) of this section, or cause the same to be done without first obtaining a separate permit for each building or structure 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 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 flammable 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 permittee, or his authorized agent, who may be required to submit evidence to indicate such authority.

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.

> **EXCEPTION:** The building official may waive the submission of plans, calculations, 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) **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 and specifications, 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 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 shall be done in accordance with the approved plans.

The building official may issue a permit for the construction of part of a

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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 and specifications 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. No permit presuming to give authority to violate or cancel the provisions of this code shall 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 so to do, 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 exeeeded one year.

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 commenee work within the time required by this section for good and satisfaetory reasons. The building offieial 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. In order to renew action on a permit after expiration, the permittee shall pay a new full permit fee.

(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.

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Fees

Sec. 304. (a) **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.

(b) **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.

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.

(c) **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.

(d) **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 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.

(e) **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

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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 certain types of construction shall have continuous inspection by special inspectors as specified in Section 306.

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. It shall be the duty of the permit applicant to cause the work to be 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.

(b) **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 proper inspection of such work.

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

(d) **Approval Required.** No work shall be done on any part of the building or structure beyond the point indicated in each successive inspection without first obtaining the approval of the building official. Such approval shall be given only after an inspection shall have been made of each successive step in the construction as indicated by each of the inspections required in Subsection (e).

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

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

The building official, upon notification from the permit holder or his agent, shall make the following inspections and shall either approve that portion of the construction as completed or shall notify the permit holder or his agent wherein the same fails to comply with this code:

1. **FOUNDATION INSPECTION:** To be made after trenches are excavated and forms erected and when all materials for the foundation are delivered on the job. Where concrete from a central mixing plant (commonly termed "transit mixed") is to be used, materials need not be on the job.

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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 poured 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 be 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 occupancy.

(f) **Other Inspections.** In addition to the called inspections specified above, the building official may make 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 fee may be assessed for each inspection or 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.

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 shall employ a special inspector during construction on the following types of work:

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

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2. For foundation concrete when the structural design is based on a f'_c no greater than 2000 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 full-supported on earth and concrete where no special hazard exists.

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

3. **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 conformance with the approved plans, prior to the closing of forms or the delivery of concrete to the job site.

4. **WELDING:** A. Ductile moment-resisting steel frames. As required by Section 2722 (f) 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 (c) 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.

5. **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 "type" of connection, for a representative number of total connections established by the plans and specifications.

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.

6. **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. Where the f'_m is less than 2600 psi and special inspection stresses are used, test specimens may consist of either one prism test for each 5000 square feet of wall area or a series of tests based on both grout and mortar for the first three consecutive days and each third day thereafter.

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EXCEPTION: Special inspection will not be required for structures designed in accordance with the values in appropriate tables for noncontinuous inspection.

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

8. **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.

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

10. **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 3 for concrete and reinforcing steel inspection.

11. **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.

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

(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 to be certain it conforms to the 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) **Approved Fabricators.** Special inspections required by this section and elsewhere in this code shall not be required where the work is done on the

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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 or Occupancy.** No building or structure of Group A, E, I, H, B or R, Division 1 Occupancy, 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.

(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 final inspection when it is found that the building or structure complies with the provisions of this code and 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.
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 complies 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

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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.

TABLE NO. 3-A—BUILDING PERMIT FEES

TOTAL VALUATION	FEE
$1.00 to $500.00	$10.00
$501.00 to $2,000.00	$10.00 for the first $500.00 plus $1.50 for each additional $100.00 or fraction thereof, to and including $2,000.00
$2,001.00 to $25,000.00	$32.50 for the first $2,000.00 plus $6.00 for each additional $1,000.00 or fraction thereof, to and including $25,000.00
$25,001.00 to $50,000.00	$170.50 for the first $25,000.00 plus $4.50 for each additional $1,000.00 or fraction thereof, to and including $50,000.00
$50,001.00 to $100,000.00	$283.00 for the first $50,000.00 plus $3.00 for each additional $1,000.00 or fraction thereof, to and including $100,000.00
$100,001.00 and up	$433.00 for the first $100,000.00 plus $2.50 for each additional $1,000.00 or fraction thereof

Other Inspections and Fees:

1. Inspections outside of normal business hours . . . . . $15.00 per hour (minimum charge—two hours)
2. Reinspection fee assessed under provisions of Section 305 (g) . . . . . $15.00 each
3. Inspections for which no fee is specifically indicated . . . . . $15.00 per hour (minimum charge—one-half hour)
4. Additional plan review required by changes, additions or revisions to approved plans . . . . . $15.00 per hour (minimum charge—one-half hour)

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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 1961, shall be considered as providing ordinarily accepted meanings.

A

Sec. 402. 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 space 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.

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 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 (f) 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,

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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.

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.

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 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 comfort heating plant equipment installed in such a manner to supply heat by means of ducts or pipes to areas other than the room 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.

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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.

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.

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.

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. 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 lumber or plywood impregnated with chemicals 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. Materials which may be exposed to the weather shall maintain this fire-retardant classification when tested in accordance

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with the rain and weathering tests of U.B.C. Standard No. 32-7.

All materials shall bear identifieation showing the fire performance rating thereof and, if intended for exterior use, shall be further identified to indicate suitability for exposure to the weather. Such identifications shall be issued by an approved agency having a service for inspection of materials at the factory.

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.

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 classifieation of lumber in regard to strength and utility.

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.

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

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

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.

I

Sec. 410. No definitions.

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

LIQUID STORAGE ROOM is a Group H, Division 2 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 2 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 inspec-

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tion 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 which are used by not more than five guests 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 ⅛ inch thick which has a flame-spread rating of 50 or less.

"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.

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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).

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.

PLATFORM, ENCLOSED, is a partially enclosed portion of an assembly room the ceiling of which is not more than 5 feet above the proscenium opening and which is designed or used for the presentation of plays, demonstrations or other entertainment wherein scenery, drops, decorations or other effects may be installed or used.

PLUMBING CODE is the adopted plumbing code of the jurisdiction.

PUBLIC WAY. See Section 3301 (b).

Q

Sec. 418. No definitions.

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. 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 detector which 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 is a partially enclosed portion of an assembly building which is designed or used for the presentation of plays, demonstrations or other entertainment wherein scenery, drops or other effects may be installed or used, and where the distance between the top of the proscenium opening and the ceiling above the stage is more than 5 feet.

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.

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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 more than 8 feet below grade, as defined herein, at any point.

STREET is any thoroughfare or public space 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 promulgated by the International Conference of Building Officials, as adopted by this jurisdiction. (See Chapter 60.)

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.

VENTILATING CEILING is a suspended ceiling containing many small apertures through which air, at low pressure, is forced downward from an overhead plenum dimensioned by the concealed space between suspended ceiling and the floor or roof above.

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.

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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 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).

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 divided by the allowable area for such 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

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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). Except for buildings containing Group H, Division 1 through Division 4 Occupancies, the provisions of this paragraph are applicable to buildings constructed under the provisions of Section 506 (b) for unlimited area.

An occupancy shall not be located above the story or height set forth in Table No. 5-D, except as provided in Section 507.

(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 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 occupancy 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. 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.

2. In Groups A, Division 1, E and I Occupancies a three-hour occupancy

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separation is permitted from a Group B, Division 1 Occupancy used only as a garage for the parking of passenger motor vehicles having a capacity of not more than nine persons per vehicle and provided no repair or fueling is done.

3. In Group R, Division 1 Occupancies, a one-hour occupancy separation is permitted from a Group B, Division 1 Occupancy used only as a garage for the parking of passenger motor vehicles having a capacity of not more than nine persons per vehicle and provided no repair or fueling is done and the area does not exceed 3000 square feet in a building.

4. 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 1⅜ inches in thickness will be permitted in lieu of a one-hour fire assembly. Fire dampers shall not be required in ducts piercing this separation for ducts constructed of not less than No. 26 gauge galvanized steel.

5. The following occupancies need not be separated from the uses to which they are accessory: assembly rooms having a floor area of not over 750 square feet; adminstrative and clerical offices and similar rooms which in the aggregate do not exceed 25 percent of the floor area of the major use when not related to Group H, Division 1 and Group H, Division 2 Occupancies.

Location on Property

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

For the purpose of this section, the center line of an adjoining street or alley 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.

(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 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.

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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 with an existing building, the assumed property line from the existing building shall be the distance to the property line for each occupancy 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.

(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.

(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.

(d) **Basements.** A basement need not be included in the total allowable area, provided such basement does not qualify as a story nor 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.

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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.

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

4. Parapets of area separation walls shall have noncombustible faces 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 space, streets 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.

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2. **Separation on three sides.** Where public space, streets 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 space, streets 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 width exceeds 20 feet. Such increases shall not exceed 100 percent, except for buildings not exceeding two stories in height of Group B, Division 4 Occupancy and one-story buildings housing aircraft storage hangars and as further limited in Section 902 (b) for aircraft repair hangars.

(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 38, and entirely surrounded and adjoined by public space, streets 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 space, streets 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 and 2 Occupancies.
3. Substitution for one-hour fire-resistive construction pursuant to Section 508.
4. Section 1715, Atriums.

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.

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 and 2 Occupancies.
2. Section 506, for an increase in allowable area.
3. Substitution for one-hour fire-resistive construction pursuant to Section 508.

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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 space, streets or yards not less in width than one and one-half times the height of the building.

4. Section 1715, Atriums.

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. Shaft enclosures (Section 1706).
5. Corridors [Section 3305 (g) and (h)].
6. Stair enclosures (Section 3309).
7. Exit passageways [Section 3312 (a)].
8. Type of construction separation (Section 1701).
9. Atriums constructed in accordance with Section 1715.

Arcades

Sec. 509. Arcades connecting buildings and used exclusively as passageways need not be considered as adjacent buildings for the provisions of this chapter, provided that the walls of the building adjoining the arcades are finished with the same construction as required for the exterior walls of the building, with no communicating openings between the arcades and the building, except doors; and provided that the arcades are of not less than one-hour fire-resistive construction or of noncombustible materials, fire-retardant treated wood or of heavy timber construction with 2-inch nominal sheathing.

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

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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.

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.

Access To Toilets and Other Facilities

Sec. 511. (a) **Access to Water Closets.** Each water closet stool shall he 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 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. Grab bars near each side or one side and the back of the toilet stool securely attached 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 1¼ inch nor more than 1½ inches and shall provide a clearance of

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1½ inches between the grab bar and adjacent surface. Grab bars need not be provided in Group R, Division 1 apartment houses.

5. 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 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 Types II One-hour, II-N and V buildings, see table below. Exceptions to limitation for Types II One-hour, II-N and Type V construction, as provided in Sections 709, 1903 and 2203 apply. For Types I, II-F.R., III and IV construction, see Sections 1803, 1903, 2003 and 2103.

GROUP	DESCRIPTION OF OCCUPANCY	FIRE RESISTANCE OF EXTERIOR WALLS	OPENINGS IN EXTERIOR WALLS
A See also Section 602	1—Any assembly building with a stage and an occupant load of 1000 or more in the building	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 stage 2.1—Any building or portion of a building having an assembly room with an occupant load of 300 or more without a 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 elsewhere	Not permitted less than 5 feet 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 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 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 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 flammable liquids 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 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 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 highly flammable liquids Open parking garages (For requirements, See Section 709.) Heliports	1 hour less than 20 feet	Not permitted less than 5 feet Protected less than 20 feet
	4—Ice plants, power plants, pumping plants, cold storage and creameries Factories and workshops using noncombustible and nonexplosive materials Storage and sales rooms of noncombustible and nonexplosive materials	1 hour less than 5 feet	Not permitted less than 5 feet
E 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 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 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 Protected less than 10 feet[1]
H See also Sections 902 and 903	1—Storage, handling, use or sale of hazardous and highly flammable or explosive materials other than flammable liquids [See also Section 901 (a), Division 1.]	See Chapter 9 and the Fire Code	
	2—Storage, handling, use or sale of Classes I, II and III-A liquids; dry cleaning plants using Class I, II or III-A liquids; paint stores with bulk handling; paint shops and spray-painting rooms and shops [See also Section 901 (a), Division 2.] 3—Woodworking establishments, planing mills, box factories, buffing rooms for tire-rebuilding plants and picking rooms; shops, factories or warehouses where loose combustible fibers or dust are manufactured, processed, generated or stored; and pin-refinishing rooms 4—Repair garages not classified as a Group B, Division 1 Occupancy	4 hours less than 5 feet, 2 hours less than 10 feet, 1 hour less than 20 feet	Not permitted less than 5 feet Protected less than 20 feet

[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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H (Cont.)	5—Aircraft repair hangars	1 hour less than 60 feet	Protected less than 60 feet
I See also Section 1002	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)	2 hours less than 5 feet, 1 hour elsewhere	Not permitted less than 5 feet 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 See also Section 1202	1—Hotels and apartment houses 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 streets, 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	I	M[2]	R-1	R-3
A-1		N	N	N	N	4	3	3	3	N	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	4	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	4	2	1	1	1	4	1	3[1]	1
B-2	3	1	1	N	1	1		1	1	1	2	1	1	1	2	1	1	N
B-3	3	1	1	1	1	1	1		1	1	2	1	1	1	4	1	1	N
B-4	3	1	1	N	1	1	1	1		1	2	1	1	1	4	N	1	N
E	N	N	N	N	N	4	1	1	1		4	4	4	4	1	1	1	1
H-1	4	4	4	4	4	2	2	2	2	4		1	1	1	4	1	4	4
H-2	4	4	4	4	4	1	1	1	1	4	1		1	1	4	1	3	3
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
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	1	1		1	1
R-1	1	1	1	1	1	3[1]	1	1	1	1	4	3	3	3	1	1		N
R-3	1	1	1	1	1	1	N	N	N	1	4	3	3	3	1	1	N	

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

[1]The three-hour separation may be reduced to two hours where the Group B, Division 1 Occupancy is limited to the storage of passenger motor vehicles having a capacity of not more than nine persons. This shall not apply where provisions of Section 702 (a) apply.

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

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TABLE NO. 5-C—BASIC ALLOWABLE FLOOR AREA FOR BUILDINGS ONE STORY IN HEIGHT[6]
(In Square Feet)

OCCUPANCY	TYPES OF CONSTRUCTION								
	I	II			III		IV	V	
	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	Unlimited	29,900	13,500	9,100	13,500	9,100	13,500	10,500	6,000
B) 1-2-3[1]	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) 1-2[2]	15,000	12,400	5,600	3,700	5,600	3,700	5,600	4,400	2,500
H) 3-4-5	Unlimited	24,800	11,200	7,500	11,200	7,500	11,200	8,800	5,100
I) 1-2	Unlimited	15,100	6,800	Not Permitted	6,800	Not Permitted	6,800	5,200	Not Permitted
I-3	Unlimited	15,100	Not Permitted[3]						
M[4]	See Chapter 11								
R-1	Unlimited	29,900	13,500	9,100[5]	13,500	9,100[5]	13,500	10,500	6,000[5]
R-3	Unlimited								

[1]For open parking garages, see Section 709.
[2]See Section 903.
[3]See Section 1002 (b)
[4]For agricultural buildings, see also Appendix Chapter 11.
[5]For limitations and exceptions, see Section 1202 (b).
[6]For multistory buildings, see Section 505 (b).

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	Unlimited	12	2	1	2	1	2	2	1
B) 1-2-3[1]	Unlimited	12	4	2	4	2	4	3	2
B-4	Unlimited	12	4	2	4	2	4	3	2
E[2]	Unlimited	4	2[2]	1	2[2]	1	2[2]	2[2]	1
H-1	Unlimited	2	1	1	1	1	1	1	1
H) 2-3-4-5	Unlimited	5	2	1	2	1	2	2	1
I-1	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[3]						
M[4]	See Chapter 11								
R-1	Unlimited	12	4	2[5]	4	2[5]	4	3	2[5]
R-3	Unlimited	3	3	3	3	3	3	3	3

[1]For open parking garages, see Section 709.
[2]See Section 802 (c).
[3]See Section 1002 (b)
[4]For agricultural buildings, see also Appendix Chapter 11.
[5]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 with a stage and an occupant load of 1000 or more in the building.

Division 2. Any building or portion of a building having an assembly room with an occupant load of less than 1000 and a 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 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 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. Division 4 structures of open skeleton-frame type without roof, cover or enclosed usable spaces shall not be limited in area or height.

2. 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 enclosed platforms as defined in Sections 417 and 420 shall be constructed in accordance with 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 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.

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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 of structures housing Division 4 Occupancies shall conform to the requirements of this code.

Structures housing Division 4 Occupancies, other than those of open skeleton-frame type, when more than one story in height or 400 square feet in area, shall be of not less than one-hour fire-resistive construction.

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 all Division 4 structures to be reinspected at least once every six months.

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.)

(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

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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 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 toilet facility, with 50 additional 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.

Exit lighting in portions of buildings other than the stage shall be on a separate circuit from that of the stage. Such exit lighting shall be controlled from the box office or other approved central control center located in a portion of the building other than the stage.

All registers or vents supplying air backstage shall be equipped with automatic closing devices with fusible links. Such closing devices 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.

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.

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

Shaft 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 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 3901.

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.

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

Flammable liquids shall not be placed or stored in any Group A Occupancy.

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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 or central heating plant shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

EXCEPTION: Boilers or central heating plants 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 ¾-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 highly flammable 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 highly flammable liquids.

Open parking garages.

Heliports.

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

Factories and workshops using noncombustible and nonexplosive materials.

Storage and sales rooms of noncombustible and nonexplosive materials.

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.
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 laundry rooms and mechanical equipment rooms incidental to the operation of the building.

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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.

(b) **Special Provisions.** 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 airplanes 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.

Storage areas in excess of 1000 square feet in connection with wholesale or retail sales in Division 2 Occupancies shall be separated from the public areas by a one-hour fire-resistive occupancy separation as defined in Chapter 5. Such areas may be increased to 3000 square feet when sprinklers, not otherwise required, are installed in the storage area.

EXCEPTION: A one-hour fire-resistive occupancy separation is not required where an approved automatic sprinkler system is installed throughout the building. Area increases also shall be permitted as specified in Section 506 (c).

Storage garages in connection with Group R, Division 1 Occupancies shall have an unobstructed headroom clearance of not less than 6 feet 6 inches above the finish floor to any ceiling, beam, pipe or similar construction, except for wall-mounted shelves, storage surfaces, racks or cabinets.

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

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

For smoke and heat venting, see Section 3206.

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.

Light, Ventilation and Sanitation

Sec. 705. All portions of Group B 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.

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In all buildings or portions thereof where flammable liquids are used, exhaust ventilation shall be provided sufficient to produce four air changes per hour. Such exhaust ventilation shall be taken from a point at or near the floor level.

In all enclosed parking garages 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 not exceeding an area of 5000 square feet, 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 toilet facility, with 50 additional 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 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.

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Sprinkler 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 volatile flammable 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 flammable 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 volatile flammable liquids or gas are used or stored.

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

> **EXCEPTION:** Boilers or central heating plants 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) **Definition.** For the purpose of this section, an open parking garage is a structure of Type I or II construction which is open on two or more sides totaling not less than 40 percent of the building perimeter and which is used exclusively for parking or storage of private pleasure cars. For a side to be considered open, the total area of openings distributed along the side shall be not less than 50 percent of the exterior area of the side at each tier. The area of openings may be reduced below the minimum 50 percent for 40 percent of the perimeter, provided the percentage of the perimeter in which the openings are contained is increased proportionately.

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

Open parking garages are further classified as either ramp-access or mechanical-access. Ramp-access open parking garages are those 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. Mechanical-access parking garages are those 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.

(c) **Construction.** Construction shall be of noncombustible materials. Open parking garages shall meet the design requirements of Chapter 23. Adequate

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curbs and railings 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. In structures with sides open [as defined in Subsection (b)] three fourths of the building perimeter may be increased 25 percent in area and one tier in height. Structures with sides open [as defined in Subsection (b)] around the entire building perimeter may be increased 50 percent in area and one tier in height.

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 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.** When located adjacent to interior property lines, exterior walls shall be of the degree of fire resistance set forth in Table No. 7-B and such walls shall be without openings.

(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,

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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 stairs, exits and 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 flammable liquid spillage to the landing area itself 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.

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

TYPE OF CONSTRUCTION	AREA PER TIER (Square Feet)	HEIGHT		
		RAMP-ACCESS	MECHANICAL-ACCESS	
			Automatic Fire-extinguishing System	
			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

DISTANCE FROM PROPERTY LINE TO BUILDING	WALL CONSTRUCTION
0'-20'	One-hour

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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 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, except 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, the following definitions are applicable:

COMMON ATMOSPHERE. A common atmosphere exists between rooms, spaces 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, spaces 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 shall apply only to the requirements for providing separate atmospheres.

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 without the hose stream test.

Ducts penetrating atmospheric separation walls, partitions or floors shall be

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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 detectors of products of combustion other than heat.

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 day-care purposes, kindergarten, first or second grade pupils and Division 3 Occupancies shall not be located above the first story.

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

(d) **Special Hazards.** Rooms or groups of rooms in which flammable liquids, combustible dust or similar hazardous materials are used, stored, developed or handled shall be separated from other portions of the building by not less than a one-hour fire-resistive occupancy separation.

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.)

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.

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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 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 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 or central heating plant shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

EXCEPTION: Boilers or central heating plants 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.

Flammable liquids shall not be placed, stored or used in any Group E Occupancies, except in approved quantities as necessary in laboratories and 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 cabinet for flammable 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.** Group H Occupancies shall be:

Division 1. Storage, handling, use or sale of hazardous and highly flammable or explosive materials other than flammable liquids.

> **EXCEPTION:** The storage, handling, use or sale of hazardous materials or chemicals that do not exceed the quantities listed in Table No. 9-A are permitted in other occupancies, provided the storage, handling, use or sale of such hazardous materials or chemicals is in compliance with the Fire Code.

Division 2. Storage, handling, use or sale of Classes I, II and III-A liquids; dry cleaning plants using Class I, II or III-A liquids; paint stores with bulk handling; paint shops and spray-painting rooms and shops.

> **EXCEPTION:** The storage, handling, use or sale of liquids in quantities that do not exceed those set forth in Table No. 9-A are permitted in other occupancies, provided the storage, handling, use or sale is in compliance with the provisions of the Fire Code.

Division 3. Woodworking establishments, planing mills, box factories, buffing rooms for tire-rebuilding plants and picking rooms; shops, factories or warehouses where loose combustible fibers or dust are manufactured, processed, generated or stored; and pin-refinishing rooms.

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

Division 5. Aircraft repair hangars.

(b) **Special Provisions.** In buildings used for educational purposes, vocational shops, laboratories and similar areas need not be classified as Group H Occupancies, provided:

1. Such areas are separated from classrooms other than the classroom directly related to the use by not less than a one-hour fire-resistive occupancy separation.
2. Such areas are separated from each other by not less than a one-hour fire-resistive occupancy separation unless the uses are determined to be compatible.
3. The requirements of Sections 908, 910 and the Fire Code shall be met when applicable.

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

Where an approved spray booth constructed as specified in the Fire Code is installed, such booth need not be separated from other Group H or Group B Occupancies.

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.

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(b) **Special Provisions.** Division 5 Occupancies shall have exterior walls of not less than one-hour fire-resistive construction or shall be surrounded by public space, streets or yards not less than 60 feet in width.

The area increases allowed by Section 506 (a) shall not exceed 500 percent for aircraft repair hangars.

In areas where motor vehicles, boats or airplanes are stored, repaired or operated and where flammable liquids are stored or used, floor surfaces shall be of noncombustible nonabsorbent materials.

EXCEPTION: Floors may be surfaced or waterproofed with asphaltic paving materials where no repair work is done.

For special provisions and hazardous chemicals and magnesium, see also the Fire Code.

A Division 4 Occupancy having a floor area not exceeding 2500 square feet shall 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 10 feet from a property line.

For smoke and heat venting, see Section 3206.

(c) **Special Occupancies.** 1. **Liquid storage rooms.** The design and construction of liquid storage rooms in which Class I, II or III-A liquids are stored shall be in accordance with the requirements for a Group H, Division 2 Occupancy and the following:

A. Floors shall be of noncombustible liquid-tight construction designed to prevent liquids from flowing to adjacent rooms by any of the following methods:

(i) Recessing the floor at least 4 inches lower than the floor of adjacent rooms.

(ii) Installation of liquid-tight sills at least 4 inches in height. Sills may be omitted at openings when trenches are constructed in accordance with Item (iii) below.

(iii) Installation of an open-grate trench which drains to an approved location.

B. Shelving, racks, dunnage, scuffboards, floor overlay and similar installations shall be of noncombustible construction or wood not less than 1-inch nominal thickness.

2. **Inside liquid rooms.** Rooms that do not have an exterior wall may be used for the storage or the storage and use, dispensing or mixing of Class I, II or III-A liquids, provided they do not exceed 500 square feet in area and are separated from other areas by occupancy separations having a fire-resistive rating 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 be not less than required by Table No. 5-B.

3. **Liquid storage warehouses.** The design and construction of liquid storage warehouses in which flammable or combustible liquids are stored shall be in accordance with the requirements for a Group H, Division 2 Occupancy and this

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section. Liquid storage warehouses shall be used for the storage of flammable or combustible liquids only and shall be separated from all other uses by a four-hour area separation wall.

All liquid storage warehouses shall be provided with adequate drainage. Drainage systems shall be sized and designed to carry off any anticipated spill, plus the minimum calculated fire flow of the sprinkler system to a safe location. If connected to a public drain or sewer system, a clarifier shall be installed.

Floors and equipment in liquid storage warehouses shall comply with the applicable provisions of Subsection (c) 1, Items A and B, above.

Location on Property

Sec. 903. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 504 and Part IV.

Group H, Division 1 Occupancies shall be located 60 feet from all property lines including property lines adjacent to public ways.

Group H, Division 2 Occupancies containing hazardous materials in excess of the amounts listed in Table No. 9-A shall not exceed 1500 square feet in area unless there is more than 30 feet from all property lines including property lines adjacent to public ways.

When a building is of mixed occupancy and contains a Group H, Division 2 Occupancy, the Group H, Division 2 Occupancy shall be separated from the other occupancy as required in Table No. 5-B. Such Group H, Division 2 Occupancies shall be on the outer perimeter of the building and all walls of the Group H, Division 2 Occupancy shall be located a minimum of 30 feet from property line.

EXCEPTION: Inside liquid rooms that comply with the limitations in Section 902 (c) 2.

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. All portions of Group H 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.

In all buildings or portions thereof where flammable liquids are used, exhaust ventilation shall be provided sufficient to produce four complete air changes per hour. Such exhaust ventilation shall be taken from a point at or near the floor level.

In all buildings used for the repair or handling of automobiles operating under their own power, ventilation shall be provided capable of exhausting a minimum of 1 cfm per square foot. Additionally, 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

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minute. Connecting offices and waiting rooms shall be supplied with conditioned air under positive pressure.

EXCEPTION: In public repair garages and aircraft hangars not exceeding an area of 5000 square feet, 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.

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 toilet facility, with 50 additional 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 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 Systems

Sec. 907. When required by other provisions of this code, automatic sprinkler systems and standpipes shall be 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 or central heating plant shall be separated from the rest of the building by a two-hour fire-resistive occupancy separation.

In Divisions 1 and 2, there shall be no openings in such occupancy separations except for necessary ducts and piping.

In any room in a Group H, Division 1, 2 or 3 Occupancy in which volatile, flammable liquids or hazardous materials are stored or used, energy-consuming equipment shall not be used unless such equipment has been listed specifically for the hazardous atmosphere that may develop.

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

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The use, handling and sale of Classes I, II and III-A liquids shall be in accordance with the Fire Code.

Dry-cleaning plants shall comply with the Fire Code.

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.

The storage and handling of cellulose nitrate plastics other than film shall be in accordance with the Fire Code. Storage and handling of combustible fiber in amounts beyond the exemptions of Table No. 9-A shall be in accordance with the Fire Code.

Combustible fiber storage rooms or vaults having a capacity exceeding 500 cubic feet shall be separated from the remainder of the building by a two-hour fire-resistive occupancy separation.

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

Fire Alarms

Sec. 909. An approved fire alarm system shall be installed in Group H, Division 2 Occupancies used for the manufacturing of organic coatings as specified in the Uniform Fire Code.

Explosion Venting

Sec. 910. (a) **Flammable Dusts.** Rooms or portions of a building wherein flammable dusts are stored, manufactured, processed or used and may be in suspension in the air continuously or intermittently, shall conform with the following:

1. Wall and ceiling surfaces shall be smooth. Ledges shall be beveled at 60 degrees to the horizontal to prevent the accumulation of dust.

2. Every dust-producing process shall be provided with a dust-collection system adequate in capacity to prevent hazardous concentrations of dust within the room.

3. Effective venting devices equal in area to at least 1 square foot for each 80 cubic feet of volume shall be provided for every flammable dust-collection or storage container having a volume exceeding 250 cubic feet.

The venting devices shall be of light noncombustible construction and shall vent directly to the exterior of the building. Venting devices shall be located in walls facing yards 30 feet or more in width, or located in roofs where there are no snow loads.

(b) **Flammable Liquids.** Rooms used for dispensing of Class I-B liquids and rooms used for storage or dispensing of Class I-A liquids shall have roofs or walls designed to relieve internal explosion forces.

Group H, Division 2 Occupancies involving chemical operations such as oxidation, reduction, polygenization, hydrogenation, alcoholization, polymerization and similar chemical processes shall have roofs or walls designed to relieve explosion forces.

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TABLE NO. 9-A—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS, LIQUIDS AND CHEMICALS

MATERIAL	MAXIMUM QUANTITIES
1. Flammable liquids[1]	
Class I-A	30 gal.[2]
Class I-B	60 gal.[2]
Class I-C	90 gal.[2]
2. Combustible liquids[1]	
Class II	120 gal.[2]
Class III-A	250 gal.[2]
3. Combination flammable liquids[3]	120 gal.[2]
4. Flammable gases	3000 cu. ft. at one atmosphere of pressure at 70°F.
5. Liquefied flammable gases	60 gal.
6. Flammable fibers—loose	100 cu. ft.
7. Flammable fibers—baled	1000 cu. ft.
8. Flammable solids	500 lbs.
9. Unstable materials	No exemptions
10. Corrosive liquids	55 gal.
11. Oxidizing material—gases	6000 cu. ft.
12. Oxidizing material—liquids	50 gal.
13. Oxidizing material—solids	500 lbs.
14. Organic peroxides	10 lbs.
15. Nitromethane (unstable materials)	No exemptions
16. Ammonium nitrate	1000 lbs.
17. Ammonium nitrate compound mixtures containing more than 60% nitrate by weight	1000 lbs.
18. Highly toxic material and poisonous gas	No exemptions
19. Smokeless powder	20 lbs.[4]
20. Black sporting powder	1 lb.[5]

[1]The quantities of alcoholic beverages in retail sales or storage uses are unlimited, provided the liquids are packaged in individual containers not exceeding 4 liters.

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 solution not being flammable, in retail sales or storage occupancies are unlimited when packaged in individual containers not exceeding 4 liters.

[2]Quantities may be increased by 100 percent in areas which are not accessible to the public. In buildings where automatic fire-extinguishing systems are installed, the quantities may be increased 100 percent in areas accessible to the public.

[3]Containing not more than the exempt amounts of Class I-A, I-B or I-C flammable liquids.

[4]Quantities of smokeless powder may be increased to a maximum of 100 pounds, providing those amounts exceeding 20 pounds are stored in an approved Class II magazine as specified in the Uniform Fire Code.

[5]Quantities of black sporting powder may be increased to a maximum of 5 pounds, providing said amount is stored in an approved Class II magazine as specified in the Uniform Fire Code.

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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.

(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. See Section 3321 (g) for limitation on locking devices.

Every story of a Group I, Division 1 Occupancy accommodating more than five nonambulatory persons, unless provided with a horizontal exit, shall be divided into not less than two compartments accommodating approximately the same number of nonambulatory persons in each compartment by a smoke-stop partition meeting the requirements of a one-hour occupancy separation so as to provide an area of refuge within the building. Corridor openings in the smoke-stop partition shall be protected with doors as required in Section 3305 (h). Other openings shall be limited to ducts which have smoke-detector-activated fire dampers in the plane of the wall.

Rooms occupied by inmates or patients whose personal liberties are restrained shall have noncombustible floor surfaces.

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.

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Exit Facilities

Sec. 1004. Stairs, exits and smokeproof enclosures customarily used by human beings shall be provided as specified in Chapter 33. (See also Section 3321.)

Light, Ventilation and Sanitation

Sec. 1005. All portions of Group I Occupancies 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 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 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.

Storage of volatile flammable liquids shall not be allowed in Group I Occupancies and the handling of such liquid shall not be permitted in any Group I Occupancies in quantities of more than one gallon unless such handling complies 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 or central heating plant shall be separated from the rest of the building by not less than a one-hour fire-resistive occupancy separation.

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

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.

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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 in Group M, Division 1 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 this section. Any building or portion thereof that exceeds the limit specified in this chapter shall be classed in the occupancy group other than Group M, Division 1 that it most nearly resembles.

For a mixed occupancy building, the total area of private garages used exclusively for the parking of passenger motor vehicles having a capacity of not more than nine persons per vehicle may be 3000 square feet, provided the exterior wall and opening protection are as required for the major occupancy of the building. The allowable floor area of the building shall be as permitted for the major occupancy of the building. Each portion of a building separated as specified in Section 505 may be considered a separate building. Such increase in area may apply to a single-occupancy building, provided the use of the building is as specified and the exterior wall and opening protection are as required for a Group R, Division 1 Occupancy building.

(b) **Special Provisions.** Garages in connection with Group R, Division 1 Occupancies shall have an unobstructed headroom clearance of not less than 6 feet 6 inches 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.

Under no circumstances shall a private garage have any opening into a room used for sleeping purposes.

Flammable liquids shall not be stored, handled or used in Group M Occupancies unless such storage or handling shall comply with the Fire Code.

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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.** 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 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.

Every apartment house three stories or more in height or containing more than 15 dwelling units and every hotel three stories or more in height or containing 20 or more guest rooms shall have an approved fire alarm system as specified in the Fire Code.

> **EXCEPTION:** An 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 has an exit direct to a yard or public way.

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.

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Exit Facilities

Sec. 1204. Stairs, exits and smokeproof enclosures shall be as specified in Chapter 33.

Every sleeping room below the fourth story shall have at least one operable window or exterior door approved for emergency escape or rescue. The units shall be operable from the inside to provide a full clear opening without the use of separate tools.

All escape or rescue windows from sleeping rooms shall have a minimum net clear opening of 5.7 square feet. The minimum net clear opening height dimension shall be 24 inches. The minimum net clear opening width dimension shall be 20 inches. Where 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) **Light and Ventilation.** 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. 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 1½ square feet.

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. In bathrooms, water closet compartments, laundry rooms and similar rooms a mechanical ventilation system connected directly to the outside, capable of providing five air changes per hour, shall be provided.

For the purpose of determining light and ventilation requirements, 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.

Required exterior openings for natural light and ventilation shall open directly

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onto a street or public alley 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 street, 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) **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.

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 510.

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 street 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 space. 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. Kitchens, halls, bathrooms and toilet compartments may have a ceiling height of

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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 150 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 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.

Fire-warning and Sprinkler Syatems

Sec. 1210 (a) **Fire-warning Systems.** Every dwelling unit and every guest room in a hotel or lodging house used for sleeping purposes shall be provided with smoke detectors conforming to U.B.C. Standard No. 43-6. 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 rooms used for sleeping purposes. In an efficiency dwelling unit, hotel sleeping room and in hotel suites, the detector shall

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be centrally located on the ceiling of the main room or hotel sleeping room. Where sleeping rooms are on an upper level, the detector shall be placed at the center of the ceiling directly above the stairway. All detectors shall be located in accordance with approved manufacturer's instructions. When actuated, the detector shall provide an alarm in the dwelling unit or guest room.

When alterations, repairs or additions requiring a permit and having a valuation in excess of $1000 occur, or when one or more sleeping rooms are added or created in existing Group R, Division 3 Occupancies, the entire building shall be provided with smoke detectors located as required for new Group R, Division 3 Occupancies.

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 the second paragraph of this section.

A smoke detector shall be installed in the basement of dwelling units having a stairway which opens from the basement into the dwelling. Such detector shall be connected to a sounding device or other detector to provide an alarm which will be audible in the sleeping area.

(b) **Sprinkler Systems.** When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 38.

Heating

Sec. 1211. 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. 1212. 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 volatile 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 or central heating plant 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 servicing only one dwelling unit.

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Access to Buildings and Facilities

Sec. 1213. 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

To determine the total number of aeeessible 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 510.

Modifications

Sec. 1214. A one-story carport entirely open on two or more sides need not have a fire separation between the carport and the dwelling.

Windows between the carport and the dwelling shall not be openable. Doors may be of any type, provided that any sash used in a door be fixed; doors between a dwelling and a carport shall be self-closing.

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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 a 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 (d) 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 buildings 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.

Roofs

Sec. 1704. Roof coverings shall be as specified in Section 3202 (b).

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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 of 30 or more 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 showcases 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 ⅜-inch nominal thickness may be applied to walls, provided the veneer does not exceed 15 feet above grade, and further

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provided such veneer shall be placed either directly against noncombustible surfaces or furred out from such surfaces not to exceed 1⅛ 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. 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 ½ inch and a maximum width of 4 inches and (3) has a flame-spread rating no greater than 75. Unprotected wood doors and windows may be used except where openings are required to be fire protected.

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.

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 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-clad 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

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gas vents and for ducts or 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.

(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.

(d) **Elevator Shafts.** Shafts housing elevators and extending through more than two stories shall be vented to the outside. The area of vents shall be not less than 3½ percent of the area of the elevator shaft, with a minimum of 3 square feet per elevator.

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 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.

Weather-protective 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,

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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 not less than one-hour fire protection.

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. The height of the parapet shall be not less than 30 inches above the point where the roof surface and the wall intersect. Where the roof slopes toward a parapet at slopes greater than 2:12, the parapet 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 Section 3305 for additional requirements applicable to exterior exit balconies.)

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.

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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 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. Guardrails shall be not less than 42 inches in height. Open guardrail and stair railings shall have intermediate rails or an ornamental pattern such that a sphere 6 inches in diameter cannot pass through. The height of stair railings on open sides may be as specified in Section 3306 (j) in lieu of providing a guardrail. Ramps shall, in addition, have handrails when required by Section 3307.

EXCEPTIONS: 1. Guardrails need not be provided on the loading side of loading docks.

2. Guardrails for Group R, Division 3 and Group M, Division 1 Occupancies may be 36 inches in height.

3. Interior guardrails within individual dwelling units or guest rooms of Group R, Division 1 Occupancies may be 36 inches in height.

4. 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 increased such that a 12-inch-diameter sphere cannot pass through.

5. 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.

6. Guardrails need not be provided on the auditorium side of a stage or enclosed platform.

Foam Plastic Insulation

Sec. 1712. (a) **General.** The provisions of this section shall govern the requirements and uses of foam plastic in buildings and structures. For trim, see Section 1705 (e).

Except where otherwise noted in this section, all foam plastics 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 and foam plastic 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 by an approved thermal barrier having an index of 15 when tested over calcium silicate board 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 pro-

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vided by Section 1712 (c) or by other sections of this code, foam plastics may be used as follows:

1. **Masonry or concrete construction.** Foam plastics may be used without the thermal barrier described above, regardless of the type of construction, when the foam plastic 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 plastics 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 installed and meeting the requirements of (a) above when tested in a thickness of 4 inches may be used in a thickness up to 10 inches in cold storage buildings, ice plants, food-processing rooms and similar areas. For rooms within a building, the foam plastic shall be protected by a thermal barrier on both sides having an index of 15.

Foam plastic insulation may be used in freestanding coolers and freezers without the thermal barrier when the foam plastic has a flame-spread rating of 25 or less when tested in the thickness intended for use, 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.

> **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.

4. **Metal-clad building units.** Foam plastic insulation having a flame spread of 25 or less may be used without the thermal barrier in or on walls in a thickness of not more than 4 inches when the foam plastic is covered by a thickness of not less than 0.032-inch aluminum or corrosion-resistant steel having a base metal thickness not less than 0.0160 inch at any point and the area is protected with automatic sprinklers. Such walls shall not be used where noncombustible or fire-resistive construction is required.

5. **Roofing.** Foam plastics 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 accordance with U.B.C. Standard No. 32-7. Foam plastic 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 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 when the foam is separated from the interior of the building by plywood sheathing not less than ½ inch in

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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 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 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 ½ 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 plastics 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 a 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 3204.

(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 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

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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.

Atriums

Sec. 1715. (a) **General.** Buildings of other than Group H Occupancy with automatic sprinkler protection throughout may have atriums complying with the provisions of this section. Such atriums 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 atruim. 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 atriums 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 exhaust and supply system for the atrium shall operate automatically upon the actuation of the automatic sprinkler system within the atrium or areas open to the atrium or by the actuation of two or more smoke detectors required by this section. The exhaust and supply equipment shall also be manually operable by controls designed for fire department use. The smoke-control system may 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.

Enclosed tenant spaces shall be provided with a smoke-control system complying with the requirements of a sprinklered building in Section 1807 (g), Item No. 2 or 3.

The atrium smoke-control system shall exhaust not less than the following quantities of air:

1. For atriums having a volume of not more than 600,000 cubic feet, including the volume of any levels not physically separated from the atrium, not

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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 atriums 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 at the perimeter and on the ceiling of the atrium and on the ceiling of each floor level that is open to the atrium. In floor levels open to the atrium, such detectors shall be within 15 feet of the atrium. Detectors shall be located in accordance with their listing.

(c) **Enclosure of Atriums.** Atriums shall be separated from adjacent spaces by not less than one-hour fire-resistive construction.

EXCEPTION: Open exit balconies are permitted within the atrium.

Openings in the atrium enclosure other than fixed glazing shall be protected by tight-fitting doors which are maintained automatic closing, in accordance with Section 4306 (b), by actuation of a smoke detector, or self-closing.

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. In occupancies other than Group R, Division 1, the tenant space may be separated from the atrium by a wired, tempered or laminated glass wall, subject to the following:

A. The glass shall be protected by a sprinkler system equipped with 135°F. heads. 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.

The separation between the tenant space and the atrium as specified within Exception 2 may be omitted on a maximum of any three floor levels, provided the remaining floor levels are separated as specified herein.

(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

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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 the last 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) **Inspection of the Smoke-control System.** All operating parts of the smoke-control systems shall be tested by an approved inspection agency or by the owner or his representative when so approved. Such inspections shall be made every three months and a log of the tests be kept by the testing agency. The log shall be on the premises and available for examination by fire department personnel.

(k) **Combustible Furnishings in Atriums.** The quantity of combustible furnishings in atriums 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 the area of the room in which it is 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.

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3. In industry facilities, mezzanines used for control equipment may be glazed on all sides.

5. Two exits shall be provided from mezzanines having an occupant load of more than 10 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 in which it is located.

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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.

BUILDING ELEMENT	TYPE I	TYPE II			TYPE III		TYPE IV	TYPE V	
	NONCOMBUSTIBLE				COMBUSTIBLE				
	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	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	2	2	1	N	1	N	H.T.	1	N
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 specificd 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.

EXCEPTIONS: 1. Nonbearing walls fronting on streets 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 street or public space.

No openings shall be permitted in exterior walls of Groups A, E, I, H 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.

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 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

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permanent partitions so that there is no communication under the flooring between adjoining rooms.

EXCEPTION: Firestopping need not be provided in such floors when at or below grade level in gymnasiums.

Stair Construction

Sec. 1805. Stairs and stair platforms 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.

Stairs shall be designed and constructed as specified in 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 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.

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 covering shall be fire-retardant roofing as specified in Section 3202 (b).

Special Provisions for Group B, Division 2 Office Buildings and Group R, Division 1 Occupancies

Sec. 1807. (a) **Scope.** This section shall apply to all Group B, Division 2 office buildings 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 vehicle access. Such buildings shall be provided with either an approved automatic sprinkler system in accordance with Section 1807 (c), or safe areas of refuge (compartmentation) in accordance with Section 1807 (1).

(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.

(c) **Automatic Sprinkler System.** When provided as required in Section 1807 (a), 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:

1. Shutoff valves and a water flow device shall be provided for each floor. The

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sprinkler riser may be combined with the standpipe riser.

2. 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.

(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

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control station. It shall be established on a selective or general basis to the following terminal areas:

A. Elevators.
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. Panels or windows in the exterior walls which can be opened remotely from an approved location other than the fire floor. Such venting facilities shall be provided at the rate of 20 square feet per 50 lineal feet of exterior wall in each story and shall be distributed around the perimeter at not more than 50-foot intervals. Such windows or panels and their controls shall be clearly identified.

> **EXCEPTION:** When a complete automatic sprinkler system is installed, windows or panels manually openable from within the fire floor or approved fixed tempered glass may be used in lieu of the remotely operated openable panels and windows. Such windows shall be clearly identified and shall be of the size and spacing called for in Section 1807 (g) 1.

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-

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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.

(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.

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. System 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 supplying 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 as 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 to be 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.

(l) **Areas of Refuge (Compartmentation) Alternate.** Areas of refuge conforming to the following may be provided as an alternate to the automatic sprinkler system:

1. Every story shall be divided into two or more areas of approximately the same size with no single area exceeding 15,000 square feet. The wall and door shall be constructed as required for a horizontal exit in Section 3307.

2. Each area of refuge (compartment) shall contain one elevator to the main floor and a minimum of one enclosed exit stairway.

3. Openings in exterior walls, where such openings are within 5 feet of each other horizontally on vertically adjacent floors, shall be protected by approved flame barriers either extending 30 inches beyond the exterior wall in the plane of the floor or by approved vertical panels not less than 3 feet in height above the floor.

4. Horizontal exit walls used for compartmenting a building shall have a fire-resistance rating of not less than two hours. Duct penetrations of this wall shall not be permitted. Ferrous or copper piping and conduit may penetrate or pass through the wall only if the openings are caulked with impervious noncombustible materials sufficiently tight to prevent the transfer of smoke or combustion gases

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from one side of the wall to the other and are so maintained. The fire door serving as the horizontal exit between compartments shall be so installed, fitted and gasketed that it will provide a substantial barrier to the passage of smoke.

5. The fire-resistive floor or the floor-ceiling construction shall extend to and be tight against the exterior wall so that the fire-resistive integrity between stories is maintained. No penetrations or other installations which will impair the fire-resistive integrity of the floor or floor-ceiling assembly shall be permitted.

6. A manual fire alarm system (pull boxes) shall be installed in accordance with U.B.C. Standard No. 18-1.

(m) **Automatic Sprinkler System Alternatives.** When a complete approved automatic sprinkler system complying with this section is installed in a building, the following modifications of code requirements are permitted:

1. 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.

2. 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.

3. Fixed tempered glass may be used in lieu of openable panels for smoke control purposes.

4. Travel distance from the most remote point in the floor area to a horizontal exit or to an enclosed stairway may be 300 feet.

5. The manually operated fire alarm system required in the compartmented building is not required.

6. Spandrel walls, eyebrows and compartmentation are not required; however, the fire resistance of the floors and juncture of exterior walls with each floor must be maintained.

7. Fire dampers, other than those needed to protect floor-ceiling assemblies to maintain the fire resistance of the assembly, are not required except for those which may be necessary to bypass smoke to the outside, those provided to convert from recirculated air to 100 percent outside air, and those which may be required to protect the fresh air supply intake against smoke which may be outside the building.

8. Emergency windows required by Section 1204 are not required.

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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. For fire protection of exterior walls as determined by location on property, see Table No. 5-A for Type II One-hour and Type II-N buildings.

EXCEPTIONS: 1. Nonbearing walls fronting on streets 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 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

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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 street or public space.

No openings shall be permitted in exterior walls of Type II-F.R. buildings housing Groups A, E, I, H 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 fire protection of exterior wall openings of Type II One-hour and Type II-N buildings as determined by location on property, see Section 504 and Table No. 5-A.

Floors

Sec. 1904. Where wood sleepers are used for laying wood flooring on masonry or concrete fire-resistive floors of Type II-F.R. buildings, 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.

EXCEPTION: Firestopping need not be provided in such floors when at or below grade level in gymnasiums.

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.

Stair Construction

Sec. 1905. Stairs and stair platforms 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. Stairs of Type II One-hour and Type II-N buildings shall be of noncombustible construction.

Stairs shall be designed and constructed as specified in Chapter 33.

Roof Construction

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 covering shall be a fire-retardant roofing as specified in Section 3202 (b).

Special Provisions for Group B, Division 2 Office Buildings and Group R, Division 1 Occupancies

Sec. 1907. Type II-F.R. buildings shall comply with the special provisions on high-rise buildings in Section 1807.

EXCEPTION: The reduction provisions for roofs in Section 1807 (m), Item No. 1, 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.

EXCEPTIONS: 1. Nonbearing walls fronting on streets, 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 street or public space.

No openings shall be permitted in exterior walls of Groups A, E, I, H 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.

(c) **Partitions.** Bearing partitions, when constructed of wood, shall comply with Section 2516 (d).

Stair Construction

Sec. 2004. Stairs in buildings not exceeding three stories in height may be constructed of any material permitted by this code.

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In buildings more than three stories in height, stairs shall be constructed as required for Type I buildings.

Stairs shall comply with the requirements of Chapter 33.

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.

EXCEPTIONS: 1. Nonbearing walls fronting on streets, 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 street or public space.

No openings shall be permitted in exterior walls of Groups A, E, I, H 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.

(c) **Partitions.** Bearing partitions, when constructed of wood, shall comply with Section 2516 (d).

Stair Construction

Sec. 2104. Stairs shall be constructed as specified in Section 2106.

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In buildings more than three stories in height, stairs shall be constructed as required for Type I buildings.

Stairs shall comply with the requirements of Chapter 33.

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 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 ½-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 ½-inch plywood. The lumber shall be laid so that no continuous line of joints will occur except at points of

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support. Floors shall not extend closer than ½ inch to walls. Such ½-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 floor 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 1⅛-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.

(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.

(j) **Stairs.** Stairs shall be constructed with wood treads and risers of not less than 2-inch thickness, except where built on laminated or plank inclines as required for floors, when they may be of 1-inch thickness or may be constructed as required in Type I buildings. Stair stringers shall be a minimum of 3 inches in thickness and not less than 10 inches in depth.

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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. For fire protection of exterior walls and openings as determined by location on property, see Section 504 and Table No. 5-A.

EXCEPTION: Exterior walls of a Type V nonrated building fronting on streets or yards having a width of at least 40 feet may be of unprotected construction.

Stair Construction

Sec. 2204. Stair construction may be of any type permitted in this code and shall conform to the requirements of Chapter 33.

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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 prescribes 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 vertical 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 including 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 constructed to sustain, within the stress limitations specified in this code, all dead loads and all other loads specified in this chapter or elsewhere in this code. Impact 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 conventional 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-

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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.

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) 4.

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. Dead plus floor live plus roof live (or snow).[1]
2. Dead plus floor live plus wind (or seismic).
3. Dead plus floor live plus wind plus snow/2.[1]
4. Dead plus floor live plus snow plus wind/2.[1]
5. Dead plus floor live plus snow[2] plus seismic.

[1]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.

[2]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.

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 occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but which create or accommodate similar loadings.

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EXCEPTION: In designing floors to be used for industrial or commercial purposes, the actual live load caused by the use to which the building or part of the building is to be put shall be used in the design of such building or part thereof, and special provision shall be made for machine or apparatus loads when such machine or apparatus would cause a greater load than specified for such use.

(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. Garages for the storage of private pleasure cars shall have the 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.

(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.

EXCEPTION: Alternate span loading need not be considered where the uniform roof live load is 20 pounds per square foot or more and the provisions of Section 2305 (d) are met.

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(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.

(e) **Special-purpose Roofs.** 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 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:

$$R = r\,(A - 150) \quad \text{.....(6-1)}$$

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:

$$R = 23.1\,(1 + D/L) \quad \text{.....(6-2)}$$

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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.

(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.

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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 $\frac{1}{240}$ of the span for walls with brittle finishes and $\frac{1}{120}$ of the span for walls with flexible finishes. See Table No. 23-J 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 (j) 2 C and 2312 (j) 3 A.

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 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. 4, 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. 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

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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 (h).

(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. The weight of earth superimposed over footings may be used to calculate the dead-load-resisting moment.

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 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 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.

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The wind pressures from Subsections (e) and (f) need not be combined.

(g) **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.

(h) **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.

Earthquake Regulations

Sec. 2312. (a) **General.** Every building or structure and every portion thereof shall be designed and constructed to resist stresses produced by lateral forces as provided in this section. Stresses shall be calculated as the effect of a force applied horizontally at each floor or roof level above the base. The force shall be assumed to come from any horizontal direction.

Structural concepts other than set forth in this section may be approved by the building official when evidence is submitted showing that equivalent ductility and energy absorption are provided.

Where prescribed wind loads produce higher stresses, such loads shall be used in lieu of the loads resulting from earthquake forces.

(b) **Definitions.** The following definitions apply only to the provisions of this section:

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.

BOX SYSTEM is a structural system without a complete vertical load-carrying space frame. In this system the required lateral forces are resisted by shear walls or braced frames as hereinafter defined.

BRACED FRAME is a truss system or its equivalent which is provided to resist lateral forces in the frame system and in which the members are subjected primarily to axial stresses.

DUCTILE MOMENT-RESISTING SPACE FRAME is a moment-resisting space frame complying with the requirements for a ductile moment-resisting space frame as given in Section 2312 (j).

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ESSENTIAL FACILITIES—See Section 2312 (k).

LATERAL FORCE-RESISTING SYSTEM is that part of the structural system assigned to resist the lateral forces prescribed in Section 2312 (d).

MOMENT-RESISTING SPACE FRAME is a vertical load-carrying space frame in which the members and joints are capable of resisting forces primarily by flexure.

SHEAR WALL is a wall designed to resist lateral forces parallel to the wall.

SPACE FRAME is a three-dimensional structural system without bearing walls, composed of interconnected members laterally supported so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.

VERTICAL LOAD-CARRYING SPACE FRAME is a space frame designed to carry all vertical loads.

(c) **Symbols and Notations.** The following symbols and notations apply only to the provisions of this section:

C = Numerical coefficient as specified in Section 2312 (d).

C_p = Numerical coefficient as specified in Section 2312 (g) and as set forth in Table No. 23-J.

D = The dimension of the structure, in feet, in a direction parallel to the applied forces.

δ_i = Deflection at level i relative to the base, due to applied lateral forces, Σf_i, for use in Formula (12-3).

$F_i F_n F_x$ = Lateral force applied to level i, n or x, respectively.

F_p = Lateral forces on a part of the structure and in the direction under consideration.

F_t = That portion of V considered concentrated at the top of the structure in addition to F_n.

f_i = Distributed portion of a total lateral force at level i for use in Formula (12-3).

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 = Occupancy Importance Factor as set forth in Table No. 23-K.

K = Numerical coefficient as set forth in Table No. 23-I.

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.

N = The total number of stories above the base to level n.

S = Numerical coefficient for site-structure resonance.

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T = Fundamental elastic period of vibration of the building or structure in seconds in the direction under consideration.

T_s = Characteristic site period.

V = The total lateral force or shear at the base.

W = The total dead load as defined in Section 2302 including the partition loading specified in Section 2304 (d) where applicable.

EXCEPTION: W shall be equal to the total dead load plus 25 percent of the floor live load in storage and warehouse occupancies. Where the design snow load is 30 psf or less, no part need be included in the value of W. Where the snow load is greater than 30 psf, the snow load shall be included; however, where the snow load duration warrants, the building official may allow the snow load to be reduced up to 75 percent.

$w_i w_x$ = That portion of W which is located at or is assigned to level i or x respectively.

W_p = The weight of a portion of a structure or nonstructural component.

Z = Numerical coefficient dependent upon the zone as determined by Figures No. 1, No. 2 and No. 3 in this chapter. For locations in Zone No. 1, $Z = 3/16$. For locations in Zone No. 2, $Z = 3/8$. For locations in Zone No. 3, $Z = 3/4$. For locations in Zone No. 4, $Z = 1$.

(d) **Minimum Earthquake Forces for Structures.** Except as provided in Section 2312 (g) and (i), every structure shall be designed and constructed to resist minimum total lateral seismic forces assumed to act nonconcurrently in the direction of each of the main axes of the structure in accordance with the following formula:

$$V = ZIKCSW \quad \text{(12-1)}$$

The value of K shall be not less than that set forth in Table No. 23-I. The value of C and S are as indicated hereafter except that the product of CS need not exceed 0.14.

The value of C shall be determined in accordance with the following formula:

$$C = \frac{1}{15\sqrt{T}} \quad \text{(12-2)}$$

The value of C need not exceed 0.12.

The period T shall be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis such as the following formula:

$$T = 2\pi\sqrt{\left(\sum_{i=1}^{n} w_i d_i^2\right) \div \left(g \sum_{i=1}^{n} f_i d_i\right)} \quad \text{(12-3)}$$

where the values of f_i represent any lateral force distributed approximately in accordance with the principles of Formulas (12-5), (12-6) and (12-7) or any other

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rational distribution. The elastic deflections, δ_i, shall be calculated using the applied lateral forces, f_i.

In the absence of a determination as indicated above, the value of T for buildings may be determined by the following formula:

$$T = \frac{0.05h_n}{\sqrt{D}} \quad \text{(12-3A)}$$

Or in buildings in which the lateral force-resisting system consists of ductile moment-resisting space frames capable of resisting 100 percent of the required lateral forces and such system is not enclosed by or adjoined by more rigid elements tending to prevent the frame from resisting lateral forces:

$$T = 0.10N \quad \text{(12-3B)}$$

The value of S shall be determined by the following formulas, but shall be not less than 1.0:

$$\text{for } T/T_s = 1.0 \text{ or less} \quad S = 1.0 + \frac{T}{T_s} - 0.5\left[\frac{T}{T_s}\right]^2 \quad \text{(12-4)}$$

$$\text{for } T/T_s \text{ greater than } 1.0 \text{ or less} \quad S = 1.2 + 0.6\frac{T}{T_s} - 0.3\left[\frac{T}{T_s}\right]^2 \quad \text{(12-4A)}$$

WHERE:

T in Formulas (12-4) and (12-4A) shall be established by a properly substantiated analysis but T shall be not less than 0.3 second.

The range of values of T_s may be established from properly substantiated geotechnical data, in accordance with U.B.C. Standard No. 23-1, except that T_s shall not be taken as less than 0.5 second nor more than 2.5 seconds. T_s shall be that value within the range of site periods, as determined above, that is nearest to T.

When T_s is not properly established, the value of S shall be 1.5.

EXCEPTION: Where T has been established by a properly substantiated analysis and exceeds 2.5 seconds, the value of S may be determined by assuming a value of 2.5 seconds for T_s.

(e) **Distribution of Lateral Forces. 1. Structures having regular shapes or framing systems.** The total lateral force V shall be distributed over the height of the structure in accordance with Formulas (12-5), (12-6) and (12-7).

$$V = F_t + \sum_{i=1}^{n} F_i \quad \text{(12-5)}$$

The concentrated force at the top shall be determined according to the following formula:

$$F_t = 0.07TV \quad \text{(12-6)}$$

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F_t need not exceed $0.25V$ and may be considered as 0 where T is 0.7 second or less. The remaining portion of the total base shear V shall be distributed over the height of the structure including level n according to the following formula:

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12\text{-}7)$$

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 on that level.

2. **Setbacks.** Buildings having setbacks wherein the plan dimension of the tower in each direction is at least 75 percent of the corresponding plan dimension of the lower part may be considered as uniform buildings without setbacks, provided other irregularities as defined in this section do not exist.

3. **Structures having irregular shapes or framing systems.** The distribution of the lateral forces in structures which have highly irregular shapes, large differences in lateral resistance or stiffness between adjacent stories, or other unusual structural features, shall be determined considering the dynamic characteristics of the structure.

4. **Accidental torsion.** In addition to the requirements of Section 2303 (b) 2, where the vertical resisting elements depend on diaphragm action for shear distribution at any level, the shear-resisting elements shall be capable of resisting a torsional moment assumed to be equivalent to the story shear acting with an eccentricity of not less than 5 percent of the maximum building dimension at that level.

(f) **Overturning.** At any level the incremental changes of the design overturning moment, in the story under consideration, shall be distributed to the various resisting elements in the same proportion as the distribution of the shears in the resisting system. Where other vertical members are provided which are capable of partially resisting the overturning moments, a redistribution may be made to these members if framing members of sufficient strength and stiffness to transmit the required loads are provided.

Where a vertical resisting element is discontinuous, the overturning moment carried by the lowest story of that element shall be carried down as loads to the foundation.

(g) **Lateral Force on Elements of Structures and Nonstructural Components.** Parts or portions of structures, nonstructural components and their anchorage to the main structural system shall be designed for lateral forces in accordance with the following formula:

$$F_p = ZIC_pW_p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12\text{-}8)$$

The values of C_p are set forth in Table No. 23-J. The value of the I coefficient shall be the value used for the building.

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EXCEPTIONS: 1. The value of I for panel connectors shall be as given in Section 2312 (j) 3 C.

2. The value of I for anchorage of machinery and equipment required for life safety systems shall be 1.5.

The distribution of these forces shall be according to the gravity loads pertaining thereto.

For applicable forces on diaphragms and connections for exterior panels, refer to Sections 2312 (j) 2 C and 2312 (j) 3 C.

(h) **Drift and Building Separations.** Lateral deflections or drift of a story relative to its adjacent stories shall not exceed 0.005 times the story height unless it can be demonstrated that greater drift can be tolerated. The displacement calculated from the application of the required lateral forces shall be multiplied by $(1.0/K)$ to obtain the drift. The ratio $(1.0/K)$ shall be not less than 1.0.

All portions of structures shall be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally by a distance sufficient to avoid contact under deflection from seismic action or wind forces.

(i) **Alternate Determination and Distribution of Seismic Forces.** Nothing in Section 2312 shall be deemed to prohibit the submission of properly substantiated technical data for establishing the lateral forces and distribution by dynamic analyses. In such analyses the dynamic characteristics of the structure must be considered.

(j) **Structural Systems.** 1. **Ductility requirements.** A. All buildings designed with a horizontal force factor $K = 0.67$ or 0.80 shall have ductile moment-resisting space frames.

B. Buildings more than 160 feet in height shall have ductile moment-resisting space frames capable of resisting not less than 25 percent of the required seismic forces for the structure as a whole.

EXCEPTION: Buildings more than 160 feet in height in Seismic Zones Nos. 1 and 2 may have concrete shear walls designed in accordance with Section 2627 or braced frames designed in conformance with Section 2312 (j) 1 G of this code in lieu of a ductile moment-resisting space frame, provided a K value of 1.00 or 1.33 is utilized in the design.

C. In Seismic Zones No. 2, No. 3 and No. 4 all concrete space frames required by design to be part of the lateral force-resisting system and all concrete frames located in the perimeter line of vertical support shall be ductile moment-resisting space frames.

EXCEPTION: Frames in the perimeter line of the vertical support of buildings designed with shear walls taking 100 percent of the design lateral forces need only conform with Section 2312 (j) 1 D.

D. In Seismic Zones No. 2, No. 3 and No. 4 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 and induced moment due to $3/K$ times the distortions resulting from the code-required lateral forces. The rigidity of other elements shall be considered in accordance with Section 2303 (b) 1.

E. Moment-resisting space frames and ductile moment-resisting space frames

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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.

F. Necessary ductility for a ductile moment-resisting space frame shall be provided by a frame of structural steel with moment-resisting connections (complying with Section 2722 for buildings in Seismic Zones No. 3 and No. 4 or Section 2723 for buildings in Seismic Zones No. 1 and No. 2) or by a reinforced concrete frame (complying with Section 2625 for buildings in Seismic Zones No. 3 and No. 4 or Section 2626 for buildings in Seismic Zones No. 1 and No. 2).

EXCEPTION: Buildings with ductile moment-resisting space frames in Seismic Zones No. 1 and No. 2 having an importance factor I greater than 1.0 shall comply with Section 2625 or 2722.

G. In Seismic Zones No. 3 and No. 4 and for buildings having an importance factor I greater than 1.0 located in Seismic Zone No. 2, all members in braced frames shall be designed for 1.25 times the force determined in accordance with Section 2312 (d). Connections shall be designed to develop the full capacity of the members or shall be based on the above forces without the one-third increase usually permitted for stresses resulting from earthquake forces.

Braced frames in buildings shall be composed of axially loaded bracing members of A36, A441, A500 Grades B and C, A501, A572 (Grades 42, 45, 50 and 55) or A588 structural steel, or reinforced concrete members conforming to the requirements of Section 2627.

H. Reinforced concrete shear walls for all buildings shall conform to the requirements of Section 2627.

I. In structures where $K = 0.67$ and $K = 0.80$, the special ductility requirements for structural steel or reinforced concrete specified in Section 2312 (j) 1 F, shall apply to all structural elements below the base which are required to transmit to the foundation the forces resulting from lateral loads.

2. **Design requirements.** A. **Minor alterations.** Minor structural alterations may be made in existing buildings and other structures, but the resistance to lateral forces shall be not less than before such alterations were made, unless the building as altered meets the requirements of this section.

B. **Reinforced masonry or concrete.** All elements within structures located in Seismic Zones No. 2, No. 3 and No. 4 which are of masonry or concrete shall be reinforced so as to qualify as reinforced masonry or concrete under the provisions of Chapters 24 and 26. Principal reinforcement in masonry shall be spaced 2 feet maximum on center in buildings using a moment-resisting space frame.

C. **Diaphragms.** Floor and roof diaphragms and collectors shall be designed to resist the forces determined in accordance with the following formula:

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \qquad \text{.....(12-9)}$$

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WHERE:

F_i = the lateral force applied to level i.

w_i = the portion of W at level i.

w_{px} = the weight of the diaphragm and the elements tributary thereto at level x, including 25 percent of the floor live load in storage and warehouse occupancies.

The force F_{px} determined from Formula (12-9) need not exceed $0.30ZIw_{px}$.

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 offsets 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 (12-9).

However, in no case shall lateral force on the diaphragm be less than $0.14ZIw_{px}$.

Diaphragms supporting concrete or masonry walls shall have continuous ties between diaphragm chords to distribute, into the diaphragm, the anchorage forces specified in this chapter. Added chords may be used to form subdiaphragms to transmit the anchorage forces to the main cross ties. Diaphragm deformations shall be considered in the design of the supported walls. See Section 2312 (j) 3 A for special anchorage requirements of wood diaphragms.

3. **Special requirements.** A. **Wood diaphragms providing lateral support for concrete or masonry walls.** Where wood diaphragms are used to laterally support concrete or masonry walls the anchorage shall conform to Section 2310. In Zones No. 2, No. 3 and No. 4 anchorage shall not be accomplished by use of toenails or nails subjected to withdrawal; nor shall wood framing be used in cross-grain bending or cross-grain tension.

B. **Pile caps and caissons.** Individual pile caps and caissons of every building or structure shall be interconnected by ties, each of which can carry by tension and compression a minimum horizontal force equal to 10 percent of the larger pile cap or caisson loading, unless it can be demonstrated that equivalent restraint can be provided by other approved methods.

C. **Exterior elements.** Precast or prefabricated nonbearing, nonshear wall panels or similar elements which are attached to or enclose the exterior shall be designed to resist the forces determined from Formula (12-8) and shall accommodate movements of the structure resulting from lateral forces or temperature changes. The concrete panels or other similar elements shall be supported by means of cast-in-place concrete or 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 or $(3.0/K)$ times the calculated elastic story displacement caused by required seismic forces, or ½ inch, whichever is greater. Connections to permit movement in the plane of the panel for story drift shall be properly designed sliding connections using slotted or oversized holes or may be connections which permit movement by bending of steel or other connections providing equivalent sliding and ductility capacity.

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Bodies of connectors 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 connector shall be designed for one and one-third times the force determined by Formula (12-8). Fasteners attaching the connector to the panel or the structure such as bolts, inserts, welds, dowels, etc., shall be designed to ensure ductile behavior of the connector or shall be designed for four times the load determined from Formula (12-8).

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 connector assembly in Formula (12-8).

(k) **Essential Facilities.** Essential facilities are those structures or buildings which must be safe and usable for emergency purposes after an earthquake in order to preserve the health and safety of the general public. Such facilities shall include but not be limited to:

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.

The design and detailing of equipment which must remain in place and be functional following a major earthquake shall be based upon the requirements of Section 2312 (g) and Table No. 23-J. In addition, their design and detailing shall consider effects induced by structure drifts of not less than $(2.0/K)$ times the story drift caused by required seismic forces nor less than the story drift caused by wind. Special consideration shall also be given to relative movements at separation joints.

(l) **Earthquake-recording Instrumentations.** For earthquake-recording instrumentations see Appendix, Section 2312 (l).

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TABLE NO. 23-A—UNIFORM AND CONCENTRATED LOADS

USE OR OCCUPANCY		UNIFORM LOAD[1]	CONCENTRATED LOAD
CATEGORY	DESCRIPTION		
1. Armories		150	0
2. Assembly areas[4] and auditoriums and balconies therewith	Fixed seating areas	50	0
	Movable seating and other areas	100	0
	Stage areas and enclosed platforms	125	0
3. Cornices, marquees and residential balconies		60	0
4. Exit facilities[5]		100	0[8]
5. Garages	General storage and/or repair	100	[3]
	Private pleasure car storage	50	[3]
6. Hospitals	Wards and rooms	40	1000[2]
7. Libraries	Reading rooms	60	1000[2]
	Stack rooms	125	1500[2]
8. Manufacturing	Light	75	2000[2]
	Heavy	125	3000[2]
9. Offices		50	2000[2]
10. Printing plants	Press rooms	150	2500[2]
	Composing and linotype rooms	100	2000[2]
11. Residential[6]		40	0[8]
12. Rest rooms[7]			
13. Reviewing stands, grandstands and bleachers		100	0
14. Roof deck	Same as area served or for the type of occupancy accommodated		
15. Schools	Classrooms	40	1000[2]
16. Sidewalks and driveways	Public access	250	[3]
17. Storage	Light	125	
	Heavy	250	
18. Stores	Retail	75	2000[2]
	Wholesale	100	3000[2]

[1]See Section 2306 for live load reductions.
[2]See Section 2304 (c), first paragraph, for area of load application.
[3]See Section 2304 (c), second paragraph, for concentrated loads.
[4]Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, play-

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grounds, plazas, terraces and similar occupancies which are generally accessible to the public.

[5]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.

[6]Residential occupancies include private dwellings, apartments and hotel guest rooms.

[7]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.

[8]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.

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, see Sec. 3902 (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 x Total loads[6]	
7. Mechanical and electrical equipment (dead load)		Total loads	
8. Cranes (dead and live load)[7]	Total load including impact increase	1.25 x Total load[7]	0.10 x 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-J

(Footnotes on following page)

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FOOTNOTES FOR TABLE NO. 23-B

[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 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 provided 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
Primary frames and systems	**Method 1** (Normal Force Method)	
	Windward wall	0.8 inward
	Leeward wall	0.5 outward
	Leeward roof or flat roof	0.7 outward
	Windward roof	
	Slope < 9:12	0.7 outward
	Slope 9:12 to 12:12	0.4 inward
	Slope > 12:12	0.7 inward
	Wind parallel to ridge	
	Enclosed structures	0.7 outward
	Open structures[1]	1.2 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	
	Enclosed structure	0.7 upward
	Open structure[1]	1.2 upward
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[1]	
	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
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

(Continued)

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TABLE NO. 23-H—PRESSURE COEFFICIENTS (C_q)—(Continued)

STRUCTURE OR PART THEREOF	DESCRIPTION	C_q FACTOR
	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	
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
Open-frame towers[3,4]		2.0 any direction
Signs, flagpoles, lightpoles, minor structures		1.4 any direction

[1]A structure with more than 30 pereent of any one side open shall be considered an open structure. Nonimpact-resistant glazing shall be considered as an opening.

[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]The area to which the design pressure shall be applied shall be the projected area of all elements other than those in planes parallel to the direction of application.

[4]For radio and transmission towers, the area shall be the projected area of the members on one face multiplied by 2.0 for rectangular towers and 1.8 for triangular towers.

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TABLE NO. 23-I—HORIZONTAL FORCE FACTOR *K* FOR BUILDINGS OR OTHER STRUCTURES[1]

TYPE OR ARRANGEMENT OF RESISTING ELEMENTS	VALUE[2] OF *K*
1. All building framing systems except as hereinafter classified	1.00
2. Buildings with a box system as specified in Section 2312 (b) **EXCEPTION:** Buildings not more than three stories in height with stud wall framing and using plywood horizontal diaphragms and plywood vertical shear panels for the lateral force system may use $K = 1.0$.	1.33
3. Buildings with a dual bracing system consisting of a ductile moment-resisting space frame and shear walls or braced frames using the following design criteria: a. The frames and shear walls or braced frames shall resist the total lateral force in accordance with their relative rigidities considering the interaction of the shear walls and frames b. The shear walls or braced frames acting independently of the ductile moment-resisting portions of the space frame shall resist the total required lateral forces c. The ductile moment-resisting space frame shall have the capacity to resist not less than 25 percent of the required lateral force	0.80
4. Buildings with a ductile moment-resisting space frame designed in accordance with the following criteria: The ductile moment-resisting space frame shall have the capacity to resist the total required lateral force	0.67
5. Elevated tanks plus full contents, on four or more cross-braced legs and not supported by a building	2.5[3]
6. Structures other than buildings and other than those set forth in Table No. 23-J	2.00

[1]Where wind load as specified in Section 2311 would produce higher stresses, this load shall be used in lieu of the loads resulting from earthquake forces.

[2]See Figures Nos. 1, 2 and 3 in this chapter and definition of *Z* as specified in Section 2312 (c).

[3]The minimum value of *KC* shall be 0.12 and the maximum value of *KC* need not exceed 0.25.

The tower shall be designed for an accidential torsion of 5 percent as specified in Section 2312 (e) 4. Elevated tanks which are supported by buildings or do not conform to type or arrangement of supporting elements as described above shall be designed in accordance with Section 2312 (g) using $C_p = .3$.

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TABLE NO. 23-J—HORIZONTAL FORCE FACTOR C_p FOR ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS

PART OR PORTION OF BUILDINGS	DIRECTION OF HORIZONTAL FORCE	VALUE OF C_p[1]
1. Exterior bearing and nonbearing walls, interior bearing walls and partitions, interior nonbearing walls and partitions—see also Section 2312 (j) 3 C. Masonry or concrete fences over 6 feet high	Normal to flat surface	0.3[6]
2. Cantilever elements: a. Parapets	Normal to flat surfaces	0.8
b. Chimneys or stacks	Any direction	
3. Exterior and interior ornamentations and appendages	Any direction	0.8
4. When connected to, part of, or housed within a building: a. Penthouses, anchorage and supports for chimneys, stacks and tanks, including contents b. Storage racks with upper storage level at more than 8 feet in height, plus contents c. All equipment or machinery	Any direction	0.3[2,3]
5. Suspended ceiling framing systems (applies to Seismic Zones Nos. 2, 3 and 4 only)—see also Section 4701 (e)	Any direction	0.3[4,7]
6. Connections for prefabricated structural elements other than walls, with force applied at center of gravity of assembly	Any direction	0.3[5]

[1] C_p for elements laterally self-supported only at the ground level may be two thirds of value shown.

[2] W_p for storage racks shall be the weight of the racks plus contents. The value of C_p for racks over two storage support levels in height shall be 0.24 for the levels below the top two levels. In lieu of the tabulated values steel storage racks may be designed in accordance with U.B.C. Standard No. 27-11.

Where a number of storage rack units are interconnected so that there are a minimum of four vertical elements in each direction on each column line designed to resist horizontal forces, the design coefficients may be as for a building with K values from Table No. 23-I, $CS = 0.2$ for use in the formula $V = ZIKCSW$ and W equal to the total dead load plus 50 percent of the rack-rated capacity. Where the design and rack configurations are in accordance with this paragraph, the design provisions in U.B.C. Standard No. 27-11 do not apply.

[3] For flexible and flexibly mounted equipment and machinery, the appropriate values of C_p shall be determined with consideration given to both the dynamic properties of the equipment and machinery and to the building or structure in which it is placed but shall be not less than the listed values. The design of the equipment and machinery and their anchorage is an integral part of the design and specification of such equipment and masonry.

For essential facilities and life safety systems, the design and detailing of equipment which must remain in place and be functional following a major earthquake shall consider drifts in accordance with Section 2312 (k).

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[4]Ceiling weight shall include all light fixtures and other equipment which is laterally supported by the ceiling. For purposes of determining the lateral force, a ceiling weight of not less than 4 pounds per square foot shall be used.

[5]The force shall be resisted by positive anchorage and not by friction.

[6]See also Section 2309 (b) for minimum load and deflection criteria for interior partitions.

[7]Does not apply to 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.

TABLE NO. 23-K—VALUES FOR OCCUPANCY IMPORTANCE FACTOR I

TYPE OF OCCUPANCY	I
Essential facilities[1]	1.5
Any building where the primary occupancy is for assembly use for more than 300 persons (in one room)	1.25
All others	1.0

[1]See Section 2312 (k) for definition and additional requirements for essential facilities.

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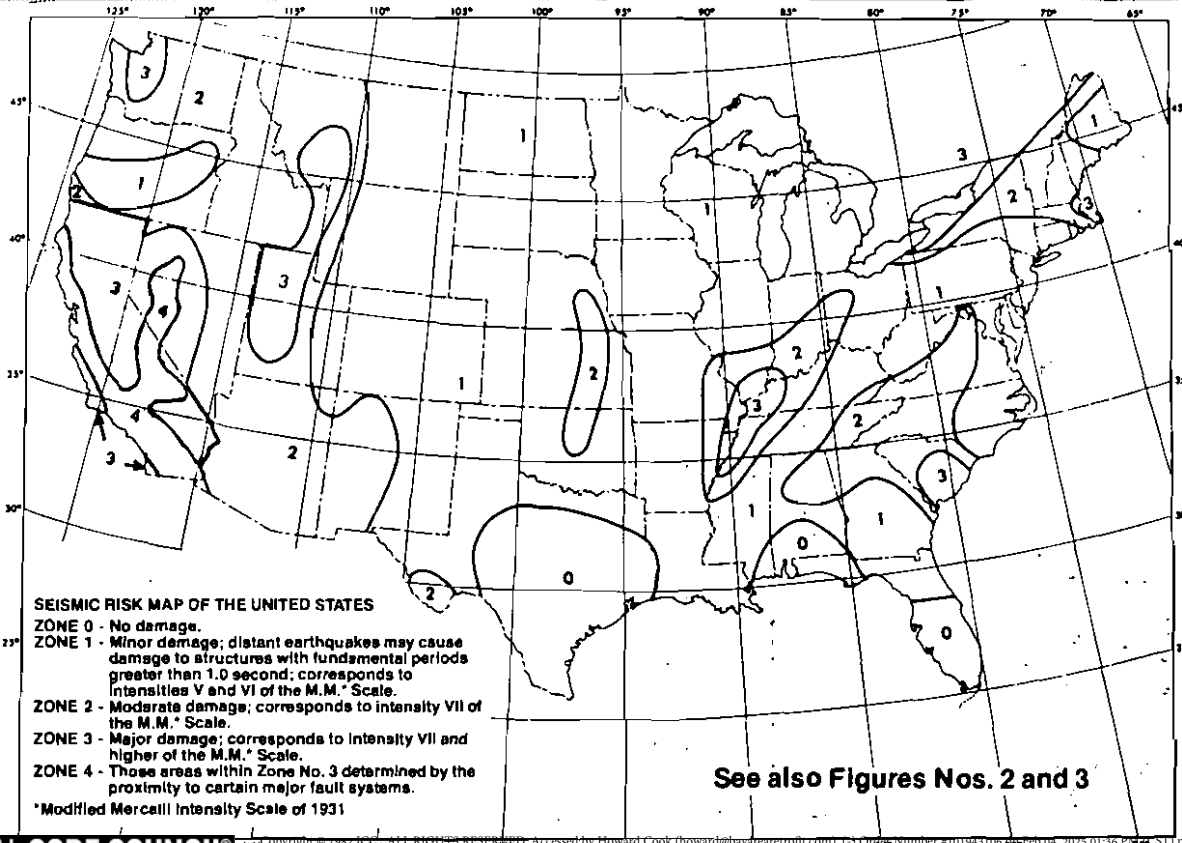

FIGURE NO. 1—SEISMIC ZONE MAP OF THE UNITED STATES
For areas outside of the United States, see Appendix Chapter 23

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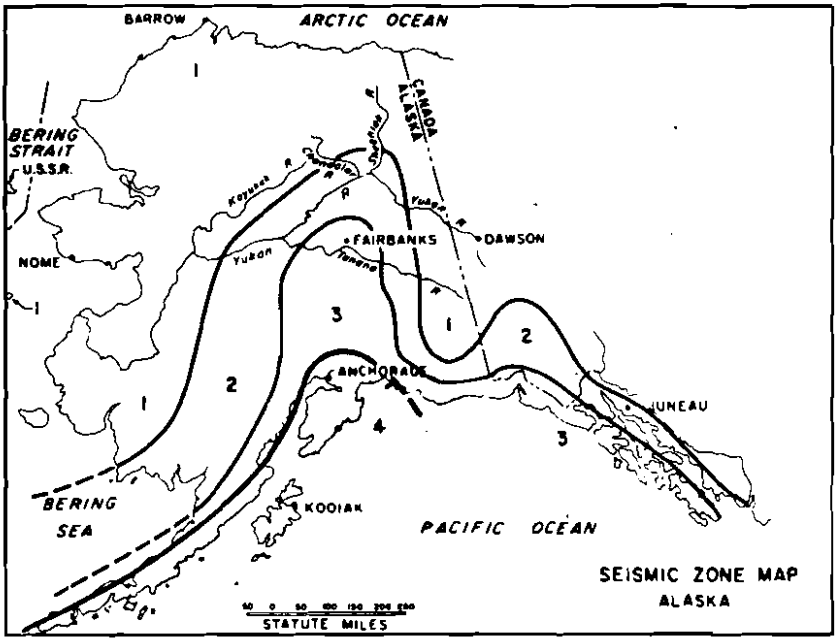

FIGURE NO. 2

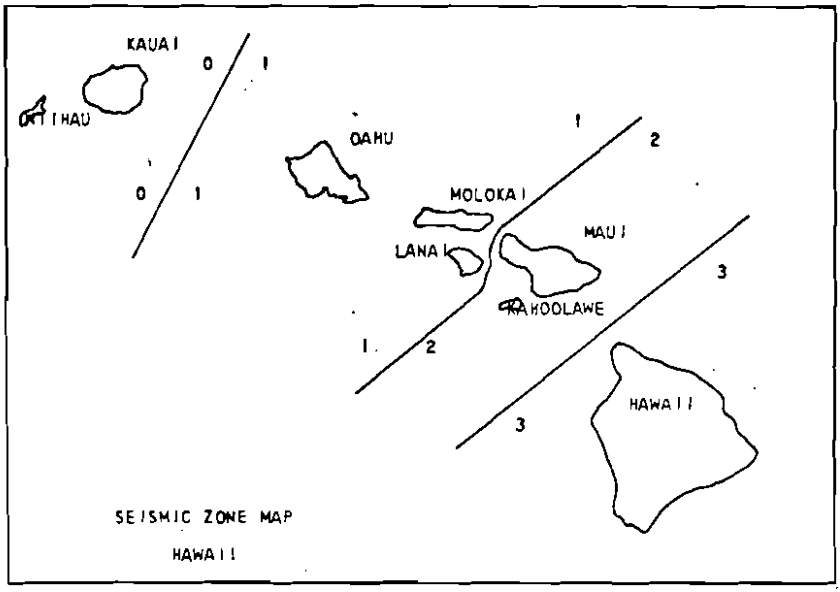

FIGURE NO. 3

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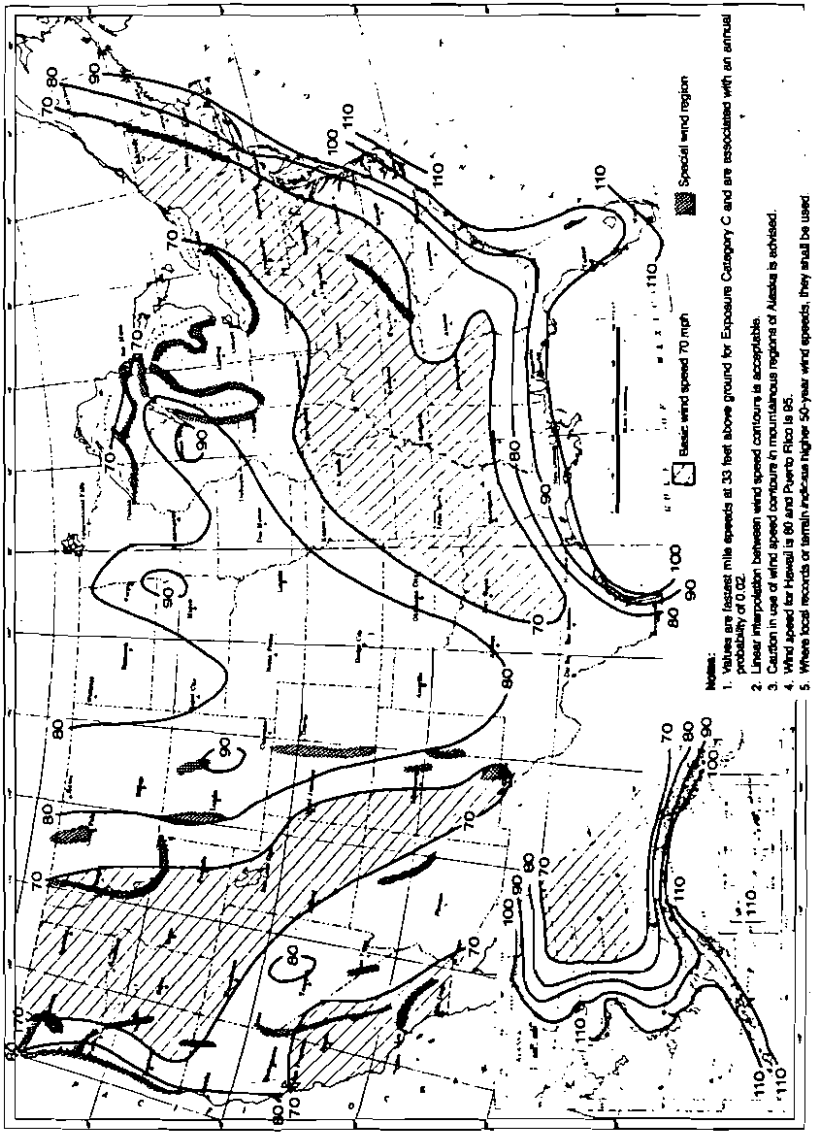

Figure No. 4—Basic Wind Speeds in Miles Per Hour

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Chapter 24
MASONRY

Scope

Sec. 2401. All masonry shall conform to the regulations of this code.

Definitions

Sec. 2402. For the purpose of this chapter, certain terms are defined as follows:

DIMENSIONS. Dimensions given are nominal; actual dimensions of unit masonry may not be decreased by more than ½ inch.

GROSS CROSS-SECTIONAL AREA OF HOLLOW UNITS, the total area including cells of a section perpendicular to the direction of loading. Re-entrant spaces are included in the gross area; unless these spaees are to be occupied in masonry by portions of adjacent units.

GROUT LIFT is an increment of grout height within the total pour; a pour may consist of one or more lifts.

GROUT POUR is the total height of masonry wall to be poured prior to the erection of additional masonry. A pour will consist of one or more lifts.

MASONRY CLEANOUT is an aperture at the bottom of cells or walls to be grouted of such frequency and size as to permit removal of debris or obstructions from the wall which might prevent proper grouting.

MASONRY UNIT, any brick, tile, stone or block conforming to the requirements specified in Section 2403.

NET CROSS-SECTIONAL AREA OF HOLLOW UNITS, the gross cross-sectional area of a section minus the average area of ungrouted cores of cellular spaces.

VIRTUAL ECCENTRICITY, the eccentricity of a resultant axial load required to produce axial and bending stresses equivalent to those produced by applied axial loads and moments.

Materials

Sec. 2403. (a) **General.** The quality, testing and design of masonry 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) **Brick Made from Clay or Shale.** Building brick of clay or shale shall be of a quality at least equal to the requirements set forth in U.B.C. Standard No. 24-1. When in contact with the ground, brick shall be of at least Grade MW. Where severe frost action occurs in the presence of moisture, brick shall be at least Grade SW.

(c) **Brick Made from Sand-lime.** Building brick made from sand-lime shall be of a quality at least equal to the requirements set forth in U.B.C. Standard No. 24-2. When in contact with the ground, brick shall be of at least Grade MW. Where severe frost action occurs in the presence of moisture, brick shall be at least Grade SW.

(d) **Concrete Brick.** Building brick of concrete shall be of a quality at least

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equal to the requirements set forth in U.B.C. Standard No. 24-3.

(e) **Concrete Masonry Units.** Concrete masonry units shall be of a quality at least equal to the requirements set forth in U.B.C. Standard No. 24-4 or No. 24-5 when used for bearing walls or piers or when in contact with ground or exposed to the weather; or equal to the requirements set forth in U.B.C. Standard No. 24-6 when used for nonbearing purposes and not exposed to the weather. Solid units subject to the action of weather or soil shall be Grade N. Concrete masonry units shall be tested as set forth in U.B.C. Standard No. 24-7.

(f) **Structural Clay Tile.** Structural clay tile shall be of a quality at least equal to the requirements set forth in U.B.C. Standard No. 24-8, Grade LB, when used for bearing walls or piers, or Grade LBX when exposed to the weather or soil; or equal to the requirements set forth in U.B.C. Standard No. 24-9 when used for interior nonload-bearing purposes; or equal to the requirements set forth in U.B.C. Standard No. 24-10 when used for floor construction.

(g) **Cast Building Stone.** Cast building stone shall be equal to the requirements set forth in U.B.C. Standard No. 24-13. Every concrete unit more than 18 inches in any dimension shall conform to the requirements for concrete in Chapter 26.

(h) **Stabilized Unburned Clay Brick.** Stabilized unburned clay brick shall be stabilized with emulsified asphalt and shall conform to the requirements specified in U.B.C. Standard No. 24-14.

(i) **Stone.** Natural stone shall be sound, clean, and in conformity with other provisions of this chapter.

(j) **Structural Glass Block.** Structural glass block shall have unglazed surfaces to allow adhesion on all mortared faces.

(k) **Glazed Building Units.** Glazed brick shall conform to the structural requirements for building brick of clay or shale, and glazed structural tile shall conform to the structural requirements for structural clay tile. Glazed structural clay facing tile shall conform to the requirements set forth in U.B.C. Standard No. 24-25.

(l) **Reinforcing Steel.** Reinforcing steel shall conform to the physical and chemical requirements for metal reinforcement in concrete, as specified in U.B.C. Standard No. 26-4.

(m) **Masonry Joint Reinforcement.** Wire reinforcement shall conform to U.B.C. Standard No. 24-15.

(n) **Water.** Water used in mortar, grout or masonry work shall be clean and free from injurious amounts of oil, acid, alkali, organic matter or other harmful substances.

(o) **Cement.** Cement for mortar shall be Type I, II or III portland cement as set forth in U.B.C. Standard No. 26-1, or Type I-A, II-A or III-A air-entraining portland cement as set forth in U.B.C. Standard No. 26-1, or masonry cement as set forth in U.B.C. Standard No. 24-16.

EXCEPTION: Approved types of plasticizing agents may be added to portland cement Type I or II in the manufacturing process, but not in excess of 12 percent of

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the total volume. Plastic or waterproofed cements so manufactured shall meet the requirements for portland cement as set forth in U.B.C. Standard No. 26-1 except in respect to the limitations on insoluble residue, air-entrainment and additions subsequent to calcination.

(p) **Lime.** Quicklime shall conform to U.B.C. Standard No. 24-17. Hydrated lime shall conform to the requirements of U.B.C. Standard No. 24-18. Lime putty shall be made from quicklime or hydrated lime.

If made from other than processed pulverized quicklime, the lime shall be slaked and then screened through a No. 16 mesh sieve. After slaking, screening, and before using, it shall be stored and protected for not less than 10 days. The resulting lime putty shall weigh not less than 83 pounds per cubic foot.

Processed pulverized quicklime conforming to U.B.C. Standard No. 24-19 shall be slaked for not less than 48 hours and shall be cool when used.

(q) **Mortar.** 1. **General.** Mortar used in masonry construction shall be classified in accordance with (a) the materials and proportions set forth in Table No. 24-A, or (b) the properties as established by laboratory tests as set forth in U.B.C. Standard No. 24-20. Tests made to classify mortar by compressive strength shall be as set forth in U.B.C. Standard No. 24-20, using the proportions and materials proposed for use. Aggregates for mortar shall conform to the provisions set forth in U.B.C. Standard No. 24-21.

2. **Admixtures.** Admixtures shall not be added to the mortar unless approved by the building official.

Only pure mineral oxide colors shall be used for color.

3. **Strength.** The strength of mortar using cementitious materials set forth in Table No. 24-A shall meet the minimum compressive strength shown in U.B.C. Standard No. 24-20. The building official may require field tests to verify compliance with this section. Such tests shall be made in accordance with U.B.C. Standard No. 24-22.

(r) **Grout.** 1. **General.** Grout shall be proportioned by volume and shall have sufficient water added to produce consisteney for pouring without segregation. Aggregate shall eonform to the requirements set forth in U.B.C. Standard No. 24-23.

2. **Type.** Fine grout shall be composed of one part portland cement, to which may be added not more than one-tenth part hydrated lime or lime putty, and two and one-fourth to three parts sand.

Coarse grout shall be eomposed of one part portland cement to which may be added not more than one-tenth part hydrated lime or lime putty, and two to three parts sand, and not more than two parts gravel.

EXCEPTION: Type M or S mortar may be used for grout in fireplaces and their chimneys.

Coarse grout may be used in grout spaces in brick masonry 2 inches or more in horizontal dimension and in grout spaces in filled-cell construction 4 inches or more in both horizontal dimensions.

3. **Strength.** Grout shall attain a minimum compressive strength of 2000 pounds per square inch at 28 days. The building official may require a compres-

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sive field strength test of grout made in accordance with U.B.C. Standard No. 24-22.

4. **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.

(s) **Mortar Limitations.** Masonry units used in foundation walls and footings shall be laid up in Type S or Type M mortar. Type O mortar may be used only in interior nonstructural walls. See Sections 2412 (b), 2414 (a) and 2418 (a).

(t) **Aggregates.** Aggregates for mortar shall be of a quality at least equal to that set forth in U.B.C. Standard No. 24-21.

(u) **Rate of Absorption.** At the time of laying, burned clay units and sand-lime units shall have a rate of absorption not exceeding 0.025 ounce per square inch during a period of one minute. In the absorption test the surface of the unit shall be held ⅛ inch below the surface of the water.

(v) **Reuse of Masonry Units.** Masonry units may be reused when clean, whole and conforming to the other requirements of this section, except that the allowable working stresses shall be 50 percent of that permitted for new masonry units. Such units may not be used under the provisions of Section 2418 (c) 2 B.

Tests

Sec. 2404. (a) **General.** Tests of materials shall be made in accordance with the standard method prescribed for the material in question.

(b) **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

$$D = \frac{L}{200} \text{ nor } D = \frac{L^2}{4000t} \quad \text{(4-1)}$$

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.

WHERE:

L = span of the member in feet.

t = thickness or depth of the member in feet.

(c) **Determination of Masonry Design Strength.** 1. **General.** The value of f'_m shall be determined by tests of masonry assemblies in accordance with the provisions of paragraph 2 of this subsection or shall be assumed in accordance

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with the provisions of paragraph 3 of this subsection. When approved by the building official, assembly or unit strength tests may be analyzed statistically considering the variability of test results.

2. **Tests:** A. **General.** When the strength f'_m is established by tests, they shall be made using prisms built of the same material and under the same conditions as for the structure. The moisture content of the units at the time of laying, consistency of mortar and workmanship shall be the same as will be used in the structure. The prism may be built in stack bond. The value of f'_m shall be the average of a given sampling of the specimens tested but shall be not more than 125 percent of the minimum value determined by test, whichever is less.

Testing shall include tests in advance of beginning operations and at least one field test during construction per each 5000 square feet of wall but not less than three such tests for any building.

The compressive strength f'_m shall be computed by dividing the ultimate load by the net area of the masonry used in the construction of the prisms. The gross area may be used in the determination of f'_m for solid masonry units as defined in U.B.C. Standard No. 24-1.

B. **Prisms.** Prisms shall be not less than 12 inches high and shall have a height-to-thickness minimum dimension ratio of not less than 1.5 nor more than 5. Hollow masonry unit prisms shall be not less than one masonry unit in length and solid masonry unit prisms or solid-filled prisms shall be not less than 4 inches in length. The thickness and type of construction of the specimen shall be representative of the masonry element under consideration. Cores in hollow masonry shall not be filled, except for solid-filled construction. The strength f'_m shall be taken as the compressive strength of the specimens multiplied by the following correction factor:

Ratio of H/d	1.5	2.0	3.0	4.0	5.0
Correction factor	0.86	1.00	1.20	1.30	1.37

WHERE:

H = height of specimen, in inches.

d = minimum dimension of specimen, in inches.

Intermediate values may be interpolated.

C. **Storage of test prisms.** Test prisms shall be stored for seven days in air at a temperature of 70 degrees, plus or minus 5 degrees, in a relative humidity exceeding 90 percent, and then in air at a temperature of 70 degrees, plus or minus 5 degrees, at a relative humidity of 30 percent to 50 percent until tested. Those constructed in the field shall be stored undisturbed for from 48 to 96 hours under wet material to simulate 90 percent humidity, then transported to laboratory for continued curing as above. Prisms shall be capped and tested in compression similar to tests for molded concrete cylinders as specified in U.B.C. Standard No. 26-13.

D. **Sampling.** Not less than five specimens shall be made for each initial preliminary test to establish f'_m. Not less than three shall be made for each field

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test to confirm that the materials are as assumed in the design. The standard age of test specimens shall be 28 days, but seven-day tests may be used, provided the relation between the seven-day and 28-day strengths of the masonry is established by adequate test data for the materials used.

3. **Assumed ultimate compressive strength.** When prism tests are not made as in paragraph 2, f'_m may be assumed as:

Solid Clay Units—14,000 psi gross	$f'_m = 5300$
Solid Clay Units—10,000 psi gross	$f'_m = 4000$
Solid Clay Units—6000 psi gross	$f'_m = 2600$
Solid Units—3000 psi gross	$f'_m = 1800$
Solid Units—2500 psi gross	$f'_m = 1500$
Solid Load-bearing Concrete Masonry Units—Grade N	$f'_m = 1080$
Hollow Concrete Units—Grade N	$f'_m = 1350$
Hollow Concrete Units—Grade N grouted solid	$f'_m = 1500$
Concrete Building Brick—Grade N (3500 psi units)	$f'_m = 2100$
Hollow Clay Units—Grade LB (1¼-inch minimum face shell)	$f'_m = 1350$
Hollow Clay Units—Grade LB (1¼-inch minimum face shell) grouted	$f'_m = 1500$
Hollow Clay Units—Type I 5000 psi net (grout used shall equal or exceed $1.33f'_m$)	$f'_m = 2500$

For solid units, intermediate values may be interpolated.

Compressive tests of solid clay units shall be conducted in accordance with U.B.C. Standard No. 24-24.

Where the assumed f'_m exceeds 2600 pounds per square inch, field tests in accordance with Section 2404 (c) 2 shall be required.

Unburned Clay Masonry

Sec. 2405. (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.

(b) **Units.** At the time of laying, all units shall be clean and damp at the surface and shall have been stabilized with emulsified asphalt in accordance with U.B.C. Standard No. 24-14.

(c) **Laying.** All joints shall be solidly filled with Type M or S mortar. Bond shall be provided as specified for masonry of hollow units in Section 2410.

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(d) **Stresses.** All masonry of unburned clay units shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-C.

Reinforced Gypsum Concrete

Sec. 2406. (a) **General.** Reinforced gypsum concrete shall conform to U.B.C. Standard No. 24-12.

Reinforced gypsum concrete shall develop the minimum ultimate compressive strength in pounds per square inch set forth in Table No. 24-D 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 1½ 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. 24-E except as specified in Chapter 23. Bolt values shall not exceed those set forth in Table No. 24-F.

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. 24-12. (See Table No. 24-12-A in the standard for values for commonly used roof systems.)

Glass Masonry

Sec. 2407. (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) **Horizontal Forces.** The panels shall be restrained laterally to resist the horizontal forces specified in Chapter 23 for bearing walls.

(c) **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.

(d) **Mortar.** Glass block shall be laid in Type S mortar. Both vertical and horizontal mortar joints shall be at least ¼ inch and not more than ⅜ inch thick and shall be completely filled.

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(e) **Expansion Joints.** Every exterior glass block panel shall be provided with ½-inch expansion joints at the sides and top. Expansion joints shall be entirely free of mortar and shall be filled with resilient material.

Stone Masonry

Sec. 2408. (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 thoroughly 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.** Stone masonry walls shall in no case have a minimum thickness of less than 16 inches.

(d) **Stresses.** The allowable unit working stresses in stone masonry shall not exceed the values set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-G.

Cavity Wall Masonry

Sec. 2409. (a) **General.** Cavity wall masonry is that type of construction made with brick, structural clay tile or concrete masonry units or any combination of such units in which facing and backing are completely separated except for the metal ties which serve as bonding.

(b) **Cavity Wall Construction.** In cavity walls neither the facing nor the backing shall be less than 4 inches in thickness and the cavity shall be not less than 1-inch net in width nor more than 4 inches in width. The backing shall be at least as thick as the facing.

EXCEPTION: Where both the facing and backing are constructed with clay or shale brick, the facing and backing may be 3 inches in thickness.

The facing and backing of cavity walls shall be bonded with 3/16-inch-diameter steel rods or metal ties of equivalent strength and stiffness embedded in the horizontal joints. There shall be one metal tie for not more than each 4½ square feet of wall area for cavity widths up to 3½ inches net in width. Where the cavity exceeds 3½ inches net in width, there shall be one metal tie for not more than each 3 square feet of wall area. Ties in alternate courses shall be staggered and the maximum vertical distance between ties shall not exceed 24 inches and the maximum horizontal distance shall not exceed 36 inches. Rods bent to rectangular shape shall be used with hollow masonry units laid with the cells vertical; in other walls the ends of ties shall be bent to 90-degree angles to provide hooks not less than 2 inches long. Additional bonding ties shall be provided at all openings, spaced not more than 3 feet apart around the perimeter and within 12 inches of the opening. Ties shall be of corrosion-resistant metal, or shall be coated with a corrosion-resistant metal or other approved protective coating.

(c) **Maximum Height.** The maximum height of cavity walls shall be as

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specified in Section 2418 (b) 2.

(d) **Stresses.** The allowable unit working stresses in cavity wall construction shall not exceed the values set forth in Table No. 24-B. Bolts fully embedded shall have values not to exceed those set forth in Table No. 24-G for solid masonry.

Hollow Unit Masonry

Sec. 2410. (a) **General.** Hollow unit masonry is that type of construction made with hollow masonry units in which the units are all laid and set in mortar.

All units shall be laid with full face shell mortar beds. All head and end joints shall be filled solidly with mortar for a distance in from the face of the unit or wall not less than the thickness of the longitudinal face shells.

(b) **Construction.** Where two or more hollow units are used to make up the thickness of a wall, the stretcher courses shall be bonded at vertical intervals not exceeding 34 inches by lapping at least 4 inches over the unit below or by lapping at vertical intervals not exceeding 17 inches with units which are at least 50 percent greater in thickness than the units below; or by bonding with corrosion-resistant metal ties conforming to the requirements for cavity walls. There shall be one metal tie for not more than each 4½ square feet of wall area. Ties in alternate courses shall be staggered, and the maximum vertical distance between ties shall not exceed 18 inches, and the maximum horizontal distance shall not exceed 36 inches. Walls bonded with metal ties shall conform to the requirements for allowable stress, lateral support, thickness (excluding cavity), height, and mortar for cavity walls.

(c) **Stresses.** All hollow unit masonry shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-G.

Solid Masonry

Sec. 2411. (a) **General.** Solid masonry shall be brick, concrete brick or solid load-bearing concrete masonry units laid contiguously in mortar.

All units shall be laid with full shoved mortar joints, and all head, bed and wall joints shall be solidly filled with mortar.

(b) **Construction.** In each wythe of bearing and nonbearing walls, except masonry veneer, not less than 75 percent of the units in any transverse vertical plane shall lap the ends of the units above and below a distance not less than 1½ inches or one half the height of the units, whichever is greater, or the masonry shall be reinforced longitudinally as required in Section 2416 (l) for masonry laid in stack bond. Adjacent wythes in bearing and nonbearing walls shall be bonded by either of the following methods:

1. **Headers.** The facing and backing shall be bonded so that not less than 4 percent of the exposed face area is composed of solid headers extending not less than 4 inches into the backing. The distance between adjacent full-length headers shall not exceed 24 inches vertically or horizontally. Where the backing consists of two or more wythes the headers shall extend not less than 4 inches into the most distant wythe, or the backing wythes shall be bonded together with separate headers whose area and spacing conform to the foregoing.

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2. **Metal ties.** The facing and backing shall be bonded with corrosion-resistant unit metal ties or cross wires of approved joint reinforcement conforming to the requirements of Section 2409 (b) for cavity walls. Unit ties shall be of sufficient length to engage all wythes, with ends embedded not less than 1 inch in mortar, or shall consist of two lengths, the inner embedded ends of which are hooked and lapped not less than 2 inches.

Where the space between metal tied wythes is solidly filled with 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 mortar requirements for cavity walls.

(c) **Moisture Content.** For moisture content, see Section 2403 (u).

(d) **Stresses.** All solid masonry shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-G.

Grouted Masonry

Sec. 2412. (a) **General.** Grouted masonry is that form of construction made with brick or solid concrete brick units in which interior joints of masonry are filled by pouring grout therein as the work progresses.

(b) **Materials.** At the time of laying, all masonry units shall be free of excessive dust and dirt. For moisture content, see Section 2403 (u). Only Type M or Type S mortar consisting of a mixture of portland cement, hydrated lime and aggregate shall be used.

(c) **Low-lift Grouted Construction.** Requirements for construction shall be as follows:

1. All units in the two outer tiers shall be laid with full-shoved head and bed mortar joints. Masonry headers shall not project into the grout space.

2. All longitudinal vertical joints shall be grouted and shall be not less than ¾ inch in thickness. In members of three or more tiers in thickness, interior bricks shall be embedded into the grout so that at least ¾ inch of grout surrounds the sides and ends of each unit. All grout shall be puddled with a grout stick immediately after pouring.

3. One exterior tier may be carried up 18 inches before grouting, but the other exterior tier shall be laid up and grouted in lifts not to exceed six times the width of the grout space with a maximum of 8 inches.

4. If the work is stopped for one hour or longer, the horizontal construction joints shall be formed by stopping all tiers at the same elevation and with the grout 1 inch below the top.

(d) **High-lift Grouted Construction.** Requirements for construction shall be as follows:

1. All units in the two tiers shall be laid with full head and bed mortar joints.

2. The two tiers shall be bonded together with wall ties. Ties shall be not less than No. 9 wire in the form of rectangles 4 inches wide and 2 inches in length less than the overall wall thickness. Kinks, water drips or deformations shall not be

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permitted in the ties. One tier of the wall shall be built up not more than 16 inches ahead of the other tier. Ties shall be laid not to exceed 24 inches on center horizontally and 16 inches on center vertically for running bond and not more than 24 inches on center horizontally and 12 inches on center vertically for stack bond.

3. Cleanouts shall be provided for each pour by leaving out every other unit in the bottom tier of the section being poured, or by cleanout openings in the foundation. During the work, mortar fins and any other foreign matter shall be removed from the grout space. The cleanouts shall be sealed after inspection and before grouting.

4. The grout space (longitudinal vertical joint) shall be not less than 3 inches in width and not less than the thickness required by the placement of steel with the required clearances and shall be poured solidly with grout. Masonry walls shall cure at least three days to gain strength before pouring grout.

EXCEPTION: If the grout space contains no horizontal steel, it may be reduced to 2 inches.

5. Vertical grout barriers or dams shall be built of solid masonry across the grout space the entire height of the wall to control the flow of the grout horizontally. Grout barriers shall be not more than 30 feet apart.

6. Grout shall be a plastic mix suitable for pumping without segregation of the constituents and shall be mixed thoroughly. Grout shall be placed by pumping or by an approved alternate method and shall be placed before any initial set occurs and in no case more than one and one-half hours after water has been added.

7. Grouting shall be done in a continuous pour, in lifts not exceeding 6 feet. It shall be consolidated by puddling or mechanical vibrating during placing and reconsolidated after excess moisture has been absorbed but before plasticity is lost. The grouting of any section of a wall between control barriers shall be completed in one day with no interruptions greater than one hour.

8. Special inspection during grouting shall be provided in accordance with Section 306; however, the work shall not qualify for the stresses entitled "Special Inspection" in Table No. 24-H unless fully inspected.

(e) **Stresses.** All grouted masonry shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-G.

Reinforced Grouted Masonry

Sec. 2413. (a) **General.** Reinforced grouted masonry shall conform to all of the requirements for grouted masonry specified in Section 2412 and also the requirements of this section.

(b) **Construction.** The thickness of grout or mortar between masonry units and reinforcement shall be not less than ¼ inch, except that ¼-inch bars may be laid in horizontal mortar joints at least ½ inch thick and steel wire reinforcement may be laid in horizontal mortar joints at least twice the thickness of the wire diameter.

(c) **Stresses.** See Section 2417 (a).

Reinforced Hollow Unit Masonry

Sec. 2414. (a) **General.** Reinforced hollow unit masonry is that type of

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construction made with hollow masonry units in which certain cells are continuously filled with concrete or grout and in which reinforcement is embedded. Requirements for construction shall be as follows:

1. All units shall be laid with full mortar beds on the face shells. All head joints shall be filled solidly with mortar for a distanee in from the face of the unit not less than the thickness of the longitudinal face shells.

2. Only Type M or Type S mortar consisting of portland cement, lime and aggregate shall be used.

3. End walls and eross webs forming cells to be filled shall be fullbedded in mortar to prevent leakage of grout unless the wall is to be poured solid.

4. Bond shall be provided by lapping units in successive vertical eourses or by equivalent mechanical anchorage.

5. Vertical cells to be filled shall have vertical alignment sufficient to maintain a clear, unobstructed continuous vertical cell measuring not less than 2 inehes by 3 inches. If walls are battered or if alignment is offset, the 2-inch by 3-inch elear opening shall be maintained as measured from course to course. Excessive mortar fins and any other obstructions shall be removed from the cells to be grouted.

6. At the time of laying, all masonry units shall be free of excessive dust and dirt.

7. All cells eontaining reinforcement shall be filled solidly with grout. Grout shall be a workable mix suitable for pumping without segregation and shall be thoroughly mixed. Grout shall be placed by pumping or an approved alternate method and shall be placed before initial set or hardening occurs. Grout shall be consolidated by puddling or mechanical vibration during placing and reconsolidated after excess moisture has been absorbed but before workability is lost. The grouting of any section of a wall shall be completed in one day with no interruptions greater than one hour.

8. Where the grout pour exeeeds 4 feet in height, cleanouts shall be provided by suitable openings in the face shells in the bottom course of each cell to be grouted, or other approved locations. The cleanouts shall be sealed after inspection and before grouting.

9. When the grouting is stopped for one hour or longer, horizontal construction joints shall be formed by stopping the pour of grout approximately ½ inch above or below a bed joint.

10. All reinforcing shall be in place prior to grouting. Vertical reinforcing bars shall be held in position at the top, bottom and at intervals not farther apart than 192 bar diameters.

(b) **Low-lift Grouted Construction.** Units may be laid to a height not to exceed 8 feet. If the height exceeds 4 feet, cleanouts must be used.

(c) **High-lift Grouted Construction.** Units may be laid to the full height of the wall and grouts shall be placed in 4-foot (maximum) lifts, and special inspeetion shall be provided during grouting. Special inspection at time of grouting shall not qualify the work for the stresses entitled "Special Inspection" in Table No. 24-H unless fully inspected.

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General Construction Requirements

Sec. 2415. (a) **Cold Weather Construction.** No masonry shall be laid when the temperature of the outside air is below 40°F., unless approved methods are used during construction to prevent damage to the masonry. Such methods shall include protection of the masonry for a period of at least 48 hours where masonry cement or Type I portland cement is used in the mortar and grout and for a period of at least 24 hours where Type III portland cement is used. Materials to be used and materials to be built upon shall be free from ice or snow.

(b) **Corbeling.** Corbels may be built only into solid masonry wall 12 inches or more in thickness. The projection for each course in such corbel shall not exceed 1 inch, and the maximum projection shall not exceed one third the total thickness of the wall when used to support structural members, and not more than 6 inches when used to support a chimney built into the wall. The top course of all corbels shall be a header course.

(c) **Wood.** Masonry shall not be supported by wood members except as provided for in Section 2515.

(d) **Masonry Foundations.** In one-story buildings having wood frame exterior walls, foundations not over 24 inches high may be constructed of masonry units without mortared head joints, provided the masonry units permit horizontal flow of the grout to adjacent units.

(e) **Minimum Bar Spacing.** The minimum clear distance between parallel bars, except in columns, shall be not less than the diameter of the bar except that lapped splices may be wired together. The center-to-center spacing of bars within a column shall be not less than two and one-half times the bar diameter.

(f) **Splices in Reinforcement.** Splices may be made only at such points and in such manner that the structural strength of the member will not be reduced. Lapped splices shall provide sufficient lap to transfer the working stress of the reinforcement by bond and shear but in no case shall the lap be less than 30 bar diameters. Welded or mechanical connections shall develop the strength of the reinforcement.

Wire joint reinforcement used in the design as principal reinforcing in hollow unit construction shall be continuous between all 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.

(g) **Protection for Reinforcement.** All bars shall be completely embedded in mortar or grout. Joint reinforcement embedded in horizontal mortar joints shall have not less than ⅝-inch mortar coverage from the exposed face. All other reinforcement shall have a minimum coverage of one bar diameter over all bars, but not less than ¾ inch except where exposed to weather or soil in which cases the minimum coverage shall be 2 inches.

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General Design

Sec. 2416. (a) **General.** Masonry shall be designed to withstand all vertical and horizontal loads as specified in Chapter 23, and with due allowance for the effect of eccentric loads.

(b) **Combination of Units.** In walls or other structural members composed of different kinds or grades of units, materials or mortars, the maximum stress in any portion shall not exceed the allowable stress permitted for the material of that portion. The net thickness of any facing unit which is used to resist stress shall be not less than 1½ inches.

(c) **Thickness of Walls.** For thickness limitations of walls as specified in this chapter, nominal thickness shall be used. Stresses shall be determined on the basis of the net thickness of the masonry, with consideration for reduction such as raked joints.

The thickness of masonry walls shall be designed so that allowable maximum stresses specified in this chapter are not exceeded and so that all masonry walls shall not exceed the height- or length-to-thickness ratio nor the minimum thickness as specified in this chapter and as set forth in Table No. 24-I.

EXCEPTION: The height- or length-to-thickness ratio may be increased and the minimum thickness may be decreased when data are submitted which justify a reduction in the requirements specified in this section.

(d) **Piers.** Every structural pier whose width is less than three times its thickness shall be designed and constructed as required for columns.

(e) **Chases and Recesses.** Chases and recesses in masonry walls shall be designed and constructed so as not to reduce the required strength or required fire resistance of the wall.

(f) **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.

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.

(g) **Arches and Lintels.** Members supporting masonry shall be of noncombustible materials.

(h) **Anchorage.** Masonry walls that meet or intersect shall be bonded or anchored as required in Section 2310.

Structural members framing into or supported by walls or columns shall be anchored.

(i) **End Support.** Beams, girders or other concentrated loads supported by a wall or pier shall have bearing at least 3 inches in length upon solid masonry not less than 4 inches thick or upon a metal bearing plate of adequate design and

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dimensions to distribute the loads safely on the wall or pier, or upon a continuous reinforeed masonry member projecting not less than 3 inches from the face of the wall, or by other approved methods.

Joists shall have bearing at least 3 inches in length upon solid masonry at least 2¼ inches thick; or other provisions shall be made to distribute safely the loads on the wall or pier.

(j) **Distribution of Concentrated Loads.** In calculating wall stresses, concentrated loads may be distributed over a maximum length of wall not exceeding the center-to-center distance between loads.

Where the concentrated loads are not distributed through a structural element, the length of wall considered shall not exceed the width of the bearing plus four times the wall thickness.

Concentrated loads shall not be considered as distributed by metal ties nor distributed across continuous vertical joints.

(k) **Bolt Values.** The allowable loads on bolts shall not exceed the values set forth in Table No. 24-G.

(l) **Stack Bond.** In unreinforced masonry where masonry units are laid in stack bond, longitudinal reinforcement consisting of not less than two continuous wires each with a minimum aggregate cross-sectional area of .017 square inch shall be provided in horizontal bed joints spaced not more than 16 inches on center vertically.

(m) **Bed Joints.** The initial bed joint thickness shall be not less than ¼ inch nor more than 1 inch; subsequent bed joints shall be not less than ¼ inch nor more than ⅝ inch in thickness. See Section 3707 (c) for firebrick.

Reinforced Masonry Design

Sec. 2417. (a) **General.** All reinforced masonry shall be so designed and constructed that the unit stresses do not exceed those set forth in Table No. 24-H.

All plans submitted for approval shall clearly show the assumed strength of masonry for which all parts of the structure were designed.

(b) **Allowable Steel Stresses.** Stresses in reinforcement shall not exceed the following:

	POUNDS PER SQUARE INCH
TENSILE STRESS:	
For deformed bars with a yield strength of 60,000 pounds per square inch or more and in sizes No. 11 and smaller	24,000
Joint reinforcement, 50 percent of the minimum yield point specified in U.B.C. Standards for the particular kind and grade of steel used, but in no case to exceed	30,000
For all other reinforcement	20,000
COMPRESSIVE STRESS IN COLUMN VERTICALS:	
40 percent of the minimum yield strength, but not to exceed	24,000

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COMPRESSIVE STRESS IN FLEXURAL MEMBERS:

For compression reinforcement in flexural members, the allowable stress shall not be taken as greater than the allowable tensile stress shown above.

(c) **Symbols and Notations.** The symbols and notations used in this section are defined as follows:

α = Angle between inclined web bars and axis of beam.

A_v = Total area of web reinforcement in tension within a distance of s, or the total area of all bars bent up in any one plane.

b = Width of rectangular section or width of flange of I or T sections.

d = Depth from compression face of beam or slab to centroid of longitudinal tensile reinforcement.

E_m = Modulus of elasticity of masonry in compression.

E_s = Modulus of elasticity of steel in tension or compression (30,000,000 pounds per square inch).

f_m = Allowable compressive unit stress in extreme fiber in flexure.

f'_m = Ultimate compressive strength, usually at age of 28 days, as specified in Section 2404 (c).

f_v = Allowable tensile unit stress in web reinforcement.

j = Ratio of distance between centroid of compression and centroid of tension to the depth d.

n = Ratio of modulus of elasticity of steel to that of

$$\text{masonry} = \frac{E_s}{E_m}$$

Σo = Sum of perimeters of bars in one set.

s = Spacing of stirrups or of bent bars in a direction parallel to that of the main reinforcement.

u = Bond stress per unit of surface area of bar.

v = Shearing unit stress.

v_m = Allowable unit shearing stress in the masonry.

V = Total shear.

(d) **Reinforced Masonry Flexural Design.** The design of reinforced masonry shall be in accordance with the following principal assumptions:

1. A section that is plane before bending remains plane after bending.
2. Moduli of elasticity of the masonry and of the reinforcement remain constant.
3. Tensile forces are resisted only by the tensile reinforcement.
4. Reinforcement is completely surrounded by and bonded to masonry material so that they will work together as a homogenous material within the range of working stresses.

(e) **Flexural Computations.** 1. **General.** All members shall be designed to resist at all sections the maximum bending moment and shears produced by dead

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load, live load and other forces as determined by the principle of continuity and relative rigidity.

2. **Distance between lateral supports.** The clear distance between lateral supports of a beam shall not exceed 32 times the least width of the compression flange or face.

(f) **Width in Flexural Computation.** In computing flexural stresses for masonry where reinforcement occurs, the effective width b shall be not greater than six times the wall thickness in running bond nor more than three times the wall thickness in stacked bond.

(g) **Combined Axial and Flexural Stresses.** 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:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \text{ shall not exceed } 1$$

WHERE:

f_a = Computed axial unit stress, determined from total axial load and effective area.

F_a = Axial unit stress permitted by this code at the point under consideration, if member were carrying axial load only, including any increase in stress allowed by this section.

f_b = Computed flexural unit stress.

F_b = Flexural unit stress permitted by this code if member were carrying bending load only, including any increase in stress allowed by this section.

(h) **Shear and Diagonal Tension.** 1. **Shearing unit stress.** The shearing unit stress v in reinforced masonry flexural members shall be computed by

$$v = \frac{V}{bjd} \quad \text{.....(18-1)}$$

WHERE:

b = The width of a rectangular section or the width of the web in I or T sections.

Where the values of the shearing unit stress computed by Formula (18-1) exceeds the shearing unit stress v_m permitted on masonry, web reinforcement shall be provided to carry the entire stress.

2. **Types of web reinforcement.** Web reinforcement may consist of:

A. Stirrups or web reinforcement bars perpendicular to the longitudinal steel, or

B. Stirrups or web reinforcement bars welded or otherwise rigidly attached to the longitudinal steel and making an angle of 30 degrees or more thereto, or

C. Longitudinal bars bent so that the axis of the inclined portion of the bar

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makes an angle of 15 degrees or more with the axis of the longitudinal portion of the bar, or

D. Special arrangements of bars with adequate provisions to prevent slip of bars or splitting of masonry by the reinforcement.

Stirrups or other bars to be considered effective as web reinforcement shall be anchored at both ends.

3. **Stirrups.** The area of steel required in stirrups placed perpendicular to the longitudinal reinforcement shall be computed by Formula (18-2):

$$A_v = \frac{Vs}{f_v jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18\text{-}2)$$

Inclined stirrups shall be proportioned in accordance with the provisions of paragraph 4 of this subsection.

4. **Bent bars.** Only the center three fourths of the inclined portion of any longitudinal bar that is bent up for web reinforcement shall be considered effective for that purpose, and such bars shall be bent around a pin having a diameter not less than six times the bar size.

When the web reinforcement consists of a single bent bar or of a single group of parallel bars all bent up at the same distance from the support, the required area of such bars shall be computed by Formula (18-3):

$$A_v = \frac{V}{f_v \sin \alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18\text{-}3)$$

Where there is a series of parallel bars or groups of bars bent up at different distances from the support, the required area shall be determined by Formula (18-4):

$$A_v = \frac{Vs}{f_v jd (\sin \alpha + \cos \alpha)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18\text{-}4)$$

5. **Spacing of web reinforcement.** Where web reinforcement is required it shall be so spaced that every 45-degree line (representing a potential crack) extending from the middepth of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement.

(i) **Bond and Anchorage.** 1. **Computation of bond stress in beams.** In flexural members in which the tensile reinforcement is parallel to the compression face, the bond stress at any cross section shall be computed by Formula (18-5):

$$u = \frac{V}{\Sigma o jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18\text{-}5)$$

in which V is the shear at that section and Σo is taken as the perimeter of all

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effective bars crossing the section on the tension side. To be effective the bars must be properly developed by hooks, lap or embedment on each side of the section. Bent-up bars that are not more than $d/3$ from the level of the main longitudinal reinforcement may be included. Critical sections occur at the face of the support, at each point where tension bars terminate within a span and at the point of inflection.

Bond shall be similarly computed on compressive reinforcement, but the shear used in computing the bond shall be reduced in the ratio of the compressive force assumed in the bars to the total compressive force at the section. Anchorage shall be provided by embedment past the section to develop the assumed compressive force in the bars at the bond stress in Table No. 24-H.

2. **Anchorage requirements.** Tensile negative reinforcement in any span of a continuous, restrained or cantilever beam, or in any member of a rigid frame shall be adequately anchored by bond, hooks or mechanical anchors in or through the supporting member. Within any such span every reinforcing bar except in a lapped splice whether required for positive or negative moment shall be extended at least 12 diameters beyond the point at which it is no longer needed to resist stress.

No flexural bar shall be terminated in a tension zone unless one of the following conditions is satisfied:

A. The shear is not over one half that normally permitted, including allowance for shear reinforcement, if any.

B. Additional stirrups in excess of those required are provided each way from the cutoff, a distance equal to the depth of the beam. The stirrup 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.

C. The continuing bars provide double the area required for flexure at that point or double the perimeter required for flexural bond.

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 distanee sufficient to develop by bond one half the allowable stress in such bars, not less than one sixteenth of the clear span length or not less than the depth of the member, whichever is greater. The maximum tension in any bar must be developed by bond on a sufficient straight or bent embedment or by other anchorage.

The bar may be bent across the web at an angle of not less than 15 degrees with the longitudinal portion of the bar and be made continuous with the reinforcement whieh resists moment of opposite sign.

Of the positive reinforcement in continuous beams not less than one fourth the area shall extend along the same face of the beam into the end support a distanee of 6 inches.

In simple beams, or at the freely supported end of continuous beams, at least one third the required positive reinforcement shall extend along the same face of the beam into the support a distanee of 6 inches.

Compression steel in beams and girders shall be anchored by ties or stirrups not

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less than ¼ 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.

3. **Plain bars in tension.** Plain bars in tension shall terminate in standard hooks except that hooks shall not be required on the positive reinforcement at interior supports of continuous members.

4. **Anchorage of web reinforcement.** Single separate bars used as web reinforcement shall be anchored at each end by one of the following methods:

A. Welding to longitudinal reinforcement.

B. Hooking tightly around the longitudinal reinforcement through at least 180 degrees.

C. Embedment above or below the mid-depth of the beam on the compression side, a distance sufficient to develop the stress to which the bar will be subject at a bond stress of not to exceed the bond stresses permitted in Table No. 24-H.

D. By a standard hook, considered as developing 7500 pounds per square inch, plus embedment sufficient to develop by bond the remaining stress in the bar at the unit stress set forth in Table No. 24-H. 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.

The extreme ends of bars forming a simple U-stirrup or multiple U-stirrups shall be anchored by one of the methods of this subsection 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 bar.

The loops or closed ends of such stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90 degrees or by being welded or otherwise rigidly attached thereto.

Between the anchored ends, each bend in the continuous portion of a U- or multiple U-stirrup shall be made around a longitudinal bar. Hooking or bending stirrups around the longitudinal reinforcement shall be considered effective only when these bars are perpendicular to the longitudinal reinforcement.

Longitudinal bars bent to act as web reinforcement shall, in a region of tension, be continuous with the longitudinal reinforcement. The tensile stress in each bar shall be fully developed in both the upper and the lower half of the beam by adequate anchorage through bond or hooks.

5. **Hooks.** The term "hook" or "standard hook" as used herein shall mean either:

A. A complete semicircular turn with a radius of bend on the axis of the bar of not less than three and not more than six bar diameters, plus an extension of at least four bar diameters at the free end of the bar.

B. A 90-degree bend having a radius of not less than four bar diameters plus an extension of 12 bar diameters.

C. For stirrup anchorage only, a 135-degree turn with a radius on the axis of the bar of three diameters, plus an extension of at least six bar diameters at

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the free end of the bar.

D. For tie anchorage in Seismic Zones No. 3 and No. 4, 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, when permitted by Section 2413 (b), the hook shall consist of a 90-degree bend having a radius of not less than four bar diameters plus an extension of 32 bar diameters.

Hooks having a radius of bend of more than six bar diameters shall be considered merely as extensions to the bars.

In general, 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 ends of continuous or restrained beams.

No hooks shall be assumed to carry a load which would produce a tensile stress in the bar greater than 7500 pounds per square inch.

Hooks shall not be considered effective in adding to the compressive resistance of bars.

Any mechanical device capable of developing the strength of the bar without damage to the masonry may be used in lieu of a hook. Tests must be presented to show the adequacy of such devices.

(j) **Reinforced Masonry Walls.** 1. **Minimum thickness.** The minimum nominal thickness of reinforced masonry bearing walls shall be 6 inches, except as provided in Table No. 24-I, and the ratio of height or length to thickness shall not exceed 25, except as specified in Section 2416 (c).

2. **Stresses.** The axial stress in reinforced masonry bearing walls shall not exceed the value determined by the following formula:

$$F_a = 0.20 f'_m \left[1 - \left(\frac{h}{40t}\right)^3\right] \quad \text{.....(18-6)}$$

WHERE:

F_a = Compressive unit axial stress in masonry wall.

f'_m = Ultimate compressive masonry stress as determined by Section 2404 (c). The value of f'_m shall not exceed 6000 pounds per square inch.

t = Thickness of wall in inches.

h = Clear unsupported distance in inches between supporting or enclosing members (vertical or horizontal stiffening elements).

3. **Reinforcement.** All walls using stresses permitted for reinforced masonry 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 be not less than 0.0007 times the gross cross-sectional area of the wall. The reinforcement shall be limited to a maximum spacing of 4 feet on center. The minimum diameter of reinforcement shall be ⅜ inch except that joint

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reinforcement may be considered as part of the required minimum reinforcement.

Horizontal reinforcement shall be provided in the top of footings, at the top of wall openings, at structurally connected roof and floor levels and at the top of parapet walls. Only horizontal reinforcement which is continuous in the wall shall be considered in computing the minimum area of reinforcement.

If the wall is constructed of more than two units in thickness, the minimum area of required reinforcement shall be equally divided into two layers, except where designed as retaining walls. Where reinforcement is added above the minimum requirements such additional reinforcement need not be so divided.

In bearing walls of every type of reinforced masonry there shall be not less than one ½-inch bar or two ⅜-inch bars on all sides of, and adjacent to, every opening which exceeds 24 inches in either direction, and such bars shall extend not less than 40 diameters, but in no case less than 24 inches beyond the corners of the opening. The bars required by this paragraph shall be in addition to the minimum reinforcement elsewhere required.

When the reinforcement in bearing walls is designed, placed and anchored in position as for columns, the allowable stresses shall be as for columns. The length of the wall to be considered effective shall not exceed the center-to-center distance between loads nor shall it exceed the width of the bearing plus four times the wall thickness.

(k) **Reinforced Masonry Columns.** 1. **Limiting dimensions.** The least dimension of every reinforced masonry column shall be not less than 12 inches. No masonry column shall have an unsupported length greater than 20 times its least dimension.

EXCEPTION: The minimum column dimension may be reduced to not less than 8 inches, provided the design is based upon one half the allowable stresses for axial load. Bending stresses need not be so reduced.

2. **Allowable loads.** The axial load on columns shall not exceed:

$$P = A_n\,(.18\,f'_m + 0.65\,p_n\,f_s)\left[1 - \left(\frac{h}{40t}\right)^3\right] \quad \ldots\ldots\ldots (18\text{-}7)$$

WHERE:

P = Maximum concentric column axial load.

A_g = The gross area of the column.

f'_m = Ultimate compressive masonry strength as determined by Section 2404 (c). The value of f'_m shall not exceed 6000 pounds per square inch.

p_g = Ratio of the effective cross-sectional area of vertical reinforcement to A_g.

f_s = Allowable stress in reinforcement [See Section 2417 (b)].

t = Least thickness of columns in inches.

h = Clear height in inches.

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3. **Reinforcement.** A. **Vertical reinforcement.** The ratio p_g shall be not less than 0.5 percent nor more than 4 percent. The number of bars shall be not less than four, nor the diameter less than ⅜ inch. The maximum size of bar shall be No. 10.

Where lapped splices are used, the amount of lap shall be sufficient to transfer the working stress by bond but in no case shall the length of lapped splice be less than 30 bar diameters, and welded splices shall be full butt welded.

B. **Ties.** All longitudinal bars for tied columns shall be enclosed by lateral ties. Lateral support shall be provided to the longitudinal bars, as specified below, 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 longitudinal bars shall have such support provided by a complete tie enclosing the longitudinal bars. In addition, in Seismic Zones No. 3 and No. 4, alternate longitudinal bars shall have such lateral support provided by ties and no bar shall be farther than 6 inches from such laterally supported bars.

Lateral ties shall be placed not less than 1½ inches and not more than 5 inches from the surface of the column and may be against the vertical bars or placed in the horizontal bed joints where permitted by Section 2413 (b).

In Seismic Zones No. 3 and No. 4, maximum tie spacing shall be as follows: 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 for columns in Seismic Zones No. 3 and No. 4, and for the full column height for all columns in Seismic Zone No. 0, 1 or 2, shall be not more than 16 bar diameters, 48 tie diameters or the least column dimension, but not more than 18 inches.

Ties shall be at least ¼ inch in diameter for No. 7 or smaller longitudinal bars and No. 3 bars for No. 8, No. 9 or No. 10 longitudinal bars.

> **EXCEPTION:** Ties placed in the horizontal bed joints, where permitted by Section 2413 (b), may be smaller in diameter than required above, but not less than ¼ inch in diameter, provided that the total cross-sectional area of such smaller ties crossing a vertical plane is equal to the area of the larger ties at their required spacing.

Structural members framing into or supported by a column shall be anchored thereto. Additional ties shall be provided around anchor bolts which are set in the top of a column for buildings located in Seismic Zones No. 2, No. 3 and No. 4. Such ties shall engage at least four bolts or, alternatively, 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 consist of two No. 4 or three No. 3 ties.

Bearing Walls

Sec. 2418. (a) **Partially Reinforced Masonry.** Partially reinforced masonry shall be designed as unreinforced masonry, except that reinforced areas or elements may be considered as resisting stresses in accordance with the design criteria specified in Section 2417, provided such elements fully comply with the

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design and construction requirements for reinforced masonry except as herein noted. Only Type M or S mortar shall be used.

The minimum area of reinforcement required in Section 2417 (j) 3 shall not apply to partially reinforced masonry walls. Maximum spacing of vertical reinforcement in exterior partially reinforced masonry walls shall be 8 feet. Reinforcement shall be provided each side of each opening and at each corner of all walls. Horizontal reinforcement not less than 0.2 square inch in area shall be provided at the top of footings, at the bottom and top of wall openings, near roof and floor levels and at the top of parapet walls.

Partially reinforced masonry walls shall be considered as reinforced masonry for the purpose of applying Table No. 24-I.

(b) **Unreinforced Masonry.** 1. **General.** Except for brick masonry designed in accordance with the applicable requirements of Subsection (c) of this section, unreinforced masonry walls shall comply with the empirical requirements set forth in this subsection and Table No. 24-I.

2. **Empirical requirements.** A. **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 for 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.

B. **Minimum thickness.** The minimum thickness of bearing walls of plain 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.

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.

C. **Stresses.** The stress in unreinforced bearing walls, or portions thereof, shall not exceed the values set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-G.

(c) **Engineered Unreinforced Brick Masonry.** 1. **General.** A. **Design.** The design of unreinforced brick masonry walls or columns constructed of solid masonry units made from clay or shale may be based on a general structural analysis and the requirements of this subsection. Where required there shall be special inspection as specified in Section 306 to ensure that the construction and

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workmanship requirements of this subsection and chapter are satisfied.

In determining the stresses in brick masonry, the effects of all dead and live loads shall be taken into account. Eccentricity of vertical load, the effects of lateral load, temperature changes and other forces shall be considered. Stresses shall be calculated on actual rather than nominal dimensions.

B. **Combination of dissimilar units.** In composite or faced walls or other structural members composed of different kinds or grades of units or mortars, the maximum stresses shall not exceed the allowable for the weakest of the combination of units and mortars of which the member is composed.

In cavity walls composed of different kinds or grades of units or mortars, the maximum stress shall not exceed the allowable stresses for the combinations of units and mortars of the particular wythe under consideration.

2. **Materials.** Except as may be otherwise provided herein, materials used in brick masonry shall conform to the standards and requirements specified in this subsection.

A. **Brick and solid clay or shale masonry units.** Brick and solid clay or shale masonry units shall comply with the requirements of Section 2403 (b).

Brick used in load-bearing or shear walls shall comply with the dimension and distortion tolerances specified for Type FBS of U.B.C. Standard No. 24-1. Where such brick do not comply with these requirements, the compressive strength of brick masonry shall be determined by prism tests. See Section 2418 (c) 3 B.

B. **Used brick.** Used or salvaged brick shall not be permitted under the provisions of this subsection.

C. **Mortar.** Mortar for use in engineered brick masonry shall conform to U.B.C. Standard No. 24-20, Type M, S or N, except that it shall consist of a mixture of portland cement (Type I, II or III), hydrated lime (Type nonair-entrained S) and aggregate where values given in Tables No. 24-J and No. 24-K are used.

3. **Brick masonry strength.** A. **General.** The value of f'_m used for determining the allowable stresses shall be based on the specified minimum 28-day compressive strength of the masonry or on the specified minimum compressive strength at the earlier age at which the masonry may be expected to receive its full load. All plans submitted for approval or used on the job shall clearly show the specified strength of masonry (f'_m) at an age for which all parts of the structure were designed.

B. **Determination of brick masonry strength.** The determination of the compressive strength of brick masonry (f'_m) shall be made by one of the following methods:

Method No. 1 — Prism Tests. When the compressive strength of brick masonry is to be established by tests, the tests shall be made in accordance with the requirements of Section 2404 (c) 2, except they shall have a height-to-thickness ratio (h/t) of not less than 2 nor more than 5. If the h/t of the prism tested is less than 5, the strength f'_m shall be determined by multiplying the prism

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compressive strength by the following correction factor:

Ratio of height to thickness (h/t)	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Correction factor[1]	0.82	0.85	0.88	0.91	0.94	0.98	1.00

[1]Interpolate to obtain intermediate values.

In no case, however, shall a value of f'_m in excess of 6000 pounds per square inch be used in the design.

Method No. 2 — Brick Tests. When the compressive strength of the brick masonry is not determined by prism tests and the units, mortar and workmanship conform to all applicable requirements of this subsection, the allowable stresses may be based upon an assumed value of f'_m interpolated from the values in Table No. 24-J. Compressive strength tests of brick shall be conducted in accordance with U.B.C. Standard No. 24-24.

4. **Allowable stresses.** Except as provided elsewhere in this code, the allowable stresses in unreinforced brick masonry shall not exceed the values set forth in Table No. 24-K.

5. **Design.** A. **Notations.** The following notations are used for the engineered design of unreinforced brick masonry:

A_g = Gross cross-sectional area.
C_e = Eccentricity coefficient.
C_s = Slenderness coefficient.
e = Virtual eccentricity [see Section 2418 (c) 5 G].
e_1 = Smaller virtual eccentricity at lateral supports (at either top or bottom of member).
e_2 = Larger virtual eccentricity at lateral supports (at either top or bottom of member).
f_m = Allowable compressive or bearing stress in masonry.
f'_m = Compressive strength of masonry at 28 days, unless otherwise specified.
f_t = Allowable flexural tensile stress in masonry.
h = Effective height [see Section 2418 (c) 5 D and E].
P = Allowable vertical load.
r = Radius of gyration.
t = Effective thickness [see Section 2418 (c) 5 F].

B. Slenderness ratio. The slenderness ratio of a load-bearing wall shall be taken as the ratio of its effective height h to the effective thiekness t and shall not exceed the value eomputed by

$$\frac{h}{t} \leq 10 \left(3 - \frac{e_1}{e_2}\right) \quad \text{.....(19-1)}$$

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NOTE: Value of e_1/e_2 is positive where member is bent in single curvature, and negative where member is bent in double or reverse curvature. Where e_1 and e_2 are both equal to zero, e_1/e_2 shall be assumed to be zero.

The slenderness ratio of a column shall be the greater value obtained by dividing the effective height h in any direction by the effective thickness t in the corresponding direction and shall not exceed the value computed by

$$\frac{h}{t} \leq 5\left(4 - \frac{e_1}{e_2}\right) \quad \text{.....(19-2)}$$

Where walls or columns meet all other requirements of this code, limits on slenderness ratios may be waived when approved after a review of a written justification.

C. **Slenderness coefficient.** The slenderness coefficient C_s shall be computed by the following formula:

$$C_s = 1.20 - \frac{h/t}{300}\left[5.7 + \left(1.5 + \frac{e_1}{e_2}\right)^2\right] \leq 1.0 \quad \text{.....(19-3)}$$

D. **Effective height of walls.** Where a wall is laterally supported top and bottom, its effective height shall be taken as the actual height of the wall.

Where there is no lateral support at the top of a wall, its effective height shall be taken as twice the height of the wall above the bottom lateral support.

E. **Effective height of columns.** Where a column is provided with lateral supports in the directions of both principal axes at both top and bottom, the effective height in any direction shall be taken as the actual height. The actual height shall be taken as not less than the clear distance between the floor surface and the underside of the deeper beam framing into the column in each direction at the next higher floor level.

Where a column is provided with lateral support in the directions of both principal axes at the bottom and in the direction of one principal axis at the top, its effective height relative to the direction of the top support shall be taken as the height between supports, and its effective height at right angles to this shall be taken as twice its height above the lower support.

In the absence of lateral support at the top, the effective height of a column relative to both principal axes shall be taken as twice its height above the lower support.

F. **Effective thickness.** For solid walls, the effective thickness shall be taken as the actual thickness. For metal-tied walls, the effective thickness shall be determined as for cavity walls unless the collar joints in such walls are filled with mortar or grout.

For cavity walls loaded on both wythes, each wythe shall be considered to act independently and the effective thickness of each wythe shall be taken as its actual thickness.

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For cavity walls loaded on one wythe only, the effective thickness shall be taken as the actual thickness of the loaded wythe.

For rectangular columns, the effective thickness shall be taken as its actual thickness in the direction considered.

For nonrectangular columns, the effective thickness shall be taken as equal to 3.464 times its radius of gyration r about the axis considered.

Where raked mortar joints are used, the thickness of the member shall be reduced in accordance with the depth of the raking.

G. **Eccentricity normal to plane of member.** In calculating the virtual eccentricity of loads on walls or columns, consideration shall be given to the effects of lateral load, eccentricity of vertical load, and the deflection, thermal and other movements of members.

(i) **Bending in one direction.** In solid walls and columns, the eccentricity of the load shall be considered with respect to the centroidal axis of the member.

In cavity walls loaded on one wythe, the eccentricity shall be considered with respect to the centroidal axis of the loaded wythe.

In cavity walls loaded on both wythes, the load shall be distributed to each wythe according to the eccentricity of the load about the centroidal axis of the wall.

For members composed of different kinds or grades of units or mortar, the variation in the moduli of elasticity shall be taken into account and the eccentricity shall be considered with respect to the center of resistance or the centroidal axis of the transformed area of the member.

(ii) **Eccentricity coefficient.** Where the maximum virtual eccentricity e is equal to or less than $t/20$, the eccentricity coefficient C_e shall be taken as 1.0.

Where the maximum virtual eccentricity e exceeds $t/20$ but is equal to or less than $t/6$, C_e shall be computed by the following formula:

$$C_e = \frac{1.3}{1+6\frac{e}{t}} + \frac{1}{2}\left(\frac{e}{t} - \frac{1}{20}\right)\left(1 - \frac{e_i}{e_i}\right) \quad \text{.....(19-4)}$$

Where the maximum virtual eccentricity e exceeds $t/6$ but is equal to or less than $t/3$, C_e shall be computed by the following formula:

$$C_e = 1.95\left(\frac{1}{2} - \frac{e}{t}\right) + \frac{1}{2}\left(\frac{e}{t} - \frac{1}{20}\right)\left(1 - \frac{e_i}{e_i}\right) \quad \text{.....(19-5)}$$

For members subject to transverse loads greater than 10 pounds per square foot between lateral supports, C_e shall be based on Formula (19-6) or (19-5), whichever is applicable, except e_1/e_2 shall be taken as + 1.0.

(iii) **Bending about both principal axes.** Where walls and columns are subject to bending about both principal axes and $e_t b + e_b t$ is equal to or less than $bt/20$, the eccentricity coefficient C_e shall be taken as 1.0 where e_t = virtual

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eccentricity about the principal axis which is normal to the thickness t of the member and e_b = virtual eccentricity about the principal axis which is normal to the width b of the member.

Where $e_t b + e_b t$ exceeds $bt/20$ but is equal to or less than $bt/6$, the eccentricity coefficient C_e shall be computed by Formula (19-6), except that $e_t b + e_b t/bt$ shall be substituted for e/t.

Where $e_t b + e_b t$ exceeds $bt/6$ but does not exceed $bt/3$, C_e shall be computed by Formula (19-5), except that $e_t b + e_b t$ shall be substituted for e/t.

H. **Cross-sectional area.** For solid walls and columns, A_g shall be taken as the actual gross cross-sectional area of the member. For metal-tied walls, A_g shall be determined as for cavity walls unless the collar joints in such walls are filled with mortar or grout.

For cavity walls loaded on one wythe, A_g shall be taken as the actual gross cross-sectional area of the loaded wythe.

For cavity walls loaded on both wythes, A_g shall be taken as the actual gross cross-sectional area of the wythe under consideration.

Where raked mortar joints are used, the thickness used in determining A_g shall be reduced accordingly.

I. **Allowable vertical loads on unreinforced walls and columns.** Allowable vertical loads P on unreinforced walls and columns shall be computed as follows:

Where the maximum virtual eccentricity e does not exceed $t/3$,

$$P = C_e C_s f_m A_g \quad \text{.....(19-6)}$$

WHERE:

C_e = eccentricity coefficient.

C_s = slenderness coefficient.

f_m = allowable axial compressive stress.

A_g = gross cross-sectional area.

NOTE: The value of $C_e C_s f_m$ is the average allowable compressive stress permitted in the member. Accordingly, this value should not be taken as the maximum compressive stress permitted in the extreme fiber.

Where the maximum virtual eccentricity e exceeds $t/3$, the maximum tensile stress in the masonry, assuming linear stress distribution, shall not exceed the values given in Table No. 24-K. Where these values are exceeded, the member shall be designed in accordance with the requirements of Section 2417.

Allowable vertical loads on rectangular unreinforced walls and columns subject to bending about both principal axes shall be computed as follows:

Where $e_t b + e_b t$ does not exceed $bt/3$, the allowable vertical load shall be computed in accordance with the above formula, except that the eccentricity coefficient C_e shall be determined in accordance with Section 2418 (c) 5 G.

Where $e_t b + e_b t$ exceeds $bt/3$, walls and columns shall be reinforced and designed in accordance with Section 2417.

J. **Concentrated loads.** The bearing stress under beams, lintels and girders

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and from similar concentrated loads supported on unreinforced masonry shall not exceed the values set forth in Table No. 24-K.

K. **Shear walls.** (i) **Eccentricity.** In unreinforced shear walls, the virtual eccentricity e_l about the principal axis which is normal to the length l of the shear wall shall not exceed an amount which will produce tension. In unreinforced shear walls subject to bending about both principal axes, $e_t l + e_l t$ shall not exceed $tl/3$ where e_t = virtual eccentricity about the principal axis which is normal to the thickness t of the shear wall. Where the virtual eccentricity exceeds the values given in this section, shear walls shall be designed in accordance with Section 2417 or 2418 (a).

(ii) **Allowable vertical loads.** Allowable vertical loads on unreinforced shear walls shall be determined in accordanee with Section 2418 (e) 5 I, except that the value of h used in determining C_s shall be taken as the minimum vertical or horizontal distance between lateral supports.

(iii) **Allowable shear stress.** The allowable shear stresses in unreinforced shear walls shall be taken as the allowable stresses given in Table No. 24-K, plus one fifth of the average compressive stress due to dead load at the level being analyzed. In no case, however, shall the allowable shear stresses exceed the maximum values given in Table No. 24-K.

(iv) **Intersecting walls.** Where shear walls intersect a wall or walls to form symmetrical T or I seetions, the effective flange width shall not exceed one sixth of the total wall height above the level being analyzed, and its overhanging width on either side of the shear wall shall not exceed six times the actual thickness of the intersected wall. Where shear walls intersect a wall or walls to form L or C sections, the effective overhanging flange width shall not exceed one sixteenth of the total wall height above the level being analyzed nor six times the actual thickness of the intersected wall. Limits on effective flange width may be waived when approved after a review of a written justifieation.

In computing the shear resistance of the wall, only the web shall be considered.

L. **Anchorage of diaphragms.** Anchorage of diaphragms to walls shall be in aceordance with Section 2310 and shall be sufficient to transmit all forces.

6. **Construction.** A. **General.** In addition to the construetion requirements of Sections 2409 (b), 2411 (b) and (c) and 2415, unreinforced brick masonry designed in accordance with Seetion 2418 (c) shall also comply with the requirements of this subsection.

B. **Mortar joints.** All brick shall be laid with full head and bed joints and all interior joints that are designed to receive mortar shall be filled. The average thickness of head and bed joints shall not exceed ½ inch.

C. **Bonding unreinforced load-bearing walls and shear walls.** Where two unreinforced load-bearing walls meet or intersect, or where shear walls intersect a wall [see Seetion 2418 (c) 5 K], the intersections shall be bonded by laying in a true bond at least 50 percent of the units at the intersection, or the intersecting walls shall be regularly toothed or blocked with 8-inch maximum offsets and the joints provided with metal anchors having a minimum section of ¼ inch by 1½ inches with ends bent up at least 2 inches, or with cross pins to form anchorage.

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Such anchors shall be at least 2 feet long and the maximum spacing shall be 4 feet.

Nonbearing Walls

Sec. 2419. (a) **General.** Nonbearing walls may be constructed of any masonry as specified in this chapter. Reinforced masonry nonbearing walls shall be reinforced as specified in Section 2417 (j) 3.

(b) **Thickness.** Every nonbearing masonry wall shall be so constructed and have a sufficient thickness to withstand all vertical loads and horizontal loads, where specifically required by Chapter 23, but in no case shall the thickness of such walls (including plaster when applied) be less than the values set forth in Table No. 24-I.

(c) **Anchorage.** All nonbearing partitions shall be anchored along the top edge to a structural member or a suspended ceiling, or shall be provided with equivalent anchorage along the sides.

TABLE NO. 24-A—MORTAR PROPORTIONS BY VOLUME FOR UNIT MASONRY

MORTAR TYPE	PARTS BY VOLUME OF PORTLAND CEMENT	PARTS BY VOLUME OF MASONRY CEMENT	PARTS BY VOLUME OF HYDRATED LIME OR LIME PUTTY [1]	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
M	1	1	—	Not less than 2¼ and not more than 3 times the sum of the volumes of the cements and lime used
	1	—	¼	
S	½	1	—	
	1	—	over ¼ to ½	
N	—	1	—	
	1	—	over ½ to 1¼	
O	—	1	—	
	1	—	over 1¼ to 2½	

[1] When plastic or waterproof cement is used as specified in Section 2403 (o), hydrated lime or putty may be added but not in excess of one tenth the volume of cement.

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TABLE NO. 24-B—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-C—ALLOWABLE SHEAR ON BOLTS
Masonry of Unburned Clay Units

DIAMETER OF BOLTS (Inches)	EMBEDMENTS (Inches)	SHEAR (Pounds)
½	—	—
⅝	12	200
¾	15	300
⅞	18	400
1	21	500
1⅛	24	600

TABLE NO. 24-D—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)	Es/Eg (n)	MODULUS OF RIGIDITY (G)
A	500	200,000	150	.36E
B	1000	600,000	50	.40E

TABLE NO. 24-E—ALLOWABLE UNIT WORKING STRESS REINFORCED GYPSUM CONCRETE

TYPE OF STRESS	FACTOR	CLASS A (Pounds per Sq. Inch)	CLASS B (Pounds per Sq. 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.

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TABLE NO. 24-F—SHEAR ON ANCHOR BOLTS AND DOWELS—REINFORCED GYPSUM CONCRETE[1]

BOLT OR DOWEL SIZE (Inches)	EMBEDMENT (Inches)	SHEAR[2] (Pounds)
⅜ Bolt	4	325
½ Bolt	5	450
⅝ Bolt	5	650
⅜ Deformed Dowel	6	325
½ 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.

TABLE NO. 24-G—ALLOWABLE SHEAR ON BOLTS FOR ALL MASONRY EXCEPT UNBURNED CLAY UNITS

DIAMETER OF BOLT (Inches)	EMBEDMENT[1] (Inches)	SOLID MASONRY (Shear in Pounds)	GROUTED MASONRY (Shear in Pounds)
½	4	350	550
⅝	4	500	750
¾	5	750	1100
⅞	6	1000	1500
1	7	1250	1850[2]
1⅛	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.

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TABLE NO. 24-H—MAXIMUM WORKING STRESSES IN POUNDS PER SQUARE INCH FOR REINFORCED SOLID AND HOLLOW UNIT MASONRY[1]

TYPE OF STRESS	SPECIAL INSPECTION REQUIRED	
	Yes	No
1. Compression, axial: Walls	See Section 2417	One half of the values permitted under Section 2417
2. Compression, axial: Columns	See Section 2417	One-half of the values permitted under Section 2417
3. Compression, flexural	$0.33 f'_m$ but not to exceed 900	$0.166 f'_m$ but not to exceed 450
4. Shear:		
a. No shear reinforcement:		
Flexural[2]	$1.1\sqrt{f'_m}$ 50 Max.	25
Shear walls[3]		
$M/Vd \geq 1$[4]	$.9\sqrt{f'_m}$ 34 Max.	17
$M/Vd = 0$[4]	$2.0\sqrt{f'_m}$ 50 Max.	25
b. Reinforcing taking all shear:		
Flexural	$3.0\sqrt{f'_m}$ 150 Max.	75
Shear walls[3]		
$M/Vd \geq 1$[4]	$1.5\sqrt{f'_m}$ 75 Max.	35
$M/Vd = 0$[4]	$2.0\sqrt{f'_m}$ 120 Max.	60
5. Modulus of elasticity[5]	$1000 f'_m$ but not to exceed 3,000,000	$500 f'_m$ but not to exceed 1,500,000
6. Modulus of rigidity[5]	$400 f'_m$ but not to exceed 1,200,000	$200 f'_m$ but not to exceed 600,000
7. Bearing on full area[6]	$0.25 f'_m$ but not to exeeed 900	$0.125 f'_m$ but not to exceed 450
8. Bearing on one-third area or less[6]	$0.30 f'_m$ but not to exceed 1200	$0.15 f'_m$ but not to exceed 600
9. Bond—Plain bars	60	30
10. Bond—Deformed bars	140	100

[1]Stresses for hollow unit masonry are based on net section.

[2]Web reinforcement shall be provided to carry the entire shear in excess of 20 pounds per square inch whenever there is required negative reinforcement and for a distance of one sixteenth the clear span beyond the point of inflection.

[3]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).

[4]M is the maximum bending moment occurring simultaneously with the shear load V at the section under consideration. Interpolate by straight line for M/Vd values between 0 and 1.

[5]Where determinations involve rigidity considerations in combination with other materials or where deflections are involved, the moduli of elasticity and rigidity under columns entitled "yes" for special inspection shall be used.

[6]This increase shall be permitted 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 stress on a reasonably concentric area greater than one third, but less than the full area, shall be interpolated between the values given.

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TABLE NO. 24-I—MINIMUM THICKNESS OF MASONRY WALLS

TYPE OF MASONRY	MAXIMUM RATIO UNSUPPORTED HEIGHT OR LENGTH TO THICKNESS	NOMINAL MINIMUM THICKNESS (Inches)
BEARING WALLS:		
1. Unburned Clay Masonry	10	16
2. Stone Masonry	14	16
3. Cavity Wall Masonry	18	8
4. Hollow Unit Masonry	18	8
5. Solid Masonry	20	8
6. Grouted Masonry	20	6
7. Reinforced Grouted Masonry	25	6
8. Reinforced Hollow Unit Masonry	25	4[1]
NONBEARING WALLS:		
9. Exterior Unreinforced Walls	20	2
10. Exterior Reinforced Walls	30	2
11. Interior Partitions Unreinforced	36	2
12. Interior Partitions Reinforced	48	2

[1]Nominal 4-inch-thick load-bearing reinforced hollow clay unit masonry walls with a maximum unsupported height or length to thickness of 27 may be permitted, provided net area unit strength exceeds 8000 psi, units are laid in running bond, bar sizes do not exceed ½ 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 1½ inches.

TABLE NO. 24-J—ASSUMED COMPRESSIVE STRENGTH OF UNREINFORCED BRICK MASONRY[1]

ASSUMED COMPRESSIVE STRENGTH OF UNREINFORCED BRICK MASONRY f'_m PSI			
COMPRESSIVE STRENGTH OF UNITS, PSI	WITH INSPECTION		
	TYPE N MORTAR	TYPE S MORTAR	TYPE M MORTAR
14,000 plus	3200	3900	4600
12,000	2800	3400	4000
10,000	2400	2900	3400
8,000	2000	2400	2800
6,000	1600	1900	2200
4,000	1200	1400	1600
2,000	800	900	1000

[1]See Section 2418 (c) 1.

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TABLE NO. 24-K—ALLOWABLE STRESSES IN UNREINFORCED ENGINEERING BRICK MASONRY

DESCRIPTION	ALLOWABLE STRESSES, PSI[1] Without Inspection	With Inspection
1. Compression, axial:[2 9]		
Walls f_m	$0.10 f'_m$	$0.20 f'_m$
Columns f_m	$0.08 f'_m$	$0.16 f'_m$
2. Compression, flexural:[2]		
Walls f_m	$0.16 f'_m$	$0.32 f'_m$
Columns f_m	$0.13 f'_m$	$0.26 f'_m$
3. Tensile, flexural:[5 6 9]		
Normal to bed joints[2]		
M or S mortar f_t	18	36
N mortar f_t	14	28
Parallel to bed joints[3]		
M or S mortar f_t	36	72
N mortar f_t	28	56
4. Shear:[7]		
M or S mortar v_m	$0.3\sqrt{f'_m}$ but not to exceed 40	$0.3\sqrt{f'_m}$ but not to exceed 80
N mortar v_m	$0.3\sqrt{f'_m}$ but not to exceed 28	$0.3\sqrt{f'_m}$ but not to exceed 56
5. Bearing:		
On full area	$0.125 f'_m$	$0.25 f'_m$
One one-third area or less[4] f_m	$0.188 f'_m$	$0.375 f'_m$
6. Modulus of elasticity[8] E_m	$500 f'_m$ but not to exceed 1,500,000 psi	$1000 f'_m$ but not to exceed 3,000,000 psi
7. Modulus of elasticity[8] E_v	$200 f'_m$ but not to exceed 600,000 psi	$400 f'_m$ but not to exceed 1,200,000 psi

[1]See Section 2418 (c) 3. Where f'_m is determined in accordance with brick tests, values of f'_m shall be based on Table No. 24-J.

[2]Direction of stress is normal to bed joints; vertically in normal masonry construction.

[3]Direction of stress is parrallel to bed joints; horizontally in normal masonry construction. If masonry is laid in stack bond, tensile stresses in the horizontal direction shall not be permitted in the masonry.

[4]This increase shall be permitted 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 stress on a reasonably concentric area greater than one third but less than the full area shall be interpolated between the values given.

[5]For computing the flexural resistance of cavity walls, the lateral load shall be distributed to the wythes according to their respective flexural rigidities.

[6]In the use of these allowable stresses, consideration shall be given to the influence of unusual vibration and impact forces.

[7]See Section 2418 (c) 5 K (iii).

[8]Where determinations involve rigidity or relative stiffness considerations in combination with other materials or where deflections are involved, the moduli of elasticity and rigidity given for "With Inspection" shall be used.

[9]Allowable compression and tensile stresses for the conditions of "Without Inspection" can be increased to two thirds of the allowable compression and tensile stresses for the conditions of "With Inspection" when supported by tests.

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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 neeessary 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:

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.

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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.

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.

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.

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.

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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 l/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.

$f_{c\perp}$ = 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, inch.

l_2 = distance from center of connector in end blocks to center of spacer block.

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.

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r = radius of gyration.
S = section modulus.
T = total axial tension load.
t = thickness.
V = total vertical shear.
W = total uniform load.
w = uniform load per unit of length.
Δ_A = allowable deformation or deflection.
Δ_a = actual deformation or deflection.
θ = 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.

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.

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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 shall be reduced 10 percent for lumber pressure impregnated with approved fire-retardant chemicals. The values for plywood so treated shall be reduced 16 percent except for modulus of elasticity, which shall be reduced 10 percent. Other adjustments are applicable.

Where structural glued-laminated timber is fire-retardant treated, values shall be reduced as approved by the building official.

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

33⅓ 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.

(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 (c) 7, except for lumber I beams and box beams, but are not

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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.

6. **Slenderness factor adjustments for beams.** When the depth of a beam exceeds its breadth, lateral support is required and the slenderness factor C_s shall be calculated by the following formula:

$$C_s = \sqrt{\frac{l_e d}{b^2}}$$

in which

C_s = slenderness factor.
l_e = effective length of beam, inches, from the following table.
d = depth of beam, inches.
b = breadth of beam, inches.

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	$1.06l_u$
Single-span or cantilever beam, any other load	$1.92l_u$
l_u = unsupported length of beam, inches.	

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:

$$F'_b = F_b\left[1 - \frac{1}{3}\left(\frac{C_s}{C_k}\right)^4\right]$$

in which

$C_k = \sqrt{3E/5F_b}$
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:

$$F'_b = \frac{0.4E}{(C_s)^2}$$

In no case shall C_s exceed 50.

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When the compression edge of a beam is supported throughout its length to prevent its lateral displaeement, 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 distanee between sueh 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 distanee between such points of intermediate lateral support.

Slenderness factor adjustments are not cumulative with size factor adjustments.

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:

	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.

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The average modulus of elasticity E values listed in the tables shall be multiplied by $1 - C_v$ 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 speeified in Item No. 4 do not apply to modulus of elasticity values.

9. **Temperature.** The allowable unit stresses speeified in this ehapter and as modified in this seetion apply to uses within the range of elimatic temperature ordinarily encountered in buildings. When manufacturing or equipment processes subjeet members to prolonged temperatures above this range, but not exceeding 150°F., the allowable design stresses shall be decreased by the appropriate reduetion faetors 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.

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 applieable 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 lumber, timber, plywood and poles required to be Treated Wood under Section 2516 (c) shall be identified by the quality mark of an approved inspection agency which maintains continued supervision, testing and inspection over the quality of the product as specified in U.B.C. Standard No. 25-12.

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.

(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-seetional 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 notehed 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 thiekness shall not be notched except at ends of members. Cantilevered portions of beams less than 4 inehes in nominal thickness shall not be notched unless the reduced section properties and lumber defects are considered in the design. For effeets of notch on shear strength, see Section 2506 (d).

3. **Lateral moment distribution.** Lateral moment distribution of a concen-

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trated load from a critieally 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 total vertical shear 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.

(d) **Horizontal Shear in Notched Beams.** Where girders, beams or joists are notched at points of support, they shall meet design requirements for net section in bending and in shear. The shear at such point shall not exceed the value calculated by the following formula:

$$V = \left(\frac{2bd' F_t}{3}\right)\left(\frac{d'}{d}\right)$$

WHERE:

d' = actual depth of beam at the notch.

d = total depth of beam.

(e) **Design of Eccentric Joints and of Beams Supported by Fastenings.** 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.** 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

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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)	½	1	1½	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) **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 exceeding 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 the dead load is sufficient to induce tension on the underside of the rafters, the ratio for the beam 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.

(h) **Lateral Deflection — Arches and Top Chords of Trusses.** Where roof joists, not purlins, are used between arches or the top chords of trusses, the depth, rather than the breadth, of the arch or top chord member (compression member) may be taken as its least dimension in determining the *l/d*. The roof joists shall be placed so that their upper edges are at least ½ inch above the tops of the arch or chord but also placed low enough to provide adequate lateral support.

When roof joists or planks are placed on top of an arch or top chord of a truss

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and arc well spiked or otherwise securely fastened to the arch or top chord and to blocking plaeed between the joists, or when sheathing is nailed properly to the top chord of trussed rafters, the depth of the arch or individual chord members may be used as the least dimension d in determining l/d.

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 eapable 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, l/d shall not exceed 50.

For individual members of a spaced column, l/d shall not exceed 80, nor shall l_2/d exceed 40.

(c) **Simple Solid-column Design.** These formulas for simple solid columns are based on pin-end conditions but may be applied also to square-end conditions. The effective length of the column for design purposes shall be increased where column-end conditions provide less stability than pin-end conditions and may be reduced where column-end conditions provide greater stability.

Allowable unit stresses in pounds per square inch of cross-sectional area of square or rectangular simple solid columns shall be determined by the following formulas, but such unit stresses shall not exceed values for compression, 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 (l/d of 11 or less):

$$F'_c = F_c$$

Intermediate columns (l/d greater than 11 but less than K):

$$K = 0.671\sqrt{\frac{E}{F_c}}$$

$$F'_c = F_c\left[1 - \tfrac{1}{3}\left(\frac{l/d}{K}\right)^4\right]$$

Long columns (l/d of K or greater):

$$F'_c = \frac{0.30E}{(l/d)^2}$$

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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:

$$F'_c = \frac{0.418E}{(l/d)^2}$$

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 formula 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

$$\frac{f_t}{F_t} + \frac{f_b}{F_b} \text{ does not exceed ONE}$$

(b) **Flexure and Axial Compression.** Members subjected to both flexure and axial compression shall be so proportioned that

Where $0 \leq J \leq 1$

$$\frac{f_c}{F'_c} + \frac{f_b}{F_b - Jf_c} \text{ does not exceed ONE}$$

$$J = \frac{l/d - 11}{K - 11}$$

(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 ⅜-inch or thicker plywood sheathing nailed to the narrow face of the chord in

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accordance with Table No. 25-P shall be determined from the formula:

$$C_T = 1 + 0.002\, l_e$$

WHERE:

C_T = buckling stiffness factor.

l_e = effective buckling length used in design of chord for compression loading.

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:

$$C_T = 1 + 0.001\, l_e$$

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.

The buckling stiffness factor C_T shall be applied as follows:

Short columns (l/d of 11 or less):

$$F'_c = F_c$$

Intermediate columns (l/d greater than 11 but less than K):

$$K = 0.671\sqrt{C_T (E/F_c)}$$

$$F'_c = F_c\left[1 - \tfrac{1}{3}\left(\frac{l/d}{K}\right)^4\right]$$

Long columns (l/d of K or greater):

$$F'_c = \frac{0.30EC_T}{(l/d)^2}$$

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:

$$F_n = \frac{F_c F_{c\perp}}{F_c \sin^2\theta + F_{c\perp}\cos^2\theta}$$

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Timber Connections and Fastenings

Sec. 2510. (a) **Timber Connectors.** Timber connectors may be used to transmit stress between wood members and between wood and metal members. The allowable loads and installation of timber connectors shall be as set forth in U.B.C. Standard No. 25-17.

Safe loads and design practices for types of connectors 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.** Bolted joints wherein bolts are used to resist or transfer stresses in wood structures shall be designed in accordance with the provisions set forth in U.B.C. Standard No. 25-17 except as specified in this subsection. 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, 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) **Drift Bolts or Pins.** Connections of wood structural members involving the use of drift bolts or drift pins shall be designed in accordance with the provisions set forth in U.B.C. Standard No. 25-17.

(d) **Wood Screws.** Connections involving the use of wood screws shall be designed in accordance with the provisions set forth in U.B.C. Standard No. 25-17.

(e) **Lag Screws.** Connections involving the use of lag screws shall be designed in accordance with the provisions set forth in U.B.C. Standard No. 25-17.

(f) **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, 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 or toenailed shall not be subjected to more than five sixths of the lateral load allowed when driven perpendicular to 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.

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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.

(g) **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.

(h) **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.

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 struetural 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

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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.

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.

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A, B and C = constants as follow:

β (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 β = angle between the upper edge of the member and the horizontal in degrees.

Values of K_r for intermediate values of β 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.

C. One third the allowable unit stress in horizontal shear for southern pine, redwood and hardwoods for all types of loading.

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 β as follows:

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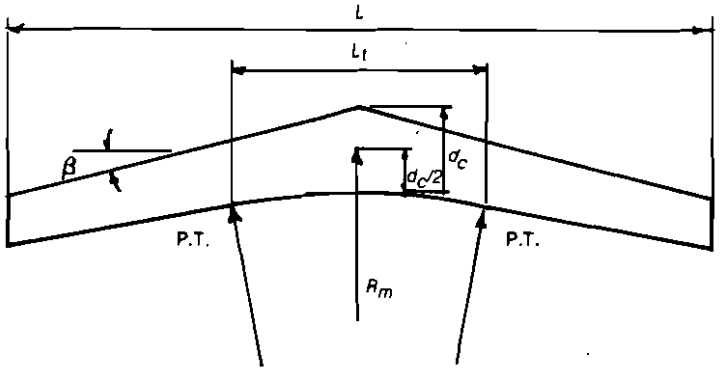
β	A	B	C	D	E	F	G	H
2.3°	-.142	.418	-2.358	-.053	—	—	.002	—
9.7°	.143	.376	- .541	-.060	—	—	.003	—
14.9°	.406	.293	- .927	-.041	—	—	.002	—
20.0°	.423	.364	-1.022	-.067	—	.146	—	—
25.2°	.540	.360	-1.061	-.070	—	.156	—	—
29.8°	.502	.372	—	-.076	-3.712	.138	.004	4.336

and β = angle between the upper edge of the member and the horizontal in degrees. Values of C_r for intermediate values may be interpolated linearly.



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:

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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 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 ¼ 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 sueh glued-laminated timbers exceed ½ inch for a 5-pound-per-square-foot uniform load.

(e) **Tapered Faces.** No sawn tapered cuts shall bc permitted on the tension face of any simple beam. Pitched or curved beams shall be so fabricated that the laminations are parallel to the tension faee. 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 projeetions.

(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

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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 Diaphragms

Sec. 2513. (a) **General.** Lumber and plywood 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 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 1½:1 for diagonal sheathing or 2:1 for special diagonal sheathed or plywood diaphragms.

In masonry or concrete buildings, lumber and plywood 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

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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.

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 for horizontal diaphragms and Table No. 25-K 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 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. 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

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eenter along panel edge bearings, and shall be firmly driven into the framing members. No unblocked panels less than 12 inches wide shall be used.

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 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 ⅜ 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 1½:1.

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.

EXCEPTION: 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.

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

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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.

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.

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 ½-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.

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They shall be covered with corrosion-resistant wire mesh with mesh openings of ¼ 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 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.

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 member 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.

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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 exposed 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 openings which afford a passage for fire at ceiling and floor levels, with noncombustible materials.

3. **Fire stop construction.** Except as provided in Item D above, firestopping shall consist of 2 inches nominal lumber or two thicknesses of 1-inch nominal lumber with broken lap joints or one thickness of ¾-inch plywood with joints backed by ¾-inch plywood.

Fire stops may also be of gypsum board, cement asbestos board, mineral wool or other approved materials securely fastened in place.

Walls having parallel or staggered studs for sound transmission control shall have fire stops of mineral wool or other approved nonrigid material.

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

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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.

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 ½-inch gypsum board, ⅜-inch plywood 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.

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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.** Siding shall have a minimum thickness of ⅜ 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 ⅜ 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 5/16 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 ½-inch plywood 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.

3. **Plywood.** Where plywood is used for covering the exterior of outside walls, it shall be of the Exterior type not less than ⅜ inch thick. Plywood panel siding shall be installed in accordance with Table No. 25-M. Unless applied over 1-inch wood sheathing or ½-inch plywood 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 ⅜ inch. Wood shingles or shakes and asbestos shingles or siding may be nailed directly to approved fiberboard nailbase sheathing not less than ½-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.

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Standard No. 25-25, not less than ⅜ inch thick when applied over approved sheathing, not less than ⅝ inch thick when applied directly to framing spaced 16 inches on center and not less than ¾ inch thick when applied directly to framing spaced 24 inches on center. Panels shall be gapped ⅛ inch and nails shall be spaced not less than ⅜ inch from edges and ends of sheathing. Unless applied over ⅝-inch net wood sheathing or ½-inch plywood sheathing or ½-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 direct to studs. 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 ¼ inch thick in the groove.

Nail size and spacing shall follow Table No. 25-O and shall penetrate framing 1½ inches. Lap siding shall overlap 1 inch minimum and be nailed through both courses and into framing members with nails located ½ inch from bottom of the overlapped course. Square-edged nongrooved panels shall be nailed ⅜ inch from the perimeter of the panel and intermediately into studs. Shiplap edge panel siding with ⅜-inch shiplap shall be nailed ⅜ inch from the edges on both sides of the shiplap. The ¾-inch shiplap shall be nailed ⅜ inch from the edge and penetrate through both the overlap and underlap. Top and bottom edges of the panel shall be nailed ⅜ 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 ⅛-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.

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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 joints 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 or No. 25-S 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 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.

(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 (c), 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

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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 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 (c).

(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 1½ 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

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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.

Joists framing from opposite sides of a beam, girder or partition shall be lapped at least 4 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 (g) 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.

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.

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, ½-inch tongue-and-groove flooring, or ⅜-inch plywood 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 ⅜-inch plywood shall be applied with the face grain at right angles to the span of the planks.

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(f) **Particleboard Underlayment.** Particleboard floor underlayment shall conform to Type 1-M grades of U.B.C. Standard No. 25-25. Underlayment shall be not less than ¼ 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 ⅜-inch-thick plywood, 1-inch-thick lumber or other approved devices which will serve as an adequate backing for the attachment of facing materials.

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 ⅛-inch by 1½-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 at each end, or as near thereto as possible, and at least every 25 feet of length 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 ⅝-inch net minimum thickness applied diagonally on studs spaced not over 24 inches on center.

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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 and No. 25-N.

D. Fiberboard sheathing 4-foot by 8-foot panels not less than ½ 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 sheathing panels not less than ½ inch thick on studs spaced not over 16 inches on center when installed in accordance with Table No. 47-I.

F. Particleboard Exterior Type 2-M-1 sheathing panels not less than 3/8 inch thick on studs spaced not more than 16 inches on center.

G. Gypsum wallboard not less than ½ inch thick on studs spaced not over 24 inches on center when installed in accordance with Table No. 47-I.

H. Portland cement plaster on studs spaced 16 inches on center installed in accordance with Table No. 47-I.

I. 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, H and I, 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.

Solid sheathing of one of the materials specified in Items B through F, gypsum wallboard in Item G applied to supports at 16 inches on center, portland cement plaster in Item H, or hardboard panel siding in Item I, shall be applied to the exterior walls of the first story of all wood framed buildings three stories in height. In Seismic Zones Nos. 3 and 4 such braced wall sections shall be located at each end, or as near thereto as possible, and shall comprise at least 40 percent of the linear length of the wall.

Solid sheathing of one of the materials specified in Items B through F, gypsum wallboard in Item G applied to supports at 16 inches on center, portland cement plaster in Item H, or hardboard panel siding in Item I, shall be applied on either face of the exterior walls of the first story of all wood framed, two-story buildings and the second story of three-story buildings located in Seismic Zones No. 3 and No. 4. Braced wall sections shall be located at each end or as near thereto as possible and comprise at least 25 percent of the linear length of the wall.

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.

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 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

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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 1½ 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 ⅛ inch thick and 1½ 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 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 ⅝ 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.

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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-ineh 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 (g). Roof trusses shall be supported laterally at points of bearing by solid blocking to previous rotation and lateral displacement.

7. **Roof sheathing.** Roof sheathing shall be in accordance with Tables No. 25-S-1 and No. 25-S-2 for plywood or No. 25-R-1 and No. 25-R-2 for lumber.

Joints in lumber sheathing shall oceur 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.

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 accordanee with Table No. 25-U. Joints in such planking may be randomly spaced, provided the system is applied to not less than threc continuous spans, planks are center-matched and end-matehed 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							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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
ASPEN (BIGTOOTH—QUAKING) (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1300	1500	775	60	185	850	1,100,000	25-4 25-5 and 25-8 (See footnotes 2 through 8, 13, 15 and 16)
No. 1		1100	1300	650	60	185	675	1,100,000	
No. 2		925	1050	525	60	185	550	1,000,000	
No. 3		500	575	300	60	185	325	900,000	
Appearance		1100	1300	650	60	185	825	1,100,000	
Stud		500	575	300	60	185	325	900,000	
Construction	2" to 4" thick 4" wide	650	750	400	60	185	625	900,000	
Standard		375	425	225	60	185	500	900,000	
Utility		175	200	100	60	185	325	900,000	
Select Structural	2" to 4" thick 5" and wider	1150	1300	750	60	185	750	1,100,000	
No. 1		950	1100	650	60	185	675	1,100,000	
No. 2		775	900	425	60	185	575	1,000,000	
No. 3 and Stud		450	525	250	60	195	375	900,000	
Appearance		950	1100	650	60	185	825	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	Design values 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 $F_{c\perp}$	Compression parallel to grain F_c	Modulus of elasticity E	
		Single-member uses	Repetitive-member uses						
BALSAM FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4"	1750	2000	1000	70	185	1350	1,500,000	
No. 1	thick	1450	1700	850	70	185	1050	1,500,000	
No. 2	2" to 4"	1200	1400	700	70	185	850	1,300,000	
No. 3	wide	675	775	400	70	185	525	1,200,000	
Appearance		1450	1700	850	70	185	1250	1,500,000	25-5
Stud		675	775	400	70	185	525	1,200,000	25-8
Construction	2" to 4"	875	1000	525	70	185	950	1,200,000	(See footnotes
Standard	thick	500	575	275	70	185	775	1,200,000	1 through 9)
Utility	4" wide	225	275	125	70	185	525	1,200,000	
Select Structural	2" to 4"	1500	1700	1000	70	185	1200	1,500,000	
No. 1	thick	1250	1450	850	70	185	1050	1,500,000	
No. 2	5" and	1050	1200	550	70	185	900	1,300,000	
No. 3	wider	600	700	325	70	185	575	1,200,000	
Appearance		1250	1450	850	70	185	1250	1,500,000	
Stud		600	700	325	70	185	575	1,200,000	
Select Structural	Beams and	1350	—	900	65	185	950	1,400,000	
No. 1	Stringers	1100	—	750	65	185	800	1,400,000	
Select Structural	Posts and	1250	—	825	65	185	1000	1,400,000	
No. 1	Timbers	1000	—	675	65	185	875	1,400,000	
Select	Decking	—	1650	—	—	—	—	1,500,000	25-8
Commercial		—	1400	—	—	—	—	1,300,000	(See footnotes 1 through 9)

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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	100	725	1,200,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
No. 1		875	1000	500	50	100	575	1,200,000	
No. 2		725	825	425	50	100	450	1,100,000	
No. 3		400	450	225	50	100	275	900,000	
Appearance		875	1000	500	50	100	700	1,200,000	
Stud		400	450	225	50	100	275	900,000	
Construction	2" to 4" thick 4" wide	525	600	300	50	100	525	900,000	
Standard		300	325	175	50	100	425	900,000	
Utility		150	150	75	50	100	275	900,000	
Select Structural	2" to 4" thick 5" and wider	875	1000	600	50	100	650	1,200,000	
No. 1		750	875	500	50	100	575	1,200,000	
No. 2		625	700	325	50	100	475	1,100,000	
No. 3 and Stud		350	425	175	50	100	300	900,000	
Appearance		750	875	500	50	100	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	425	2150	1,400,000	25-7 (See footnotes 2 through 7 9, 13, 15 and 16)
Clear Structural		2300	2650	1500	145	425	2150	1,400,000	
Select Structural	2" to 4" thick 2" to 4" wide	2050	2350	1200	80	425	1750	1,400,000	
Select Structural, Open grain		1600	1850	950	80	270	1300	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
No. 1	2" to 4" thick 2" to 4" wide	1700	1950	975	80	425	1400	1,400,000	25-7 (See footnotes 2 through 7, 9, 13, 15 and 16)
No. 1, Open grain		1350	1550	775	80	270	1050	1,100,000	
No. 2		1400	1600	800	80	425	1100	1,250,000	
No. 2, Open grain		1100	1250	625	80	270	825	1,000,000	
No. 3		800	900	475	80	425	675	1,100,000	
No. 3, Open grain		625	725	375	80	270	500	900,000	
Stud		625	725	375	80	270	500	900,000	
Construction	2" to 4" thick 4" wide	825	950	475	80	270	925	900,000	
Standard		450	525	250	80	270	775	900,000	
Utility		225	250	125	80	270	500	900,000	
Select Structural	2" to 4" thick 5" and wider	1750	2000	1150	80	425	1550	1,400,000	
Select Structural, Open grain		1400	1600	925	80	270	1150	1,100,000	
No. 1		1500	1700	975	80	425	1400	1,400,000	
No. 1, Open grain		1150	1350	775	80	270	1050	1,100,000	
No. 2		1200	1400	650	80	425	1200	1,250,000	
No. 2, Open grain		950	1100	500	80	270	875	1,000,000	
No. 3 and Stud		700	800	375	80	425	725	1,100,000	
No. 3, Open grain		550	650	350	80	270	525	900,000	
Clear Heart Structural	5" by 5" and larger	1850	—	1250	135	425	1650	1,300,000	
Clear Structural		1850	—	1250	135	425	1650	1,300,000	
Select Structural		1400	—	950	95	425	1200	1,300,000	
No. 1		1200	—	800	95	425	1050	1,300,000	
No. 2		975	—	650	95	425	900	1,100,000	
No. 3		550	—	375	95	425	550	1,000,000	

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Select Decking, Close grain Select Decking Commercial Decking	Decking 2" thick 6" & wider	1850 1450 1200	2150 1700 1350	— — —	— — —	— — —	— — —	1,400,000 1,100,000 1,000,000	25-7 (See footnotes 2, 5 and 6)
COAST SITKA SPRUCE (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural No. 1 No. 2 No. 3 Appearance Stud	2" to 4" thick 2" to 4" wide	1500 1250 1050 575 1250 600	1700 1450 1200 675 1450 675	875 750 625 350 725 350	65 65 65 65 65 65	290 290 290 290 290 290	1100 875 700 425 1050 425	1,700,000 1,700,000 1,500,000 1,300,000 1,700,000 1,300,000	
Construction Standard Utility	2" to 4" thick 4" wide	750 425 200	875 500 225	450 250 125	65 65 65	290 290 290	800 650 425	1,300,000 1,300,000 1,300,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
Select Structural No. 1 No. 2 No. 3 and Stud Appearance	2" to 4" thick 5" and wider	1300 1100 900 525 1100	1500 1250 1050 575 1250	850 725 475 275 725	65 65 65 65 65	290 290 290 290 290	975 875 750 475 1050	1,700,000 1,700,000 1,500,000 1,300,000 1,700,000	
Select Structural No. 1	Beams and Stringers	1150 950	— —	675 475	60 60	290 290	775 650	1,500,000 1,500,000	
Select Structural No. 1	Posts and Timbers	1100 875	— —	725 575	60 60	290 290	825 725	1,500,000 1,500,000	
Select Commercial	Decking	1250 1050	1450 1200	— —	— —	290 290	— —	1,700,000 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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
COAST SPECIES (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1500	1700	850	65	235	1100	1,500,000	
No. 1		1250	1450	750	65	235	875	1,500,000	
No. 2		1050	1200	625	65	235	700	1,400,000	
No. 3		575	675	350	65	235	425	1,200,000	
Appearance		1250	1450	725	65	235	1050	1,500,000	
Stud		575	675	350	65	235	425	1,200,000	
Construction	2" to 4" thick 4" wide	750	875	450	65	235	800	1,200,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
Standard		425	500	250	65	235	650	1,200,000	
Utility		200	225	125	65	235	425	1,200,000	
Select Structural	2" to 4" thick 5" and wider	1300	1500	875	65	235	975	1,500,000	
No. 1		1100	1250	725	65	235	875	1,500,000	
No. 2		900	1050	475	65	235	750	1,400,000	
No. 3 and Stud		525	600	275	65	235	475	1,200,000	
Appearance		1100	1250	725	65	235	1050	1,500,000	
Select	Decking	1250	1450	—	—	235	—	1,500,000	
Commercial		1050	1200	—	—	235	—	1,400,000	

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Stud	2" to 3" thick 2" to 4" wide	525	600	300	65	195	350	1,000,000	25-5 (See footnotes 1 through 9)
COTTONWOOD (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Construction	2" to 4" thick 4" wide	675	775	400	65	195	650	1,000,000	
Standard		375	425	225	65	195	525	1,000,000	
Utility		175	200	100	65	195	350	1,000,000	
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	455	1850	1,900,000	
Select Structural		2100	2400	1200	95	385	1600	1,800,000	
Dense No. 1		2050	2400	1200	95	455	1450	1,900,000	
No. 1	2" to 4"	1750	2050	1050	95	385	1250	1,800,000	
Dense No. 2	thick	1700	1950	1000	95	455	1150	1,700,000	
No. 2	2" to 4"	1450	1650	850	95	385	1000	1,700,000	
No. 3	wide	800	925	475	95	385	600	1,500,000	25-2 25-3 and 25-4 (See footnotes 2 through 9, 11, 13, 15 and 16)
Appearance		1750	2050	1050	95	385	1500	1,800,000	
Stud		800	925	475	95	385	600	1,500,000	
Construction	2" to 4"	1050	1200	625	95	385	1150	1,500,000	
Standard	thick	600	675	350	95	385	925	1,500,000	
Utility	4" wide	275	325	175	95	385	600	1,500,000	
Dense Select Structural		2100	2400	1400	95	455	1650	1,900,000	
Select Structural		1800	2050	1200	95	385	1400	1,800,000	
Dense No. 1	2" to 4"	1800	2050	1200	95	455	1450	1,900,000	
No. 1	thick	1500	1750	1000	95	385	1250	1,800,000	
Dense No. 2	5" and	1450	1700	775	95	455	1250	1,700,000	
No. 2	wider	1250	1450	650	95	385	1050	1,700,000	
No. 3 and Stud		725	850	375	95	385	675	1,500,000	
Appearance		1500	1750	1000	95	385	1500	1,800,000	

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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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Dense Select Structural	Beams and Stringers[12]	1900	—	1100	85	455	1300	1,700,000	25-3 (See footnotes 2 through 9)
Select Structural		1600	—	950	85	385	1100	1,600,000	
Dense No. 1		1550	—	775	85	455	1100	1,700,000	
No. 1		1300	—	675	85	385	925	1,600,000	
Dense Select Structural	Posts and Timbers[12]	1750	—	1150	85	455	1350	1,700,000	
Select Structural		1500	—	1000	85	385	1150	1,600,000	
Dense No. 1		1400	—	950	85	455	1200	1,700,000	
No. 1		1200	—	825	85	385	1000	1,600,000	
Select Dex	Decking	1750	2000	—	—	385	—	1,800,000	
Commercial Dex		1450	1650	—	—	385	—	1,700,000	
Dense Select Structural	Beams and Stringers[12]	1900	—	1250	85	455	1300	1,700,000	25-4 (See footnotes 2 through 10)
Select Structural		1600	—	1050	85	385	1100	1,600,000	
Dense No. 1		1550	—	1050	85	455	1100	1,700,000	
No. 1		1350	—	900	85	385	925	1,600,000	
Dense Select Structural	Posts and Timbers[12]	1750	—	1150	85	455	1350	1,700,000	
Select Structural		1500	—	1000	85	385	1150	1,600,000	
Dense No. 1		1400	—	950	85	455	1200	1,700,000	
No. 1		1200	—	825	85	385	1000	1,600,000	
Selected Decking	Decking	—	2000	—	—	—	—	1,800,000	
Commercial Decking		—	1650	—	—	—	—	1,700,000	
Selected Decking	Decking	—	2150	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,900,000	
Commercial Decking		—	1800					1,700,000	

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Dense Select Structural Select Structural Dense No. 1 No. 1	Beams and Stringers	1900 1600 1550 1300	— — — —	1100 950 775 675	85 85 85 85	455 385 455 385	1300 1100 1100 925	1,700,000 1,600,000 1,700,000 1,600,000	25-2 (See footnotes 2 through 9 and 11)
Dense Select Structural Select Structural Dense No. 1 No. 1	Posts and Timbers	1750 1500 1400 1200	— — — —	1150 1000 950 825	85 85 85 85	455 385 455 385	1350 1150 1200 1000	1,700,000 1,600,000 1,700,000 1,600,000	25-2 (See footnotes 2 through 9 and 11)
Select Commercial	Decking	1750 1450	2000 1650	— —	— —	385 385	— —	1,800,000 1,700,000	
DOUGLAS FIR SOUTH (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural No. 1 & Appearance No. 2 No. 3 Stud	2" to 4" thick 2" to 4" wide	2000 1700 1400 775 775	2300 1950 1600 875 875	1150 975 825 450 450	90 90 90 90 90	335 335 335 335 335	1400 1150 900 550 550	1,400,000 1,400,000 1,300,000 1,100,000 1,100,000	25-4 (See footnotes 2 through 10, 13, 15 and 16)
Construction Standard Utility	2" to 4" thick 4" wide	1000 550 275	1150 650 300	600 325 150	90 90 90	335 335 335	1000 850 550	1,100,000 1,100,000 1,100,000	
Select Structural No. 1 & Appearance No. 2 No. 3 and Stud	2" to 4" thick 5" and wider	1700 1450 1200 700	1950 1650 1350 800	1150 975 625 350	90 90 90 90	335 335 335 335	1250 1150 950 600	1,400,000 1,400,000 1,300,000 1,100,000	
Select Structural No. 1	Beams and Stringers	1550 1300	— —	1050 850	85 85	335 335	1000 850	1,200,000 1,200,000	
Select Structural No. 1	Posts and Timbers	1400 1150	— —	950 775	85 85	335 335	1050 925	1,200,000 1,200,000	
Selected Decking Commercial Decking	Decking	— —	1900 1600	— —	— —	— —	— —	1,400,000 1,300,000	
Selected Decking Commercial Decking	Decking	— —	2050 1750	(Stresses for Decking apply at 15% moisture content)				1,500,000 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	Design values in pounds per square inch: Extreme fiber in bending F_b — Single-member uses	Extreme fiber in bending F_b — Repetitive-member uses	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	U.B.C. STDS UNDER WHICH GRADED
EASTERN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structrual	2" to 4" thick 2" to 4" wide	1750	2050	1050	85	360	1350	1,200,000	25-8 (See footnotes 1 through 9)
No. 1		1500	1750	875	85	360	1050	1,200,000	
No. 2		1250	1450	725	85	360	850	1,100,000	
No. 3		675	800	400	85	360	525	1,000,000	
Appearance		1500	1750	875	85	360	1250	1,200,000	
Stud		675	800	400	85	360	525	1,000,000	
Construction	2" to 4" thick 4" wide	900	1050	525	85	360	950	1,000,000	
Standerd		500	575	300	85	360	800	1,000,000	
Utility		250	275	150	85	360	525	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1550	1750	1000	85	360	1200	1,200,000	
No. 1		1300	1500	875	85	360	1050	1,200,000	
No. 2		1050	1250	550	85	360	900	1,100,000	
No. 3		625	700	325	85	360	575	1,000,000	
Appearance		1300	1500	875	85	360	1250	1,200,000	
Stud		625	700	325	85	360	575	1,000,000	
Select Structural	Beams and Stringers	1350	—	925	80	360	950	1,200,000	
No. 1		1150	—	775	80	360	800	1,200,000	
Select Structural	Posts and Timbers	1250	—	850	80	360	1000	1,200,000	
No. 1		1050	—	700	80	360	875	1,200,000	

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EASTERN HEMLOCK—TAMARACK (Surfaced dry or surfaced green. Used at 19% max. m.c.) EASTERN HEMLOCK—TAMARACK (NORTH)									
Select Structural		1800	2050	1050	85	365	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	365	1050	1,300,000	
No. 2	2" to 4"	1250	1450	725	85	365	850	1,100,000	
No. 3	thick	700	800	400	85	365	525	1,000,000	
Appearance	2" to 4"	1300	1500	875	85	365	1300	1,300,000	
Stud	wide	700	800	400	85	365	525	1,000,000	
Construction	2" to 4"	900	1050	525	85	365	975	1,000,000	
Standard	thick	500	575	300	85	365	800	1,000,000	
Utility	4" wide	250	275	150	85	365	525	1,000,000	
Select Structural		1550	1750	1050	85	365	1200	1,300,000	
No. 1	2" to 4"	1300	1500	875	85	365	1050	1,300,000	
No. 2	thick	1050	1200	575	85	365	900	1,100,000	
No. 3 and Stud	5" and	625	725	325	85	365	575	1,000,000	
Appearance	wider	1300	1500	875	85	365	1300	1,300,000	
Select Structural		1400	—	925	80	365	950	1,200,000	25-2 (See footnotes 1 through 9 and 11)
No. 1	Beams and Stringers	1150	—	775	80	365	800	1,200,000	
Select Structural		1300	—	875	80	365	1000	1,200,000	
No. 1	Posts and Timbers	1050	—	700	80	365	875	1,200,000	
Select		1500	1700	—	—	—	—	1,300,000	
Commercial	Decking	1250	1450	—	—	—	—	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Select Structural No. 1	Beams and Stringers	1400 1150	— —	925 775	80 80	365 365	950 800	1,200,000 1,200,000	25-5 25-8 (See footnotes 2 through 9)
Select Structural No. 1	Posts and Timbers	1300 1050	— —	875 700	80 80	365 365	1000 875	1,200,000 1,200,000	
Select Commercial	Decking	1500 1250	1700 1450	— —	— —	— —	— —	1,300,000 1,100,000	25-8 (See footnotes 2 through 9)
Select Structural No. 1	Beams and Stringers	1450 1200	— —	850 600	85 85	405 405	950 800	1,300,000 1,300,000	25-2 (See footnotes 2 through 9 and 11)
Select Structural No. 1	Posts and Timbers	1300 1050	— —	875 700	80 80	365 365	1000 875	1,200,000 1,200,000	
Select Commercial	Decking	1500 1250	1700 1450	— —	— —	365 365	— —	1,300,000 1,100,000	

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EASTERN SOFTWOODS (Surfaced dry or surfaced green, Used at 19% max. m.c.)									
Select Structural No. 1 No. 2 No. 3	2" to 4" thick 2" to 4" wide	1350 1150 950 525	1550 1350 1100 600	800 675 550 300	70 70 70 70	185 185 185 185	1050 825 650 400	1,200,000 1,200,000 1,100,000 1,000,000	25-5 (See footnotes 1 through 9)
Stud	2" to 4" thick 2" to 4" wide	525	600	300	70	185	400	1,000,000	25-5 25-8 (See footnotes 1 through 8)
Construction Standard Utility	2" to 4" thick 4" wide	700 375 175	800 450 200	400 225 100	70 70 70	185 185 185	750 625 400	1,000,000 1,000,000 1,000,000	25-5 (See footnotes 1 through 9)
Select Structural No. 1 No. 2 No. 3 Appearance	2" to 4" thick 5" and wider	1150 1000 825 475 1000	1350 1150 950 550 1150	775 675 425 250 675	70 70 70 70 70	185 185 185 185 185	925 825 700 450 1000	1,200,000 1,200,000 1,100,000 1,000,000 1,200,000	
Stud	2" to 4" thick 5" and wider	475	550	250	70	185	450	1,000,000	25-5 25-8 (See footnotes 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	Design values 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 $F_{c\perp}$	Compression parallel to grain F_c	Modulus of elasticity E	
		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	230	1050	1,500,000	25-5 25-8 (See footnotes 1 through 9)
No. 1	thick	1200	1350	700	70	230	825	1,500,000	
No. 2	2" to 4"	975	1100	575	70	230	650	1,400,000	
No. 3	wide	550	625	325	70	230	400	1,200,000	
Appearance		1200	1350	700	70	230	1000	1,500,000	
Stud		550	625	325	70	230	400	1,200,000	
Construction	2" to 4"	700	800	400	70	230	750	1,200,000	
Standard	thick	400	450	225	70	230	625	1,200,000	
Utility	4" wide	175	225	100	70	230	400	1,200,000	
Select Structural	2" to 4"	1200	1350	800	70	230	925	1,500,000	
No. 1	thick	1000	1150	675	70	230	825	1,500,000	
No. 2	5" and	825	950	425	70	230	700	1,400,000	
No. 3	wider	475	550	250	70	230	450	1,200,000	
Appearance		1000	1150	675	70	230	1000	1,500,000	
Stud		475	550	250	70	230	450	1,200,000	
Select Structural	Beams and	1050	—	725	65	230	750	1,400,000	
No. 1	Stringers	900	—	600	65	230	625	1,400,000	
Select Structural	Posts and	1000	—	675	65	230	775	1,400,000	
No. 1	Timbers	800	—	550	65	230	675	1,400,000	
Select	Decking	—	1300	—	—	—	—	1,500,000	25-8 (See footnotes 1 through 9)
Commercial		—	1100	—	—	—	—	1,400,000	

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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	220	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	220	850	1,200,000	
No. 2	thick	950	1100	550	65	220	675	1,100,000	
No. 3	2" to 4"	525	600	300	65	220	400	1,000,000	
Appearance	wide	1150	1350	675	65	220	1000	1,200,000	
Stud	2" to 4" thick 2" to 4" wide	525	600	300	65	220	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	220	750	1,000,000	
Standard	thick	375	450	225	65	220	625	1,000,000	
Utility	4" wide	175	200	100	65	220	400	1,000,000	
Select Structural		1150	1350	775	65	220	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	220	850	1,200,000	
No. 2	thick	825	950	450	65	220	700	1,100,000	
No. 3 and Stud	5" and	475	550	250	65	220	450	1,000,000	
Appearance	wider	1000	1150	675	65	220	1000	1,200,000	
Select Structural	Beams and	1050	—	700	65	220	675	1,100,000	25-8 (See footnotes 2 through 9)
No. 1	Stringers	875	—	600	65	220	575	1,100,000	
Select Structural	Posts and	975	—	650	65	220	725	1,100,000	
No. 1	Timbers	800	—	525	65	220	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Select Commercial	Decking	900 775	1050 875	— —	— —	— —	— —	1,200,000 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 No. 1 No. 2 No. 3 Stud	2" to 4" thick 2" to 4" wide	1300 1100 925 500 500	1500 1300 1050 575 575	775 650 525 300 300	60 60 60 60 60	185 185 185 185 185	850 675 550 325 325	1,100,000 1,100,000 1,000,000 900,000 900,000	25-5 and 25-8 (See footnotes 2 through 9 13, 15 and 16)
Construction Standard Utility	2" to 4" thick 4" wide	650 375 175	750 425 200	400 225 100	60 60 60	185 185 185	625 500 325	900,000 900,000 900,000	
Appearance	2" to 4" thick 2" to 4" wide	1100	1300	650	60	185	825	1,100,000	
Select Structural No. 1 No. 2 No. 3 and Stud Appearance	2" to 4" thick 5" and wider	1150 950 775 450 950	1300 1100 900 525 1100	750 650 425 250 650	60 60 60 60 60	185 185 185 185 185	750 675 575 375 825	1,100,000 1,100,000 1,000,000 900,000 1,100,000	25-5 (See footnotes 2 through 9, 15 and 16)

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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	2" to 4" thick 2" to 4" wide	1350	1550	800	70	195	950	1,300,000	25-4 (See footnotes 2 through 10, 13, 15 and 16)
No. 1		1150	1350	675	70	195	750	1,300,000	
No. 2		950	1100	550	70	195	600	1,100,000	
No. 3		525	600	300	70	195	375	1,000,000	
Appearance		1150	1350	675	70	195	900	1,300,000	
Stud		525	600	300	70	195	375	1,000,000	
Construction	2" to 4" thick 4" wide	700	800	400	70	195	675	1,000,000	
Standard		375	450	225	70	195	550	1,000,000	
Utility		175	200	100	70	195	375	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1200	1350	775	70	195	850	1,300,000	
No. 1		1000	1150	675	70	195	750	1,300,000	
No. 2		825	950	425	70	195	625	1,100,000	
No. 3 and Stud		475	550	250	70	195	400	1,000,000	
Appearance		1000	1150	675	70	195	900	1,300,000	
Select Structural	Beams and Stringers	1050	—	700	65	195	675	1,100,000	
No. 1		875	—	600	65	195	550	1,100,000	
Select Structrual	Posts and Timbers	975	—	650	65	195	700	1,100,000	
No. 1		800	—	525	65	195	625	1,100,000	
Selected Decking	Decking	—	1300	—	—	—	—	1,300,000	
Commercial Decking		—	1100	—	—	—	—	1,100,000	
Selected Decking	Decking	—	1400	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,300,000	
Commercial Decking		—	1200					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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
HEM-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1650	1900	975	75	245	1300	1,500,000	25-2, 25-3 and 25-4 (See footnotes 2 through 9, 11, 12, 13 15 and 16)
No. 1		1400	1600	825	75	245	1050	1,500,000	
No. 2		1150	1350	675	75	245	825	1,400,000	
No. 3		650	725	375	75	245	500	1,200,000	
Appearance		1400	1600	825	75	245	1250	1,500,000	
Stud		650	725	375	75	245	500	1,200,000	
Construction	2" to 4" thick 4" wide	825	975	500	75	245	925	1,200,000	
Standard		475	550	275	75	245	775	1,200,000	
Utility		225	250	125	75	245	500	1,200,000	
Select Structural	2" to 4" thick 5" and wider	1400	1650	950	75	245	1150	1,500,000	
No. 1		1200	1400	800	75	245	1050	1,500,000	
No. 2		1000	1150	525	75	245	875	1,400,000	
No. 3 and Stud		575	675	300	75	245	550	1,200,000	
Appearance		1200	1400	800	75	245	1250	1,500,000	
Select Structural No. 1	Beams and Stringers	1300	—	750	70	245	925	1,300,000	25-3 (See footnotes 2 through 9, 15 and 16)
		1050	—	525	70	245	750	1,300,000	
Select Structural No. 1	Posts and Timbers	1200	—	800	70	245	975	1,300,000	
		975	—	650	70	245	850	1,300,000	
Select Dex	Decking	1400	1600	—	—	245	—	1,500,000	
Commercial Dex		1150	1350	—	—	245	—	1,400,000	

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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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Select Structural No. 1	Beams and Stringers 12	1250 1050	— —	850 725	70 70	245 245	925 775	1,300,000 1,300,000	25-2 and 25-4 (See footnotes 2 through 12)
Select Structural No. 1	Posts and Timbers	1200 950	— —	800 650	70 70	245 245	975 850	1,300,000 1,300,000	
Selected Decking Commercial Decking	Decking	— —	1600 1350	— —	— —	— —	— —	1,500,000 1,400,000	
Selected Decking Commercial Decking	Decking	— —	1700 1450	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,600,000 1,400,000	
Select Commercial	Decking	1350 1150	1550 1300	— —	— —	245 245	— —	1,500,000 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	Design values in pounds per square inch: Extreme fiber in bending F_b — Single-member uses	Extreme fiber in bending F_b — Repetitive-member uses	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	U.B.C. STDS UNDER WHICH GRADED
HEM-FIR (NORTH) (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 3"	1600	1800	925	75	235	1300	1,500,000	
No. 1	thick	1350	1550	800	75	235	1050	1,500,000	
No. 2	2" to 4"	1100	1300	650	75	235	800	1,400,000	
No. 3	wide	625	700	350	75	235	500	1,200,000	
Appearance		1350	1550	800	75	235	1250	1,500,000	
Stud		625	700	350	75	235	500	1,200,000	
Construction	2" to 4"	800	925	475	75	235	925	1,200,000	
Standard	thick	450	525	275	75	235	775	1,200,000	
Utility	4" wide	225	250	125	75	235	500	1,200,000	25-2 (See footnotes 1 through 9 and 11)
Select Structural	2" to 4"	1350	1550	900	75	235	1150	1,500,000	
No. 1	thick	1150	1350	775	75	235	1050	1,500,000	
No. 2	5" and	950	1100	500	75	235	850	1,400,000	
No. 3	wider	550	650	300	75	235	550	1,200,000	
Appearance		1150	1350	775	75	235	1250	1,500,000	
Stud		550	650	300	75	235	550	1,200,000	
Select Structural	Beams and	1250	--	725	70	235	900	1,300,000	
No. 1	Stringers	1000	--	500	70	235	750	1,300,000	
Select Structural	Posts and	1150	--	775	70	235	950	1,300,000	
No. 1	Timbers	925	--	625	70	235	850	1,300,000	
Select	Decking	1350	1500	--	--	235	--	1,500,000	
Commercial		1100	1300	--	--	235	--	1,400,000	

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IDAHO WHITE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select structural		1350	1550	775	70	190	1100	1,400,000	
No. 1	2" to 4"	1150	1300	650	70	190	875	1,400,000	
No. 2	thick	925	1050	550	70	190	675	1,300,000	
No. 3	2" to 4"	525	600	300	70	190	425	1,200,000	
Appearance	wide	1150	1300	650	70	190	1050	1,400,000	
Stud		525	600	300	70	190	425	1,200,000	
Construction	2" to 4"	675	775	400	70	190	775	1,200,000	
Standard	thick	375	425	225	70	190	650	1,200,000	
Utility	4" wide	175	200	100	70	190	425	1,200,000	
Select Structural		1150	1300	775	70	190	950	1,400,000	25-4
No. 1	**2" to 4"**	975	1100	650	70	190	875	1,400,000	(See footnotes
No. 2	**thick**	800	925	425	70	190	725	1,300,000	2 through 10
No. 3 and Stud	**5" and**	475	550	250	70	190	450	1,200,000	13, 15 and 16)
Appearance	**wider**	975	1100	650	70	190	1050	1,400,000	
Select Structural	Beams and	1000	—	700	65	190	775	1,300,000	
No. 1	Stringers	850	—	575	65	190	650	1,300,000	
Select Structural	Posts and	950	—	650	65	190	800	1,300,000	
No. 1	Timbers	775	—	525	65	190	700	1,300,000	
Selected Decking	Decking	—	1300	—	—	—	—	1,400,000	
Commercial Decking		—	1050	—	—	—	—	1,300,000	
Selected Decking	Decking	—	1400	(Surfaced at 15% max. m.c. and				1,500,000	
Commercial Decking		—	1150	used at 15% max. m.c.)				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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	250	1150	1,300,000	
No. 1		1300	1500	750	70	250	900	1,300,000	
No. 2		1050	1200	625	70	250	700	1,200,000	
No. 3		600	675	350	70	250	425	1,000,000	
Appearance		1300	1500	750	70	250	1050	1,300,000	
Stud		600	675	350	70	250	425	1,000,000	
Construction	2" to 4" thick 4" wide	775	875	450	70	250	800	1,000,000	
Standard		425	500	250	70	250	675	1,000,000	
Utility		200	225	125	70	250	425	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1300	1500	875	70	250	1000	1,300,000	25-4 (See footnotes 2 through 10, 13, 15 and 16)
No. 1		1100	1300	750	70	250	900	1,300,000	
No. 2		925	1050	475	70	250	750	1,200,000	
No. 3 and Stud		525	625	275	70	250	475	1,000,000	
Appearance		1100	1300	750	70	250	1050	1,300,000	
Select Structural	Beams and Stringers	1150	—	775	65	250	800	1,100,000	
No. 1		975	—	650	65	250	675	1,100,000	
Select Structural	Posts and Timbers	1100	—	725	65	250	850	1,100,000	
No. 1		875	—	600	65	250	725	1,100,000	
Selected Decking	Decking	—	1450	—	—	—	—	1,300,000	
Commercial Decking		—	1200	—	—	—	—	1,200,000	
Selected Decking	Decking	—	1550	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,400,000	
Commercial Decking		—	1300					1,200,000	

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MOUNTAIN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1750	2000	1000	95	370	1250	1,300,000	25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16)
No. 1		1450	1700	850	95	370	1000	1,300,000	
No. 2		1200	1400	700	95	370	775	1,100,000	
No. 3		675	775	400	95	370	475	1,000,000	
Appearance		1450	1700	850	95	370	1200	1,300,000	
Stud		675	775	400	95	370	475	1,000,000	
Construction	2" to 4" thick 4" wide	875	1000	525	95	370	900	1,000,000	
Standard		500	575	275	95	370	725	1,000,000	
Utility		225	275	125	95	370	475	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1500	1700	1000	95	370	1100	1,300,000	
No. 1		1250	1450	850	95	370	1000	1,300,000	
No. 2		1050	1200	550	95	370	825	1,100,000	
No. 3 and Stud		625	700	325	95	370	525	1,000,000	
Appearance		1250	1450	850	95	370	1200	1,300,000	
Select Structural	Beams and Stringers	1350	—	775	90	370	875	1,100,000	25-3 (See footnotes 2 through 9)
No. 1		1100	—	550	90	370	725	1,100,000	
Select Structural	Posts and Timbers	1250	—	825	90	370	925	1,100,000	
No. 1		1000	—	675	90	370	800	1,100,000	
Select Dex	Decking	1450	1650	—	—	370	—	1,300,000	
Commercial Dex		1200	1400	—	—	370	—	1,100,000	
Select Structural	Beams and Stringers	1350	—	900	90	370	875	1,100,000	25-4 (See footnotes 2 through 10)
No. 1		1100	—	750	90	370	750	1,100,000	
Select Structural	Posts and Timbers	1250	—	825	90	370	925	1,100,000	
No. 1		1000	—	675	90	370	800	1,100,000	
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	

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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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
MOUNTAIN HEMLOCK—HEM-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1650	1900	975	75	245	1250	1,300,000	
No. 1		1400	1600	825	75	245	1000	1,300,000	
No. 2		1150	1350	675	75	245	775	1,100,000	
No. 3		650	725	375	75	245	475	1,000,000	
Appearance		1400	1600	825	75	245	1200	1,300,000	
Stud		650	725	375	75	245	475	1,000,000	
Construction	2" to 4" thick 4" wide	825	975	500	75	245	900	1,000,000	
Standard		475	550	275	75	245	725	1,000,000	
Utility		225	250	125	75	245	475	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1400	1650	950	75	245	1100	1,300,000	25-4 (See footnotes 2 through 10, 13, 15 and 16)
No. 1		1200	1400	800	75	245	1000	1,300,000	
No. 2		1000	1150	525	75	245	825	1,100,000	
No. 3 and Stud		575	675	300	75	245	525	1,000,000	
Appearance		1200	1400	800	75	245	1200	1,300,000	
Select Structural	Beams and Stringers	1250	—	850	70	245	875	1,100,000	
No. 1		1050	—	725	70	245	750	1,100,000	
Select Structural	Posts and Timbers	1200	—	800	70	245	925	1,100,000	
No. 1		950	—	650	70	245	800	1,100,000	
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	

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NORTHERN ASPEN (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural		1300	1500	750	60	195	850	1,400,000	
No. 1	2" to 4"	1100	1250	650	60	195	675	1,400,000	
No. 2	thick	900	1050	525	60	195	525	1,200,000	
No. 3	2" to 4"	500	575	275	60	195	325	1,100,000	
Appearance	wide	1100	1250	650	60	195	800	1,400,000	
Stud		500	575	275	60	195	325	1,100,000	25-2 (See footnotes 2 through 9 11, 13 15 and 16)
Construction	2" to 4"	650	750	375	60	195	600	1,100,000	
Standard	thick	350	425	200	60	195	500	1,100,000	
Utility	4" wide.	175	200	100	60	195	325	1,100,000	
Select Structural		1100	1250	750	60	195	750	1,400,000	
No. 1	2" to 4"	950	1100	625	60	195	675	1,400,000	
No. 2	thick	775	900	400	60	195	575	1,200,000	
No. 3 and Stud	5" and	450	525	250	60	195	350	1,100,000	
Appearance	wider	950	1100	625	60	195	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	280	1200	1,400,000	25-5 and 25-8 (See footnotes 2 through 9, 13, 15 and 16)
No. 1		1400	1600	825	70	280	975	1,400,000	
No. 2		1150	1300	675	70	280	775	1,300,000	
No. 3		625	725	375	70	280	475	1,100,000	
Appearance		1200	1400	800	70	280	1150	1,400,000	
Stud		625	725	375	70	280	475	1,100,000	
Construction	2" to 4" thick 4" wide	825	950	475	70	280	875	1,100,000	
Standard		450	525	275	70	280	725	1,100,000	
Utility		225	250	125	70	280	475	1,100,000	
Select Structural	2" to 4" thick 5" and wider	1400	1600	950	70	280	1100	1,400,000	
No. 1		1200	1400	800	70	280	975	1,400,000	
No. 2		950	1100	525	70	280	825	1,300,000	
No. 3 and Stud		575	650	300	70	280	525	1,100,000	
Appearance		1200	1400	800	70	280	1150	1,400,000	
Select Structural	Beams and Stringers	1250	—	850	65	280	850	1,300,000	
No. 1		1050	—	700	65	280	725	1,300,000	
Select Structural	Posts and Timbers	1150	—	800	65	280	900	1,300,000	
No. 1		950	—	650	65	280	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		1350	1550	775	65	220	1050	1,100,000		
No. 1	2" to 3" thick	1150	1300	675	65	220	825	1,100,000		
No. 2		925	1050	550	65	220	650	1,000,000		
No. 3	2" to 4" wide	525	600	300	65	220	400	900,000		
Appearance		1150	1300	675	65	220	975	1,100,000		
Stud		525	600	300	65	220	400	900,000		
Construction	2" to 4" thick	675	775	400	65	220	750	900,000		
Standard		375	425	225	65	220	600	900,000		
Utility	4" wide	175	200	100	65	220	400	900,000		
Select Structural	2" to 4" thick	1150	1300	775	65	220	900	1,100,000		
No. 1		975	1150	650	65	220	825	1,100,000		
No. 2		800	925	425	65	220	675	1,000,000		
No. 3 and Stud	5" and wider	475	550	250	65	220	425	900,000		
Appearance		975	1150	650	65	220	850	1,100,000		
Select	Decking	900	1050	—	—	220	—	1,100,000		
Commercial		775	875	—	—	220	—	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	205	875	800,000	25-8 (See footnotes 2 through 9, 13, 15 and 16)
No. 1		1000	1150	600	65	205	675	800,000	
No. 2		825	950	500	65	205	550	700,000	
No. 3		450	525	275	65	205	325	600,000	
Appearance		850	1000	575	65	205	825	800,000	
Stud		450	525	275	65	205	325	600,000	
Construction	2" to 4" thick 4" wide	600	675	350	65	205	625	600,000	
Standard		325	375	200	65	205	500	600,000	
Utility		150	175	100	65	205	325	600,000	
Select Structural	2" to 4" thick 5" and wider	1000	1150	675	65	205	775	800,000	
No. 1		850	1000	575	65	205	675	800,000	
No. 2		700	825	375	65	205	575	700,000	
No. 3 and Stud		425	475	225	65	205	375	600,000	
Appearance		850	1000	575	65	205	825	800,000	
Select Structural	Beams and Stringers	900	—	600	60	205	600	700,000	
No. 1		750	—	500	60	205	500	700,000	
Select Structural	Posts and Timbers	850	—	575	60	205	650	700,000	
No. 1		675	—	450	60	205	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	235	1050	1,200,000	25-2 and 25-4 (See footnotes 2 through 13, 15 and 16)
No. 1		1200	1400	700	70	235	850	1,200,000	
No. 2		1000	1150	575	70	235	675	1,100,000	
No. 3		550	625	325	70	235	400	1,000,000	
Appearance		1200	1400	700	70	235	1000	1,200,000	
Stud		550	625	325	70	235	400	1,000,000	
Construction	2" to 4" thick 4" wide	725	825	425	70	235	775	1,000,000	
Standard		400	450	225	70	235	625	1,000,000	
Utility		200	225	100	70	235	400	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1200	1400	825	70	235	950	1,200,000	
No. 1		1050	1200	700	70	235	850	1,200,000	
No. 2		850	975	450	70	235	700	1,100,000	
No. 3 and Stud		500	575	250	70	235	450	1,000,000	
Appearance		1050	1200	700	70	235	1000	1,200,000	
Select Structural	Beams and Stringers	1100	—	725	65	235	750	1,100,000	25-2 and 25-4 (See footnotes 2 through 13)
No. 1		925	—	625	65	235	625	1,100,000	
Select Structural	Posts and Timbers	1000	—	675	65	235	800	1,100,000	
No. 1		825	—	550	65	235	700	1,100,000	
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	—	—	235[20]	—	1,300,000	
Commercial		1000[20]	1250	—	—	235[20]	—	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	280	1050	1,300,000	
No. 1		1200	1350	700	70	280	825	1,300,000	
No. 2		975	1100	575	70	280	650	1,200,000	
No. 3		525	625	325	70	280	400	1,000,000	
Appearance		1200	1350	700	70	280	975	1,300,000	
Stud		525	625	325	70	280	400	1,000,000	
Construction	2" to 4" thick 4" wide	700	800	400	70	280	750	1,000,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
Standard		400	450	225	70	280	600	1,000,000	
Utility		175	225	100	70	280	400	1,000,000	
Select Structural	2" to 4" thick 5" and wider	1200	1350	775	70	280	900	1,300,000	
No. 1		1000	1150	675	70	280	825	1,300,000	
No. 2		825	950	425	70	280	675	1,200,000	
No. 3 and Stud		500	550	250	70	280	425	1,000,000	
Appearance		1000	1150	675	70	280	975	1,300,000	
Select Structural	Beams and Stringers	1050	—	625	65	280	725	1,100,000	
No. 1		875	—	450	65	280	600	1,100,000	
Select Structural	Posts and Timbers	1000	—	675	65	280	775	1,100,000	
No. 1		800	—	550	65	280	675	1,100,000	
Select	Decking	1150	1350	—	—	280	—	1,300,000	
Commercial		975	1100	—	—	280	—	1,200,000	

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SITKA SPRUCE (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1550	1800	925	75	280	1150	1,500,000	25-3 (See footnotes 2 through 9, 13, 15 and 16)
No. 1		1350	1550	775	75	280	925	1,500,000	
No. 2		1100	1250	650	75	280	725	1,300,000	
No. 3		600	700	350	75	280	450	1,200,000	
Appearance		1350	150	750	75	280	1100	1,500,000	
Stud		600	700	350	75	280	450	1,200,000	
Construction	2" to 4" thick 4" wide	800	925	475	75	280	825	1,200,000	
Standard		450	500	250	75	280	675	1,200,000	
Utility		200	250	125	75	280	450	1,200,000	
Select Structural	2" to 4" thick 5" and wider	1350	1550	900	75	280	1000	1,500,000	
No. 1		1150	1300	775	75	280	925	1,500,000	
No. 2		925	1050	500	75	280	775	1,300,000	
No. 3 and Stud		525	600	275	75	280	500	1,200,000	
Appearance		1150	1300	750	75	280	1100	1,500,000	
Select Structural	Beams and Stringers	1200	—	675	70	280	825	1,300,000	
No. 1		1000	—	500	70	280	675	1,300,000	
Select Structural	Posts and Timbers	1150	—	750	70	280	875	1,300,000	
No. 1		925	—	600	70	280	750	1,300,000	
Select Dex	Decking	1300	1500	—	—	280	—	1,500,000	
Commercial Dex		1100	1250	—	—	280	—	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	405	1800	1,800,000	25-6 (See footnotes 3, 4, 9, 13, 15, 16, 18 and 19)
Dense Select Structural		2500	2900	1500	105	475	2100	1,900,000	
No. 1		1850	2100	1050	105	405	1450	1,800,000	
No. 1 Dense		2150	2450	1250	105	475	1700	1,900,000	
No. 2		1550	1750	900	95	405	1150	1,600,000	
No. 2 Dense		1800	2050	1050	95	475	1350	1,700,000	
No. 3		850	975	500	95	405	675	1,500,000	
No. 3 Dense		1000	1150	575	95	475	800	1,500,000	
Stud		850	975	500	95	405	675	1,500,000	
Construction	2" to 4" thick 4" wide	1100	1250	650	105	405	1300	1,500,000	
Standard		625	725	375	95	405	1050	1,500,000	
Utility		275	300	175	95	405	675	1,500,000	
Select Structural	2" to 4" thick 5" and wider	1850	2150	1200	95	405	1600	1,800,000	
Dense Select Structural		2200	2500	1450	95	475	1850	1,900,000	
No. 1		1600	1850	1050	95	405	1450	1,800,000	
No. 1 Dense		1850	2150	1250	95	475	1700	1,900,000	
No. 2		1300	1500	675	95	405	1200	1,600,000	
No. 2 Dense		1550	1750	800	95	475	1400	1,700,000	
No. 3		750	875	400	95	405	725	1,500,000	
No. 3 Dense		875	1000	450	95	475	850	1,500,000	
Stud		800	900	400	95	405	725	1,500,000	

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Dense Standard Decking	2" to 4"	2150	2450	1250	105	475	1700	1,900,000	25-6 (See footnotes 4, 9, 15, 16 18 and 19)
Select Decking	thick	1550	1750	900	95	405	1150	1,600,000	
Dense Select Decking	2" and	1800	2050	1050	95	475	1350	1,700,000	
Commercial Decking	wider	1550	1750	900	95	405	1150	1,600,000	
Dense Commercial Decking	Decking	1800	2050	1050	95	475	1350	1,700,000	
Dense Structural 86	2" to 4" thick	2800	3250	1900	165	475	2300	1,900,000	
Dense Structural 72		2400	2750	1600	135	475	1950	1,900,000	
Dense Structural 65		2150	2450	1450	125	475	1750	1,900,000	
SOUTHERN PINE (Surfaced dry. Used at 19% max. m.c.)									25-6 (See footnotes 3, 4, 9, 13, 15, 16, 18 and 19)
Select Structural	2" to 4" thick 2" to 4" wide	2000	2300	1150	100	405	1550	1,700,000	
Dense Select Structural		2350	2700	1350	100	475	1800	1,800,000	
No. 1		1700	1950	1000	100	405	1250	1,700,000	
No. 1 Dense		2000	2300	1150	100	475	1450	1,800,000	
No. 2		1400	1650	825	90	405	975	1,600,000	
No. 2 Dense		1650	1900	975	90	475	1150	1,600,000	
No. 3		775	900	450	90	405	575	1,400,000	
No. 3 Dense		925	1050	525	90	475	675	1,500,000	
Stud		775	900	450	90	405	575	1,400,000	
Construction	2" to 4" thick 4" wide	1000	1150	600	100	405	1100	1,400,000	
Standard		575	675	350	90	405	900	1,400,000	
Utility		275	300	150	90	405	575	1,400,000	
Select Structural	2" to 4" thick 5" and wider	1750	2000	1150	90	405	1350	1,700,000	
Dense Select Structural		2050	2350	1300	90	475	1600	1,800,000	
No. 1		1450	1700	975	90	405	1250	1,700,000	
No. 1 Dense		1700	2000	1150	90	475	1450	1,800,000	
No. 2		1200	1400	625	90	405	1000	1,600,000	
No. 2 Dense		1400	1650	725	90	475	1200	1,600,000	
No. 3		700	800	350	90	405	625	1,400,000	
No. 3 Dense		825	925	425	90	475	725	1,500,000	
Stud		725	850	350	90	405	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Dense Standard Decking	2" to 4" thick 2" and wider Decking	2000	2300	1150	100	475	1450	1,800,000	25-6. (See footnotes 3, 4, 9, 13, 15, 16, 17, 18 and 19)
Select Decking		1400	1650	825	90	405	975	1,600,000	
Dense Select Decking		1650	1900	975	90	475	1150	1,600,000	
Commercial Decking		1400	1650	825	90	405	975	1,600,000	
Dense Commercial Decking		1650	1900	975	90	475	1150	1,600,000	
Dense Structural 86	2" to 4" thick	2600	3000	1750	155	475	2000	1,800,000	
Dense Structural 72		2200	2550	1450	130	475	1650	1,800,000	
Dense Structural 65		2000	2800	1300	115	475	1500	1,800,000	
SOUTHERN PINE (Surfaced green. Used any condition)									
Select Structural	2½" to 4" thick 2½" to 4" wide	1600	1850	925	95	270	1050	1,500,000	
Dense Select Structural		1850	2150	1100	95	315	1200	1,600,000	
No. 1		1350	1550	800	95	270	825	1,500,000	
No. 1 Dense		1600	1800	925	95	315	950	1,600,000	
No. 2		1150	1300	675	85	270	650	1,400,000	
No. 2 Dense		1350	1500	775	85	315	750	1,400,000	
No. 3		625	725	375	85	270	400	1,200,000	
No. 3 Dense		725	850	425	85	315	450	1,300,000	
Stud		625	725	375	85	270	400	1,200,000	
Construction	2½" to 4" thick 4" wide	825	925	475	95	270	725	1,200,000	
Standard		475	525	275	85	270	600	1,200,000	
Utility		200	259	125	85	270	400	1,200,000	

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Select Structural	2½" to 4" thick 5" and wider	1400	1600	900	85	270	900	1,500,000	25-6 (See footnotes 3, 4, 9, 13 15, 16, 17, 18 and 19)
Dense Select Structural		1600	1850	1050	85	315	1050	1,600,000	
No. 1		1200	1350	775	85	270	825	1,500,000	
No. 1 Dense		1400	1600	925	85	315	950	1,600,000	
No. 2		975	1100	500	85	270	675	1,400,000	
No. 2 Dense		1150	1300	600	85	315	800	1,400,000	
No. 3		550	650	300	85	270	425	1,200,000	
No. 3 Dense		650	750	350	85	315	475	1,300,000	
Stud		575	675	300	85	270	425	1,200,000	
Dense Standard Decking	2½" to 4" thick 2" and wider Decking	1600	1800	925	95	315	950	1,600,000	
Select Decking		1150	1300	675	85	270	650	1,400,000	
Dense Select Decking		1350	1500	775	85	315	750	1,400,000	
Commercial Decking		1150	1300	675	85	270	650	1,400,000	
Dense Commercial Decking		1350	1500	775	85	315	750	1,400,000	
No. 1 SR	5" and thicker	1350	—	875	110	270	775	1,500,000	
No. 1 Dense SR		1550	—	1050	110	315	925	1,600,000	
No. 2 SR		1100	—	725	95	270	625	1,400,000	
No. 2 Dense SR		1250	—	850	95	315	725	1,400,000	
Dense Structural 86	2½" and thicker	2100	2400	1400	145	315	1300	1,600,000	
Dense Structural 72		1750	2050	1200	120	315	1100	1,600,000	
Dense Structural 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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
SPRUCE—PINE—FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)									
Select Structural	2" to 4" thick 2" to 4" wide	1450	1650	850	70	265	1100	1,500,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
No. 1		1200	1400	725	70	265	875	1,500,000	
No. 2		1000	1150	600	70	265	675	1,300,000	
No. 3		550	650	325	70	265	425	1,200,000	
Appearance		1200	1400	700	70	265	1050	1,500,000	
Stud		550	650	325	70	265	425	1,200,000	
Construction	2" to 4" thick 4" wide	725	850	425	70	265	775	1,200,000	
Standard		400	475	225	70	265	650	1,200,000	
Utility		175	225	100	70	265	425	1,200,000	
Select Structural	2" to 4" thick 5" and wider	1250	1450	825	70	265	975	1,500,000	
No. 1		1050	1200	700	70	265	875	1,500,000	
No. 2		875	1000	450	70	265	725	1,300,000	
No. 3 and Stud		500	575	275	70	265	450	1,200,000	
Appearance		1050	1200	700	70	265	1050	1,500,000	
Select Structural	Beams and Stringers	1100	—	650	65	265	775	1,300,000	
No. 1		900	—	450	65	265	625	1,300,000	
Select Structural	Posts and Timbers	1050	—	700	65	265	800	1,300,000	
No. 1		850	—	550	65	265	700	1,300,000	
Select	Decking	1200	1400	—	—	265	—	1,500,000	
Commercial		1000	1150	—	—	265	—	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	2" to 3" thick 2" to 4" wide	1500	1750	875	75	265	1200	1,100,000	25-2, 25-3 and 25-4 (See footnotes 2 through 9, 11, 12 and 13)
No. 1		1300	1500	750	75	265	950	1,100,000	
No. 2		1050	1200	625	75	265	750	1,000,000	
No. 3		600	675	350	75	265	450	900,000	
Appearance		1300	1500	750	75	265	1100	1,100,000	
Stud		600	675	350	75	265	450	900,000	
Construction	2" to 4" thick 4" wide	775	875	450	75	265	850	900,000	
Standard		425	500	250	75	265	700	900,000	
Utility		200	225	125	75	265	450	900,000	
Select Structural	2" to 4" thick 5" and wider	1300	1500	825	75	265	1050	1,100,000	
No. 1		1100	1300	750	75	265	950	1,100,000	
No. 2		925	1050	475	75	265	800	1,000,000	
No. 3 and Stud		525	625	275	75	265	500	900,000	
Appearance		1100	1300	750	75	265	1100	1,100,000	
Select Structural	Beams and Stringers	1150	—	675	70	265	875	1,000,000	25-2 and 25-3 (See footnotes 2 through 9, 11 and 12)
No. 1		925	—	475	70	265	725	1,000,000	
Select Structural	Posts and Timbers	1050	—	700	70	265	900	1,000,000	
No. 1		850	—	575	70	265	800	1,000,000	
Select Dex	Decking	1200	1400	—	—	265	—	1,100,000	25-3 (See footnotes 2 through 9)
Commercial Dex		1050	1200	—	—	265	—	1,000,000	
Select	Decking	1200	1400	—	—	165	—	1,100,000	25-2 (See footnotes 2 through 9 and 11
Commercial		1050	1200	—	—	165	—	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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	Repetitive-member Uses						
Select Structural No. 1	Beams and Stringers	1150 975	— —	775 650	70 70	265 265	875 725	1,000,000 1,000,000	25-4 (See footnotes 2 through 10)
Select Structural No. 1	Posts and Timbers	1100 875	— —	725 600	70 70	265 265	925 800	1,000,000 1,000,000	
Selected Decking Commercial Decking	Decking	— —	1450 1200	— —	— —	— —	— —	1,100,000 1,000,000	
Selected Decking Commercial Decking	Decking	— —	1550 1300	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,100,000 1,000,000	
WESTERN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.) WESTERN HEMLOCK (NORTH)									
Select Structural	2" to 4" thick 2" to 4" wide	1800	2100	1050	90	280	1450	1,600,000	25-2 (See footnote 11) 25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16)
No. 1		1550	1800	900	90	280	1150	1,600,000	
No. 2		1300	1450	750	90	280	900	1,400,000	
No. 3		700	800	425	90	280	550	1,300,000	
Appearance		1550	1800	900	90	280	1350	1,600,000	
Stud		700	800	425	90	280	550	1,300,000	
Construction	2" to 4" thick 4" wide	925	1050	550	90	280	1050	1,300,000	
Standard		525	600	300	90	280	850	1,300,000	
Utility		250	275	150	90	280	550	1,300,000	

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Select Structural No. 1 No. 2 No. 3 and Stud Appearance	2" to 4" thick 5" and wider	1550 1350 1100 650 1350	1800 1550 1250 750 1550	1050 900 575 325 900	90 90 90 90 90	280 280 280 280 280	1300 1150 975 625 1350	1,600,000 1,600,000 1,400,000 1,300,000 1,600,000	25-3 and 25-4 (See footnotes 2 through 9, 13, 15 and 16)
Select Structural No. 1	Beams and Stringers	1400 1150	— —	825 575	85 85	280 280	1000 850	1,400,000 1,400,000	25-3 (See footnotes 2 through 9)
Select Structural No. 1	Posts and Timbers	1300 1050	— —	875 700	85 85	280 280	1100 950	1,400,000 1,400,000	
Select Dex Commercial Dex	Decking	1500 1300	1750 1450	— —	— —	280 280	— —	1,600,000 1,400,000	
Select Structural No. 1	Beams and Stringers	1400 1150	— —	950 775	85 85	280 280	1000 850	1,400,000 1,400,000	25-4 (See footnotes 2 through 10)
Select Structural No. 1	Posts and Timbers	1300 1050	— —	875 700	85 85	280 280	1100 950	1,400,000 1,400,000	
Selected Decking Commercial Decking	Decking		1750 1450					1,600,000 1,400,000	
Selected Decking Commercial Decking	Decking		1900 1600	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,700,000 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 $F_{c\perp}$	Compression Parallel to Grain F_c	MODULUS OF ELASTICITY E	
		Engineered Uses (Single)	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	235	1100	1,400,000	
No. 1		1150	1300	675	65	235	875	1,400,000	
No. 2		925	1050	550	65	235	675	1,300,000	
No. 3		525	600	300	65	235	425	1,200,000	
Appearance		1150	1300	650	65	235	1050	1,400,000	
Stud		525	600	300	65	235	425	1,200,000	
Construction	2" to 4" thick 4" wide	675	775	400	65	235	775	1,200,000	
Standard		375	425	225	65	235	650	1,200,000	
Utility		175	200	100	65	235	425	1,200,000	
Select Structural	2" to 4" thick 5" and wider	1150	1300	775	65	235	975	1,400,000	25-2 (See footnotes 2 through 9, 11, 13, 15 and 16)
No. 1		975	1150	650	65	235	875	1,400,000	
No. 2		800	925	425	65	235	725	1,300,000	
No. 3 and Stud		475	550	250	65	235	450	1,200,000	
Appearance		975	1150	650	65	235	1050	1,400,000	
Select Structural	Beams and Stringers	1050	—	600	60	235	775	1,300,000	
No. 1		850	—	425	60	235	625	1,300,000	
Select Structural	Posts and Timbers	975	—	650	60	235	800	1,300,000	
No. 1		775	—	525	60	235	700	1,300,000	
Select	Decking	1100	1300	—	—	235	—	1,400,000	
Commercial		925	1050	—	—	235	—	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 No. 1 No. 2 No. 3 Appearance Stud	2" to 4" thick 2" to 4" wide	1350 1150 925 525 1150 525	1550 1300 1050 600 1300 600	775 650 550 300 650 300	70 70 70 70 70 70	190 190 190 190 190 190	950 750 600 375 900 375	1,100,000 1,100,000 1,000,000 900,000 1,100,000 900,000	
Construction Standard Utility	2" to 4" thick 4" wide	675 375 175	775 425 200	400 225 100	70 70 70	190 190 190	675 550 375	900,000 900,000 900,000	
Select Structural No. 1 No. 2 No. 3 and Stud Appearance	2" to 4" thick 5" and wider	1150 975 800 475 975	1300 1100 925 550 1100	775 650 425 250 650	70 70 70 70 70	190 190 190 190 190	850 750 625 400 900	1,100,000 1,100,000 1,000,000 900,000 1,100,000	25-4 (See footnotes 2 through 10, 13, 15 and 16)
Select Structural No. 1	Beams and Stringers	1000 850	— —	700 575	65 65	190 190	675 550	1,000,000 1,000,000	
Select Structural No. 1	Posts and Timbers	950 775	— —	650 525	65 65	190 190	700 625	1,000,000 1,000,000	
Selected Decking Commercial Decking	Decking	— —	1300 1050	— —	— —	— —	— —	1,100,000 1,000,000	
Selected Decking Commercial Decking	Decking	— —	1400 1150	(Surfaced at 15% max. m.c. and used at 15% max. m.c.)				1,100,000 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	Design values 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 $F_{c\perp}$	Compression parallel to grain F_c	Modulus of elasticity E	
		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	270	1050	1,500,000	
No. 1	thick	1250	1450	750	80	270	825	1,500,000	
No. 2	2" to 4"	1050	1200	625	75	270	650	1,300,000	
No. 3	wide	575	675	350	75	270	400	1,200,000	
Stud		575	675	350	75	270	400	1,200,000	
Construction	2" to 4"	750	875	450	80	270	750	1,200,000	25-5
Standard	thick	425	500	250	75	270	625	1,200,000	(See footnotes
Utility	4" wide	200	225	125	75	270	400	1,200,000	1 through 9)
Select Structural	2" to 4"	1300	1500	850	75	270	925	1,500,000	
No. 1	thick	1100	1250	725	75	270	825	1,500,000	
No. 2	5" and	900	1050	475	75	270	700	1,300,000	
No. 3	wider	525	600	275	75	270	425	1,200,000	
Appearance		1100	1250	725	75	270	1000	1,500,000	
Stud		525	600	275	75	270	425	1,200,000	

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FOOTNOTES FOR TABLE NO. 25-A-1

[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.

[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 percent 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

(Footnotes continue on following page)

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FOOTNOTES FOR TABLE NO. 25-A-1—(Continued)

[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]The tabulated horizontal shear values shown herein for lumber 4 inches and thinner shall be multipled by a factor of 0.92 when such lumber is manufactured unseasoned.

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
½ x wide face	1.67
¾ x wide face	1.50
1 x wide face	1.33
1½ 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
½ x narrow face	1.67
1 x narrow face	1.33
1½ x narrow face or more	1.00

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[9]Stress-rated boards of nominal 1-inch, 1¼-inch and 1½-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.

[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		

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FOOTNOTES FOR TABLE NO. 25-A-1—(Continued)

[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 pereent 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.

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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.[6] 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 per 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

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Footnotes Applicable to MACHINE STRESS RATED LUMBER

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(Continued)

[1]U.B.C. Standard No. 25-2.
[2]U.B.C. Standard No. 25-6.
[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.
[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:

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Douglas Fir-Larch	Douglas Fir-South	Hem-Fir	Western Hemlock	Pine*	Englemann Spruce	Cedar*	Southern Pine		Mixed Species†
							KD	S-DRY	
Horizontal Shear F_v									
95	90	75	90	70	70	75	95	90	70
Compression Perpendicular to Grain $F_{c\perp}$									
385	335	245	280	190	195	265		405	190

*Pine includes Idaho white, lodgepole, ponderosa or sugar pine. Cedar includes incense or western red cedar.

†Graded in accordance with U.B.C. Standard No. 25-3.

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 1 Stresses) Wet[2]	EXTERIOR A-A, A-C, C-C STRUCTURAL I A-C, C-C (Use Group 1 Stresses) Dry[3]	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 Wet[2]	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 Dry[3]	ALL OTHER GRADES OF INTERIOR INCLUDING C-D SHEATHING 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	1	205	250	205	250	210
Parallel or perpendicular to face grain	2, 3	160	185	160	185	160
(at 45° to face grain use 2 F_v)	4	145	175	145	175	155

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4. Shear, rolling, in the plane of plies Parallel or perpendicular to face grain (at 45° to face grain use 1⅓ F_s)	Marine and Structural I	63	75	63	75	
	Structural II	49	56	49	56	
	All Other	44	53	44	53	48
5. Bearing (on face)	1	210	340	210	340	340
Perpendicular to plane of plies	2, 3	135	210	135	210	210
	4	105	160	105	160	160
6. Modulus of elasticity	1	1,500,000	1,800,000	1,500,000	1,800,000	1,800,000
In bending in plane of plies	2	1,300,000	1,500,000	1,300,000	1,500,000	1,500,000
Face grain parallel or	3	1,100,000	1,200,000	1,100,000	1,200,000	1,200,000
perpendicular to span	4	900,000	1,000,000	900,000	1,000,000	1,000,000

[1]See U.B.C. Standard No. 25.9 for plywood species groups. For C-C and C-D, the combination of Identification Index and panel thickness determines the species group and therefore the stress permitted, as in the following 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.

IDENTIFICATION INDEX*

THICKNESS (Inches)	12/0	16/0	20/0	24/0	32/16	42/20	48/24
5/16	4	3	1				
3/8		4	3	1			
1/2				4	1		
5/8					3	1	
1/4						3	1
7/8						4	3

*30/12-⅞", and 36/16-¼" — Use Group 4 stresses.

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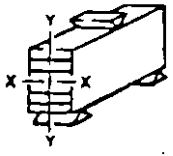
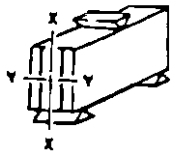
TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3 4]

Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	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 $F_{c\perp xx}$										
		Tension Zone Stressed in Tension[6] psi	Compression Zone Stressed in Tension[7] psi	Tension Face psi	Compression Face psi	Horizontal Shear F_{vxx} psi	Modulus of Elasticity E_{xx} x 10^{-6} psi	Extreme Fiber in Bending[6 18] F_{byy} psi	Compression Perpendicular to Grain $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Visually Graded Western Species														
16F-V1	DF/WW	1600	800	385[8 9]	385[8]	140	1.3	950	190	130	1.1	675	975	1.1
16F-V2	HF/HF			385[10]	245[10]	155	1.4	1250	245	135	1.3	875	1300	1.3
16F-V3	DF/DF			385[8 9]	385[8]	165	1.5	1450	385	145	1.5	950	1550	1.5
The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
16F-V4	DF/N3WW	1600	800	450	385[8]	90[10]	1.5	900	190	130	1.3	650	600	1.3
16F-V5	DF/M3DF			450	385[8]	90[13]	1.6	1000	270	135	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	385[8,9]	385[8]	165	1.5	1450	385	145	1.4	950	1550	1.5
16F-V7	HF/HF			245[10]	245[10]	155	1.4	1200	245	135	1.3	850	1350	1.3
20F-V1	DF/WW	2000	1000	450	385[8]	140	1.4	1000	190	130	1.2	750	1000	1.2
20F-V2	HF/HF			385[10]	245[10]	155	1.5	1200	245	135	1.4	975	1350	1.4
20F-V3	DF/DF			450	385[10]	165	1.6	1450	385	145	1.5	1000	1550	1.5
20F-V4	DF/DF			410[8,9]	385[10]	165	1.6	1450	385	145	1.6	1000	1550	1.6
The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
20F-V5	DF/N3WW	2000	1000	450	385[10]	90[12]	1.6	1000	190	135	1.3	750	725	1.3
20F-V6	DF/M3DF			450	385[10]	90[13]	1.6	1000	270	135	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	450	450	165	1.6	1450	385	145	1.6	1000	1600	1.6
20F-V8	DF/DF			410[8,9]	410[8,9]	165	1.7	1450	385	145	1.6	1000	1600	1.6
20F-V9	HF/HF			385[10]	385[10]	155	1.5	1400	245	135	1.4	975	1400	1.4
22F-V1	DF/WW	2200	1100	450	385[8]	140	1.6	1050	190	130	1.3	850	1100	1.3
22F-V2	HF/HF			385[10]	385[10]	155	1.5	1250	245	135	1.4	950	1350	1.4
22F-V3	DF/DF			450	385[8]	165	1.7	1450	385	145	1.6	1050	1500	1.6
22F-V4	DF/DF			410[8,9]	385[8]	165	1.7	1450	385	145	1.6	1000	1550	1.6
The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
22F-V5	DF/N3WW	2200	1100	450	385[8]	90[12]	1.6	1100	190	135	1.4	800	725	1.4
22F-V6	DF/M3DF			450	385[8]	90[13]	1.7	1250	270	135	1.6	900	925	1.6

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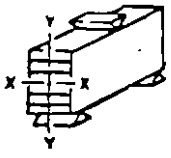
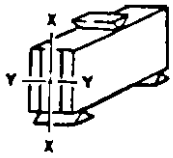
TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3 4] —(Continued)

Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	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 $F_{c\perp xx}$		Horizontal Shear F_{vxx} psi	Modulus of Elasticity E_{xx} x 10^{-6} psi	Extreme Fiber in Bending[6 18] F_{byy} psi	Compression Perpendicular to Grain $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
		Tension Zone Stressed in Tension[6] psi	Compression Zone Stressed in Tension[7] psi	Tension Face psi	Compression Face psi									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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	450	450	165	1.8	1450	385	145	1.6	1100	1650	1.6
22F-V8	DF/DF			410[8 9]	410[8 9]	165	1.7	1450	385	145	1.6	1050	1650	1.6
22F-V9	HF/HF			385[10]	385[10]	155	1.5	1250	245	135	1.4	975	1400	1.4
24F-V1	DF/WW	2400	1200	450	450	140	1.7	1250	190	130	1.4	1000	1300	1.4
24F-V2	HF/HF			385[10]	385[10]	155	1.5	1250	245	135	1.4	950	1300	1.4
24F-V3	DF/DF			450	385[8]	165	1.7	1500	385	145	1.6	1100	1600	1.6
24F-V4	DF/DF			450	450	165	1.8	1500	385	145	1.6	1150	1650	1.6
24F-V5	DF/HF			450	450	155	1.7	1350	245	140	1.5	1100	1450	1.5

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The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
24F-V6	DF/N3WW	2400	1200	450	385[8]	90[12]	1.7	1200	190	140	1.5	950	800	1.5
24F-V7	DF/M3DF			450	385[8]	90[13]	1.7	1250	270	135	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	450	450	165	1.8	1450	385	145	1.6	1100	1650	1.6
24F-V9	HF/HF			385[10]	385[10]	155	1.5	1500	245	135	1.4	1000	1450	1.4
24F-V10	DF/HF			450	450	155	1.8	1400	245	140	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	0.833	0.8	0.73	0.833
E-Rated Western Species														
16F-E1	WW/WW	1600	800	190[14]	190[14]	140	1.3	1050	190	125	1.2	725	925	1.2
16F-E2[16]	HF/HF			245[15]	245[15]	155	1.4	1250	245	135	1.3	825	1200	1.3
16F-E3	DF/DF			385[15]	385[15]	165	1.6	1450	385	145	1.5	975	1600	1.5
The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
16F-E4	DF/N3WW	1600	800	385[15]	385[15]	90[12]	1.6	900	190	130	1.3	675	675	1.3
16F-E5	DF/M3DF			385[15]	385[15]	90[13]	1.6	1050	270	135	1.5	700	900	1.5
Ths following two combinstions 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	385[15]	385[15]	165	1.6	1500	385	145	1.5	1000	1600	1.5
16F-E7[16]	HF/HF			245[15]	245[15]	155	1.4	1250	245	135	1.3	850	1150	1.3
20F-E1	WW/WW	2000	1000	190[14]	190[14]	140	1.6	1100	190	125	1.3	800	1050	1.3
20F-E2[16]	HF/HF			385[15]	385[15]	155	1.6	1400	245	135	1.4	925	1550	1.4
20F-E3	DF/DF			385[15]	385[15]	165	1.7	1550	385	145	1.6	1050	1650	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 4]—(Continued)

Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	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 $F_{c\perp xx}$										
		Tension Zone Stressed in Tension[6] psi	Compression Zone Stressed in Tension[7] psi	Tension Face psi	Compression Face psi	Horizontal Shear F_{vxx} psi	Modulus of Elasticity E_{xx} x 10^{-6} psi	Extreme Fiber in Bending[8 10] F_{byy} psi	Compression Perpendicular to Grain $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E-Rated Western Species—(Continued)														
The following two combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
20F-E4	DF/N3WW	2000	1000	450	385[15]	90[12]	1.6	1100	190	130	1.4	800	700	1.4
20F-E5	DF/N3DF			385[15]	385[13]	90[13]	1.7	1300	270	135	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	385[15]	385[15]	165	1.7	1600	385	145	1.6	1150	1650	1.6
20F-E7[16]	HF/HF			385[15]	385[15]	155	1.6	1500	245	135	1.4	1050	1550	1.4
22F-E1	DF/DF	2200	1100	450	385[15]	165	1.7	1550	385	145	1.6	1050	1600	1.6
22F-E2[16]	HF/HF			385[15]	385[15]	155	1.6	1400	245	135	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	450	385[15]	90[12]	1.7	1250	190	135	1.4	825	750	1.4
22F-E4	DF/N3DF			450	385[15]	90[13]	1.8	1350	270	135	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	450	450	165	1.7	1650	385	145	1.6	1100	1650	1.6
22F-E6[16]	HF/HF			385[15]	385[15]	155	1.7	1550	245	135	1.5	1050	1500	1.5
24F-E1	DF/DF	2400	1200	450	450	165	1.8	1550	385	145	1.6	1100	1600	1.6
24F-E2[16]	HF/HF			385[15]	385[15]	155	1.7	1450	245	135	1.5	1000	1400	1.5
24F-E3	DF/HF			450	385[15]	155	1.8	1500	245	135	1.5	1050	1550	1.5
24F-E4	DF/DF			450	450	165	1.8	1650	385	145	1.7	1100	1700	1.7
24F-E5	DF/DF			450	385[15]	165	1.8	1650	385	145	1.6	1100	1550	1.6
24F-E6[16]	HF/WW			385[15]	385[15]	140	1.8	1250	190	130	1.4	925	1350	1.4
The following three combinations are intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
24F-E7	DF/N3WW	2400	1200	450	450	90[12]	1.9	1400	190	135	1.6	975	875	1.6
24F-E8	DF/N3DF			450	450	90[13]	1.9	1400	270	135	1.7	1000	1050	1.7
24F-E9[16]	HF/N3HF			385[15]	385[15]	90[12]	1.8	1350	245	135	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	450	450	165	1.9	1850	385	145	1.7	1300	1750	1.7
24F-E11[16]	HF/HF			385[15]	385[15]	155	1.8	1600	245	135	1.5	1150	1550	1.5
24F-E12	DF/HF			450	450	155	1.9	1750	245	135	1.6	1200	1600	1.6
24F-E13	DF/DF			450	450	165	1.8	1950	385	145	1.7	1250	1700	1.7
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

(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 4] —(Continued)

Members stressed principally in bending with load applied perpendicular to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	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 $F_{c\perp xx}$										
		Tension Zone Stressed in Tension[6] psi	Compression Zone Stressed in Tension[7] psi	Tension Face psi	Compression Face psi	Horizontal Shear F_{vxx} psi	Modulus of Elasticity E_{xx} x 10^{-6} psi	Extreme Fiber in Bending[6 18] F_{byy} psi	Compression Perpendicular to Grain $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Visually Graded Southern Pine														
16F-V1	SP/SP	1600	800	385[8 9]	385[8]	200	1.4	1450	385	175	1.3	950	1450	1.3
16F-V2	SP/SP			385[8 9]	385[8]	200	1.4	1600	385	175	1.4	1000	1550	1.4
16F-V3	SP/SP			450	450	200	1.4	1450	385	175	1.3	975	1450	1.3
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
16F-V4	SP/SP	1600	800	385[8 9]	385[8]	90[17]	1.3	975	270	150	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	385[8,9]	385[8,9]	200	1.4	1600	385	175	1.4	1000	1550	1.4
20F-V1	SP/SP	2000	1000	450	385[8]	200	1.5	1450	385	175	1.4	1000	1450	1.4
20F-V2	SP/SP			450	385[8]	200	1.6	1450	385	175	1.4	1050	1550	1.4
20F-V3	SP/SP			385[8,9]	385[8]	200	1.4	1600	385	175	1.4	1000	1500	1.4
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
20F-V4	SP/SP	2000	1000	450	385[8]	90[17]	1.5	1100	270	150	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	450	450	200	1.6	1450	385	175	1.4	1050	1550	1.4
22F-V1	SP/SP	2200	1100	450	450	200	1.6	1600	385	175	1.5	1050	1650	1.5
22F-V2	SP/SP			385[8,9]	385[8]	200	1.4	1600	385	175	1.4	1000	1500	1.4
22F-V3	SP/SP			450	385[8]	200	1.6	1500	385	175	1.4	1050	1500	1.4
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
22F-V4	SP/SP	2200	1100	450	385[8]	90[17]	1.6	1250	270	155	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	450	450	200	1.6	1600	385	175	1.5	1050	1600	1.5
24F-V1	SP/SP	2400	1200	450	385[8]	200	1.7	1500	385	175	1.5	1100	1350	1.5
24F-V2	SP/SP			450	450	200	1.7	1600	385	175	1.5	1100	1600	1.5
24F-V3	SP/SP			450	450	200	1.8	1600	385	175	1.6	1150	1700	1.6
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
24F-V4	SP/SP	2400	1200	450	385[8]	90[17]	1.7	1250	270	155	1.4	850	1050	1.4

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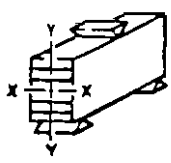
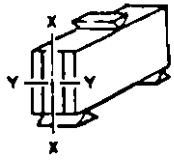
TABLE NO. 25-C-1 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3 4] —(Continued)

Members streased principally in bending with load applied perpendicular to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	BENDING ABOUT X-X AXIS						BENDING ABOUT Y-Y AXIS				AXIALLY LOADED		
		Loaded Perpendicular to Wide Faces of Laminations 						Loaded Parallel to Wide Faces of Laminations 						
		Extreme Fiber in Bending F_{bxx}		Compression Perpendicular to Grain $F_{c\perp xx}$										
		Tension Zone Stressed in Tension[6] psi	Compression Zone Stressed in Tension[7] psi	Tension Face psi	Compression Face psi	Horizontal Shear F_{vxx} psi	Modulus of Elasticity E_{xx} x 10^{-6} psi	Extreme Fiber in Bending[6 18] F_{byy} psi	Compression Perpendicular to Grain $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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	450	450	200	1.7	1600	385	175	1.5	1150	1700	1.5
Wet-use factor[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
E-Rated Southern Pine														
16F-E1	SP/SP	1600	800	385[15]	385[15]	200	1.6	1550	385	175	1.5	1050	1600	1.5
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
16F-E2	SP/SP	1600	800	385[15]	385[15]	90[17]	1.6	950	270	145	1.3	700	1050	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.														
16F-E3	SP/SP	1600	1600	385[15]	385[15]	200	1.6	1700	385	175	1.5	1100	1650	1.5
20F-E1	SP/SP	2000	1000	385[15]	385[15]	200	1.7	1600	385	175	1.5	1050	1600	1.5

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The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
20F-E2	SP/SP	2000	1000	450	385[15]	90[17]	1.6	1100	270	150	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	385[15]	385[15]	200	1.7	1800	385	175	1.5	1150	1700	1.5
22F-E1	SP/SP	2200	1100	450	385[15]	200	1.7	1600	385	175	1.5	1050	1650	1.5
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
22F-E2	SP/SP	2200	1100	450	385[15]	90[17]	1.6	1250	270	155	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	450	450	200	1.7	1750	385	175	1.5	1150	1650	1.5
24F-E1	SP/SP	2400	1200	450	385[15]	200	1.8	1600	385	175	1.6	1100	1750	1.6
24F-E2	SP/SP			450	450	200	1.9	1700	385	175	1.6	1150	1700	1.6
The following combination is intended for straight or slightly cambered members for dry use and industrial appearance.[11]														
24F-E3	SP/SP	2400	1200	450	450	90[17]	1.8	1300	270	155	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	450	450	200	1.8	2000	385	175	1.6	1250	1750	1.6
Wet-use factors[2]		0.8	0.8	0.667	0.667	0.875	0.833	0.8	0.667	0.875	0.833	0.8	0.73	0.833

(Continued)

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(Continued)

[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 22F and 24F combinations for members 15 inches and less in depth may not be readily available and the designer should check on availability prior to specifying. The 16F and 20F combinations are generally available for members 15 inches and less in depth.

[5]The symbols used for species are DF = Douglas fir-larch, HF = hem-fir, WW = western woods or Canadian softwood species, and SP = southern pine. (N3 refers to No. 3 structural joists and planks or structural light framing grade.)

[6]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.

[7]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.

[8]Where specified, this value may be increased to 450 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.

[9]For bending members greater than 15 inches in depth, the design value for compression stress perpendicular to grain is 450 psi on the tension face.

[10]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 385 psi for medium grain and 450 psi for dense.

[11]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.

[12]Where specified, this value may be increased from 90 psi to 140 psi for western woods and from 90 psi to 155 psi for hem-fir by eliminating wane.

[13]Where specified, this value may be increased from 90 psi to 140 psi by eliminating either coarse grain material or wane throughout the member, and from 90 psi to 165 psi by eliminating both coarse grain material and wane.

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[14]The compression perpendieular to grain design value of 190 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 compression perpendicular to grain stress, $F_c\perp$ may be increased to 245 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 subjected to the compression perpendicular to grain stress, $F_c\perp$ may be increased to 385 psi.

[15]Where specified, this value may be increased to 450 psi by providing in the bearing area at least one 2-inch 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 specified.

[16]*E*-rated Douglas fir-larch 200,000 psi higher in modulus of elasticity may be substituted for the specified *E*-rated hem-fir.

[17]Where specified, this value may be increased from 90 psi to 140 psi by eliminating either coarse grain material or wane throughout the member, and from 90 psi to 200 psi by eliminating both coarse grain material and wane.

[18]Footnote 6 to Table No. 25-C-1, Part B, also applies.

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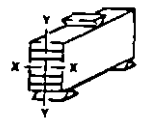
TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]

Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES[4]	GRADE[5]	MODULUS OF ELASTICITY E x 10^{-6}psi	COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi	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}
					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 psi	3 Lams psi	2 Lams psi	2 Lams to 15 In. Deep[9] psi	4 or More Lams[10] psi	2 or More Lams psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Visually Graded Western Species																
A-1	DF	L3	1.5	385[11]	900	1550	1200	1450	1250	1000	145	135	125	1250	1500	165
A-2		L2	1.7	385[11]	1250	1900	1600	1800	1600	1300	145	135	125	1700	2000	165
A-3		L2D	1.8	450	1450	2300	1850	2100	1850	1550	145	135	125	2000	2300	165
A-4		L1CL	1.9	410[11]	1400	2100	1900	2200	2000	1650	145	135	125	1900	2200	165
A-5		L1	2.0	450	1600	2400	2100	2400	2100	1800	145	135	125	2200	2400	165
A-6		N3C	1.4	270	350	875	550	550	550	550	120	115	105	450	—	140
A-7		N3M	1.5	385	900	1550	700	1450	1250	1000	145	135	125	1000	—	165
A-8		N2	1.6	385[11]	1000	1550	1150	1600	1550	1300	145	135	125	1350	1600	165

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A-9	DF	N2D	1.8	450	1150	1800	1350	1850	1800	1500	145	135	125	1600	1850	165
A-10		N1	1.8	385[11]	1300	1950	1450	1950	1750	1500	145	135	125	1750	2100	165
A-11		N1D	2.0	450	1500	2300	1700	2300	2100	1750	145	135	125	2100	2400	165
A-12		SS	1.8	385[11]	1400	1950	1650	2100	1950	1650	145	135	125	1900	2200	165
A-13		SSD	2.0	450	1600	2300	1950	2400	2300	1950	145	135	125	2200	2400	165
A-14	HF	L3	1.3	245[11]	800	1100	975	1200	1050	850	135	130	115	1100	1300	155
A-15		L2	1.4	245[11]	1050	1350	1300	1500	1350	1100	135	130	115	1450	1700	155
A-16		L1	1.6	245[11]	1200	1500	1450	1750	1550	1300	135	130	115	1600	1900	155
A-17		L1D	1.7	385	1400	1750	1700	2000	1850	1550	135	130	115	1900	2200	155
A-18		N3	1.3	245	425	900	575	700	700	700	135	130	115	575	—	155
A-19		N2	1.4	245[11]	850	1300	975	1350	1300	1100	135	130	115	1150	1350	155
A-20		N1	1.6	245[11]	975	1450	1250	1550	1500	1250	135	130	115	1350	1550	155
A-21		SS	1.6	245[11]	1100	1450	1350	1750	1650	1400	135	130	115	1500	1750	155
A-22	WW	L3	1.0	190	525	850	675	800	700	550	120	115	105	725	850	140
A-23		N3	1.0	190	275	625	450	450	450	450	120	115	105	400	—	140
A-24		N2	1.1	190	550	900	700	900	875	725	120	115	105	775	900	140
A-25		N1	1.2	190	650	1000	875	1050	1000	850	120	115	105	875	1050	140
A-26		SS	1.2	190	750	1000	1000	1150	1100	925	120	115	105	1000	1150	140

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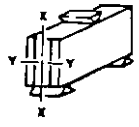
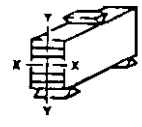
TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]—(Continued)

Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES[4]	GRADE[5]	MODULUS OF ELASTICITY E x 10^{-6}psi	COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi	AXIALLY LOADED			BENDING ABOUT Y-Y AXIS						BENDING ABOUT X-X AXIS		
					Tension Parallel to Grain F_t	Compression Parallel to Grain F_c		Loaded Parallel to Wide Faces of Laminations 						Loaded Perpendicular to Wide Faces of Laminations 		
								Extreme Fiber in Bending[6] F_{bYY}			Horizontal Shear[7] F_{vYY}			Extreme Fiber in Bending[6] F_{bXX}		Horizontal Shear F_{vXX}
					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 psi	3 Lams psi	2 Lams psi	2 Lams to 15 in. Deep[9] psi	4 or More Lams[10] psi	2 or More Lams psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E-Rated Western Species																
A-27	DF	½-1.8E	1.8	385	900	1750	1200	1450	1250	1000	145	135	125	1250	1500	165
A-28		½-2.0E	2.0	450	1100	2000	1400	1450	1250	1000	145	135	125	1500	1750	165
A-29		½-2.2E	2.2	450	1250	2300	1550	1650	1400	1150	145	135	125	1700	2000	165
A-30		⅙-1.8E	1.8	385	1550	2100	1700	2400	2400	2100	145	135	125	1800	2100	165
A-31		⅙-2.0E	2.0	450	1800	2400	1900	2400	2400	2400	145	135	125	2100	2400	165
A-32		⅙-2.2E	2.2	450	1800	2400	2100	2400	2400	2400	145	135	125	2300	2400	165

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A-33	HF	½-1.5E	1.5	245	800	1050	950	1200	1050	850	135	130	115	1100	1300	155
A-34		½-1.8E	1.8	385	900	1300	1200	1450	1250	1000	135	130	115	1250	1500	155
A-35		½-2.0E	2.0	385	1100	1550	1400	1450	1250	1000	135	130	115	1500	1750	155
A-36		¼-1.5E	1.5	245	1200	1450	1300	2100	1900	1700	135	130	115	1400	1650	155
A-37		⅙-1.8E	1.8	385	1550	1950	1700	2400	2400	2100	135	130	115	1800	2100	155
A-38		⅙-2.0E	2.0	385	1800	2400	1900	2400	2400	2400	135	130	115	2100	2400	155
A-39	WW	½-1.5E	1.5	190	800	1200	950	1200	1050	850	120	115	105	1100	1300	140
A-40		½-1.8E	1.8	190	900	1500	1200	1450	1250	1000	120	115	105	1250	1500	140
A-41		½-2.0E	2.0	190	1100	1750	1400	1450	1250	1000	120	115	105	1500	1750	140
A-42		¼-1.5E	1.5	190	1200	1550	1300	2100	1900	1700	120	115	105	1400	1650	140
A-43		⅙-1.8E	1.8	190	1550	1950	1700	2400	2400	2100	120	115	105	1800	2100	140
A-44		⅙-2.0E	2.0	190	1800	2200	1900	2400	2400	2400	120	115	105	2100	2400	140
Visually Graded Southern Pine																
A-45	SP	N3C	1.1	270	325	850	550	550	550	550	120	115	105	450	—	140
A-46		N3M	1.3	385	900	1500	675	1450	1250	1000	175	165	150	1000	—	200
A-47		N2M[12]	1.4	385[11]	1200	1900	1150	1750	1550	1300	175	165	150	1400	1600	200
A-48		N2D[12]	1.7	450	1400	2200	1350	2000	1800	1500	175	165	150	1600	1900	200
A-49		N1M[12]	1.7	385[11]	1350	2100	1450	1950	1750	1500	175	165	150	1800	2100	200
A-50		N1D[12]	1.9	450	1550	2300	1700	2300	2100	1750	175	165	150	2100	2400	200
A-51		SSM	1.7	385[11]	1300	1900	1600	2100	1950	1650	175	165	150	1750	2100	200
A-52		SSD	1.9	450[11]	1500	2200	1850	2400	2300	1950	175	165	150	2100	2400	200

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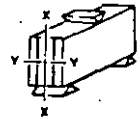
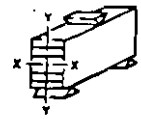
TABLE NO. 25-C-1 PART B—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED TIMBER FOR NORMAL LOADING DURATION[1 2 3]—(Continued)

Members stressed principally in axial tension or compression or in bending with load applied parallel to the wide faces of the laminations

COMBINATION SYMBOL	SPECIES[4]	GRADE[5]	MODULUS OF ELASTICITY E x 10^{-6}psi	COMPRESSION PERPENDICULAR TO GRAIN $F_{c\perp}$ psi	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}
					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 psi	3 Lams psi	2 Lams psi	2 Lams to 15 in. Deep[9] psi	4 or More Lams[10] psi	2 or More Lams psi
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E-Rated Southern Pine																
A-53	SP	½-1.8E	1.8	385	900	1900	1200	1450	1250	1000	175	165	150	1250	1500	200
A-54		½-2.0E	2.0	450	1100	2300	1400	1450	1250	1000	175	165	150	1600	1750	200
A-55		½-2.2E	2.2	450	1250	2400	1550	1650	1400	1150	175	165	150	1700	2000	200
A-56		⅙-1.8E	1.8	385	1550	1850	1700	2400	2400	2100	175	165	150	1800	2100	200
A-57		⅙-2.0E	2.0	450	1800	2400	1900	2400	2400	2400	175	165	150	2100	2400	200
A-58		⅙-2.2E	2.2	450	1800	2400	2100	2400	2400	2400	175	165	150	2300	2400	200
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	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 condition of loading. The design values for bending about the X-X axis (F_{bxx}) shown in Column 15 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 16. 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 DF = Douglas fir-larch, HF = hem-fir, WW = western woods and Canadian softwood species, and SP = southern pine.

[5]Grade designations are as follows:

Visually Graded Southern Pine

L1 is L1 laminating grade (dense for Douglas fir-larch).
L1D is L1 dense laminating grade for hem-fir.
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 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).
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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(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

⅛-2.2E has ⅛ edge characteristic with 2.2E.
⅛-2.0E has ⅛ edge characteristic with 2.0E.
⅛-1.8E has ⅛ edge characteristic with 1.8E.
¼-1.5E has ¼ edge characteristic with 1.5E.
½-2.2E, ½-2.0E, ½-1.8E, ½-1.5E 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	1.14

[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 15 are for members of from two laminations to 15 inches in depth without tension laminations.

[10]The design values in Column 16 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.

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[11]When tension laminations are used to obtain the design value for F_{bxx} shown in Column 16, the compression perpendicular to grain value, $F_c\perp$, for the tension face may be increased to 450 psi for Douglas fir-larch and southern pine, and to 385 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 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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TABLE NO. 25-C-2 PART A—ALLOWABLE UNIT STRESSES FOR STRUCTURAL GLUED-LAMINATED CALIFORNIA REDWOOD VISUALLY GRADED[1 2 3]

Members stresaed 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 — Loaded Parallel to Wide Faces of the Laminations						Bending About Y-Y Axis — Loaded Perpendicular to Wide Faces of Laminations				Axially Loaded		
		Extreme Fiber in Bending		Compression Perpendicular to Grain		Horizontal Shear F_{vxx} psi	Modulus of Elasticity F_{xx} x 10^{-6} psi	Extreme Fiber in Bending[5] F_{byy} psi	Compression Perpendicular to Grain Side Face $F_{c\perp yy}$ psi	Horizontal Shear F_{vyy} psi	Modulus of Elasticity E_{yy} x 10^{-6} psi	Tension Parallel to Grain F_t psi	Compression Parallel to Grain F_c psi	Modulus of Elasticity E x 10^{-6} psi
		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									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B-16F V1	CR/CR	1600	800	270	270	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 Seetion 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 stresses in tension.

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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 E x 10^{-6} psi	Compression Perpendicular to Grain	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
				$F_{c\perp}$	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	270	875	1350	1350	1450	1300	1100	110	105	95	1200	125
B-2	CR	L4	1.0	270	875	1350	1350	1450	1300	1100	110	105	95	1200	125
B-3	CR	L3	1.2	270	1000	1550	1550	1450	1300	1100	110	105	95	1350	125
B-4	CR	L2	1.2	270	1000	1600	1600	1500	1350	1150	110	105	95	1350	125
B-5	CR	L1	1.2	270	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.

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(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_{bxt} is 1400 psi for combinations B-1 and B-2 and 1600 psi for B-3, B-4 and B-5.

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TABLE NO. 25-D—PART A—ALLOWABLE UNIT STRESSES FOR GLUED HARDWOOD LAMINATED LUMBER[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)	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)
			Stress Module	Steepest Grain Slope	Stress Module	Steepest Grain Slope	Stress Module	Steepest Grain Slope	Stress Module
A	0.1	4 to 14 15 or more	800 800	1:16 1:16	500 500	1:16 1:16	970 970	1:15 1:15	1,000,000
B	.2	4 to 14 15 or more	770 800	1:16 1:16	500 500	1:16 1:16	920 930	1:15 1:15	1,000,000
C	.3	4 to 14 15 or more	600 660	1:12 1:12	450 450	1:15 1:16	860 870	1:14 1:14	900,000
D	.4	4 to 14 15 or more	450 520	1:8 1:8	350 350	1:10 1:12	780 810	1:12 1:12	800,000
E	.5	4 to 14 15 or more	300 380	1:8 1:8	300 300	1:8 1:8	690 730	1:10 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.

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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	135	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					1450	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 ponnds
q = Safe loads perpendicular to grain in pounds

Length of Bolt in Main Wood Member[3] (In Inches)		DIAMETER OF BOLT (IN INCHES)								
		3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 1/2
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. 25-7 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]	
				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.)

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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 Maximum Span-Width Ratios	VERTICAL DIAPHRAGMS Maximum Height-Width Ratios
1. Diagonal sheathing, conventional	3:1	2:1
2. Diagonal sheathing, special	4:1	3½:1
3. Plywood, nailed all edges	4:1	3½:1
4. Plywood, blocking omitted at intermediate joints	4:1	2:1

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TABLE NO. 25-J—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).				UNBLOCKED DIAPHRAGM: Nails spaced 6" max. at supported end	
					6	4	2½[2]	2[2]	Load perpendicular to unblocked edges and continuous panel joints (Case 1)	Other configurations (Cases 2, 3 & 4)
					Nail spacing at other plywood panel edges					
					6	6	4	3		
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	1⅝	½	2	320	425	640[2]	730[2]	285	215
				3[2]	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
			½	2	270	360	530	600	240	180
				3	300	400	600	675	265	200
	10d	1⅝	½	2	290	385	575[2]	655[2]	255	190
				3[2]	325	430	650	735	290	215
			5/8	2	320	425	640[2]	730[2]	285	215
				3[2]	360	480	720	820	320	240

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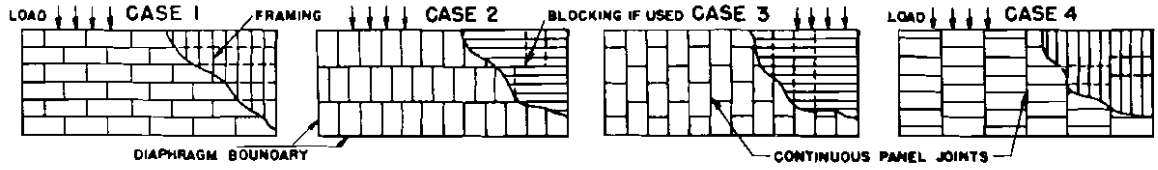
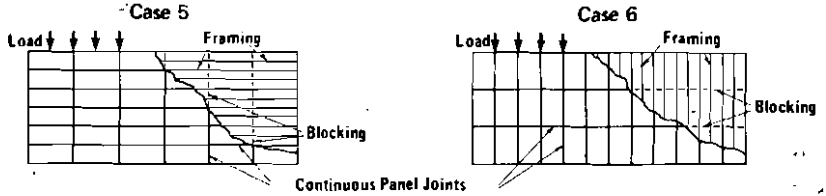
[1]These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading. Space nails 10 inches on center for floors and 12 inches on center for roofs along intermediate framing members.

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 shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches or 2½ inches on center, and where 10d nails having penetration into framing of more than 1⅜ inches are spaced 3 inches on center.





NOTE: Framing may be located in either direction for blocked diaphragms.

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TABLE NO. 25-K—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]

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 ½-INCH GYPSUM SHEATHING — Nail Spacing at Plywood Panel Edges			
				6	4	3	2		6	4	3	2
STRUCTURAL I	5/16	1¼	6d	200	300	390	510	8d	200	300	390	510
	3/8	1½	8d	230[3]	360[3]	460[3]	610[3]	10d	280	430	550[2]	730[2]
	½	1⅝	10d	340	510	665[2]	870[2]	—	—	—	—	—
C-D, C-C STRUCTURAL II and other grades covered in U.B.C. Standard No. 25-9.	5/16	1¼	6d	180	270	350	450	8d	180	270	350	450
	3/8	1½	8d	220[3]	320[3]	410[3]	530[3]	10d	260	380	490[2]	640[2]
	½	1⅝	10d	310	460	600[2]	770[2]	—	—	—	—	—
			NAIL SIZE (Galvanized Casing)					NAIL SIZE (Galvanized Casing)				
Plywood panel siding in grades covered in U.B.C. Standard No. 25-9	5/16	1¼	6d	140	210	275	360	8d	140	210	275	360
	3/8	1½	8d	130[3]	200[3]	260[3]	340[3]	10d	160	240	310[2]	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 ⅜-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 shall be 3-inch nominal or wider and nails shall be staggered where nails are spaced 2 inches on center, and where 10d nails having penetration into framing of more than 1⅜ inches are spaced 3 inches on center.

[3]The values for ⅜-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 or if the plywood thickness is increased to ½ inch or greater.

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"	—

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TABLE NO. 25-M—EXPOSED PLYWOOD PANEL SIDING

MINIMUM THICKNESS[1]	MINIMUM NO. OF PLIES	STUD SPACING (INCHES) PLYWOOD SIDING APPLIED DIRECT TO STUDS OR OVER SHEATHING
1. ⅜"	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) ⅜-inch plywood sheathing with face grain of sheathing perpendicular to studs.

TABLE NO. 25-N—PLYWOOD WALL SHEATHING[1] (Not Exposed to the Weather, Face Grain Parallel or Perpendicular to Studs)

MINIMUM THICKNESS AND CONSTRUCTION	PANEL IDENTIFICATION INDEX	STUD SPACING (Inches)		
		Siding Nailed to Studs	Sheathing Under Coverings Specified in Section 2517 (g) 4	
			Sheathing Parallel to Studs	Sheathing Perpendicular to Studs
1. 5/16"	12/0, 16/0, 20/0	16	—	16
2. ⅜", ½"—3 ply	16/0, 20/0, 24/0, 32/16	24	16	24
3. ½"—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.

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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. **Particleboard:**[5]	
Wall Sheathing (to framing):	
3/8"-1/2"	6d[3]
5/8"-3/4"	8d[3]
25. **Plywood:**[5]	
Subfloor, roof and wall sheathing (to framing):	
1/2" and less	6d[2]
5/8"-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):	
1/4" and less	6d[4]
7/8"-1"	8d[4]
1 1/8"-1 1/4"	10d[3] or 8d[4]
26. **Panel Siding (to framing):**	
1/2" or less	6d[6]
5/8"	8d[6]
27. **Fiberboard Sheathing:**[7]	
1/2"	No. 11 ga.[8] 6d[3] No. 16 ga.[9]
25/32"	No. 11 ga.[8] 8d[3] 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 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

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TABLE NO. 25-R-3—SIZE, HEIGHT AND SPACING OF WOOD STUDS[1]

STUD SIZE (Inches)	BEARING WALLS				NONBEARING WALLS	
	STUD HEIGHT (Feet)	SUPPORTING ROOF AND CEILING ONLY (Inches)	SUPPORTING ONE FLOOR, ROOF AND CEILING (Inches)	SUPPORTING TWO FLOORS, ROOF AND CEILING (Inches)	STUD HEIGHT (Feet)	SPACING (Inches)
1. 2 x 3[2]	10	—	—	—	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

[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.

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, 9]

PANEL IDENTIFICATION INDEX[3]	PLYWOOD THICKNESS (Inch)	ROOF[2]				FLOOR MAXIMUM SPAN[4] (In Inches)
		Maximum Span (In Inches)		Load (In Pounds per Square Foot)		
		Edges Blocked	Edges Unblocked	Total Load	Live Load	
1. 12/0	5/16	12		155	150	0
2. 16/0	5/16, 3/8	16		95	75	0
3. 20/0	5/16, 3/8	20		75	65	0
4. 24/0	3/8	24	16	65	50	0
5. 24/0	1/2	24	24	65	50	0
6. 30/12	5/8	30	26	70	50	12[5]
7. 32/16	1/2, 5/8	32	28	55	40	16[7]
8. 36/16	3/4	36	30	55	50	16[7]
9. 42/20	5/8, 3/4, 7/8	42	32	40[6]	35[6]	20[7, 8]
10. 48/24	3/4, 7/8	48	36	40[6]	35[6]	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.

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(Continued)

[3]Identification index 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 ¼-inch minimum thickness underlayment, or 1½ 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]May be 16 inches if $^{25}/_{32}$-inch wood strip flooring is installed at right angles to joists.

[6]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 identification index.

[7]May be 24 inches if $^{25}/_{32}$-inch wood strip flooring is installed at right angles to joists.

[8]May be 24 inches where a minimum of 1½ inches of approved cellular or lightweight concrete is placed over the subfloor and the plywood sheathing is manufactured with exterior glue.

[9]Floor or roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2516.

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	½	4	24	35	25
	½	5	24	55	40
Other grades covered in U.B.C. Standard No. 25-9	½	5	24	30	25
	⅝	4	24	40	30
	⅝	5	24	60	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.

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TABLE NO. 25-T—ALLOWABLE SPAN FOR PLYWOOD COMBINATION SUBFLOOR-UNDERLAYMENT[1] Plywood Continuous over Two or More Spans and Face Grain Perpendicular to Supports

SPECIES GROUPS[2]	MAXIMUM SPACING OF JOISTS		
	16"	20"	24"
1	1/2"	5/8"	3/4"
2, 3	5/8"	3/4"	7/8"
4	3/4"	7/8"	1"

[1]Applicable to Underlayment grade, C-C (plugged) and all grades of sanded exterior-type plywood. Spans limited to values 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. 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 23/32-inch wood strip. If wood strips are perpendicular to supports, thicknesses shown for 16- and 20-inch spans may be used on 24-inch span. Except for 1/2 inch, Underlayment grade and C-C (plugged) panels may be of nominal thicknesses 1/32 inch thinner than the nominal thicknesses shown when marked with the reduced thickness.

[2]See U.B.C. Standard No. 25-9 for plywood species groups.

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 1/360	160	170,000 256,000
	30	1/240 1/360	210	256,000 384,000
	40	1/240 1/360	270	340,000 512,000
4.5	20	1/240 1/360	200	242,000 305,000
	30	1/240 1/360	270	363,000 405,000
	40	1/240 1/360	350	484,000 725,000
5.0	20	1/240 1/360	250	332,000 500,000
	30	1/240 1/360	330	495,000 742,000
	40	1/240 1/360	420	660,000 1,000,000

(Continued)

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TABLE NO. 25-U—ALLOWABLE SPANS FOR 2-INCH TONGUE-AND-GROOVE DECKING—(Continued)

SPAN[1] (In Feet)	LIVE LOAD	DEFLECTION LIMIT	f (psi)	E (psi)
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
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 (IN)	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	8-6 720	8-10 780	9-2 830	9-6 890	9-9 940	10-0 990	10-3 1040	10-6 1090	10-9 1140	10-11 1190	11-2 1230	11-4 1280	11-7 1320	11-11 1410
	16.0	7-9 790	8-0 860	8-4 920	8-7 980	8-10 1040	9-1 1090	9-4 1150	9-6 1200	9-9 1250	9-11 1310	10-2 1360	10-4 1410	10-6 1460	10-10 1550
	24.0	6-9 900	7-0 980	7-3 1050	7-6 1120	7-9 1190	7-11 1250	8-2 1310	8-4 1380	8-6 1440	8-8 1500	8-10 1550	9-0 1610	9-2 1670	9-6 1780
2x8	12.0	11-3 720	11-8 780	12-1 830	12-6 890	12-10 940	13-2 990	13-6 1040	13-10 1090	14-2 1140	14-5 1190	14-8 1230	15-0 1280	15-3 1320	15-9 1410
	16.0	10-2 790	10-7 850	11-0 920	11-4 980	11-8 1040	12-0 1090	12-3 1150	12-7 1200	12-10 1250	13-1 1310	13-4 1360	13-7 1410	13-10 1460	14-3 1550
	24.0	8-11 900	9-3 980	9-7 1050	9-11 1120	10-2 1190	10-6 1250	10-9 1310	11-0 1380	11-3 1440	11-5 1500	11-8 1550	11-11 1610	12-1 1670	12-6 1780
2x10	12.0	14-4 720	14-11 780	15-5 830	15-11 890	16-5 940	16-10 990	17-3 1040	17-8 1090	18-0 1140	18-5 1190	18-9 1230	19-1 1280	19-5 1320	20-1 1410
	16.0	13-0 790	13-6 850	14-0 920	14-6 980	14-11 1040	15-3 1090	15-8 1150	16-0 1200	16-5 1250	16-9 1310	17-0 1360	17-4 1410	17-8 1460	18-3 1550
	24.0	11-4 900	11-10 980	12-3 1050	12-8 1120	13-0 1190	13-4 1250	13-8 1310	14-0 1380	14-4 1440	14-7 1500	14-11 1550	15-2 1610	15-5 1670	15-11 1780
2x12	12.0	17-5 720	18-1 780	18-9 830	19-4 890	19-11 940	20-6 990	21-0 1040	21-6 1090	21-11 1140	22-5 1190	22-10 1230	23-3 1280	23-7 1320	24-5 1410
	16.0	15-10 790	16-5 860	17-0 920	17-7 980	18-1 1040	18-7 1090	19-1 1150	19-6 1200	19-11 1250	20-4 1310	20-9 1360	21-1 1410	21-6 1460	22-2 1550
	24.0	13-10 900	14-4 980	14-11 1050	15-4 1120	15-10 1190	16-3 1250	16-8 1310	17-0 1380	17-5 1440	17-9 1500	18-1 1550	18-5 1610	18-9 1670	19-4 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 deed load of 5 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
2x4	12.0	9-10 710	10-3 770	10-7 830	10-11 880	11-3 930	11-7 980	11-10 1030	12-2 1080	12-5 1130	12.8 1180	12-11 1220	13-2 1270	13-4 1310	13-9 1400
	16.0	8-11 780	9-4 850	9-8 910	9-11 970	10-3 1030	10-6 1080	10-9 1140	11-0 1190	11-3 1240	11-6 1290	11-9 1340	11-11 1390	12-2 1440	12-6 1540
	24.0	7-10 900	8-1 970	8-5 1040	8-8 1110	8-11 1170	9-2 1240	9-5 1300	9-8 1360	9-10 1420	10-0 1480	10-3 1540	10-5 1600	10-7 1650	10-11 1760
2x6	12.0	15-6 710	16-1 770	16-8 830	17-2 880	17-8 930	18-2 980	18-8 1030	19-1 1080	19-6 1130	19-11 1180	20-3 1220	20-8 1270	21-0 1310	21-8 1400
	16.0	14-1 780	14-7 850	15-2 910	15-7 970	16-1 1030	16-6 1080	16-11 1140	17-4 1190	17-8 1240	18-1 1290	18-5 1340	18-9 1390	19-1 1440	19-8 1540
	24.0	12-3 900	12-9 970	13-3 1040	13-8 1110	14-1 1170	14-5 1240	14-9 1300	15-2 1360	15-6 1420	15-9 1480	16-1 1540	16-4 1600	16-8 1650	17-2 1760
2x8	12.0	20-5 710	21-2 770	21-11 830	22-8 880	23-4 930	24-0 980	24-7 1030	25-2 1080	25-8 1130	26-2 1180	26-9 1220	27-2 1270	27-8 1310	28-7 1400
	16.0	18-6 780	19-3 850	19-11 910	20-7 970	21-2 1030	21-9 1080	22-4 1140	22-10 1190	23-4 1240	23-10 1290	24-3 1340	24-8 1390	25-2 1440	25-11 1540
	24.0	16-2 900	16-10 970	17-5 1040	18-0 1110	18-6 1170	19-0 1240	19-6 1300	19-11 1360	20-5 1420	20-10 1480	21-2 1540	21-7 1600	21-11 1650	22-8 1760
2x10	12.0	26-0 710	27-1 770	28-0 830	28-11 880	29-9 930	30-7 980	31-4 1030	32-1 1080	32-9 1130	33-5 1180	34-1 1220	34-8 1270	35-4 1310	36-5 1400
	16.0	23-8 780	24-7 850	25-5 910	26-3 970	27-1 1030	27-9 1080	28-6 1140	29-2 1190	29-9 1240	30-5 1290	31-0 1340	31-6 1390	32-1 1440	33-1 1540
	24.0	20-8 900	21-6 970	22-3 1040	22-11 1110	23-8 1170	24-3 1240	24-10 1300	25-5 1360	26-0 1420	26-6 1480	27-1 1540	27-6 1600	28-0 1650	28-11 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. liva 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	8-6 0.26	9-4 0.35	10-0 0.44	10-9 0.54	11-5 0.64	12-0 0.75	12-7 0.86	13-2 0.98	13-8 1.11	14-2 1.24	14-8 1.37	15-2 1.51	15-8 1.66	16-1 1.81	16-7 1.96
	16.0	7-4 0.23	8-1 0.30	8-8 0.38	9-4 0.46	9-10 0.55	10-5 0.65	10-11 0.75	11-5 0.85	11-10 0.97	12-4 1.07	12-9 1.19	13-2 1.31	13-7 1.44	13-11 1.56	14-4 1.70
	24.0	6-0 0.19	6-7 0.25	7-1 0.31	7-7 0.38	8-1 0.45	8-6 0.53	8-11 0.61	9-4 0.70	9-8 0.78	10-0 0.88	10-5 0.97	10-9 1.07	11-1 1.17	11-5 1.28	11-8 1.39
2x8	12.0	11-2 0.26	12-3 0.35	13-3 0.44	14-2 0.54	15-0 0.64	15-10 0.75	16-7 0.86	17-4 0.98	18-0 1.11	18-9 1.24	19-5 1.37	20-0 1.51	20-8 1.66	21-3 1.81	21-10 1.96
	16.0	9-8 0.23	10-7 0.30	11-6 0.38	12-3 0.46	13-0 0.55	13-8 0.65	14-4 0.75	15-0 0.85	15-7 0.96	16-3 1.07	16-9 1.19	17-4 1.31	17-10 1.44	18-5 1.56	18-11 1.70
	24.0	7-11 0.19	8-8 0.25	9-4 0.31	10-0 0.38	10-7 0.45	11-2 0.53	11-9 0.61	12-3 0.70	12-9 0.78	13-3 0.88	13-8 0.97	14-2 1.07	14-7 1.17	15-0 1.28	15-5 1.39
2x10	12.0	14-3 0.26	15-8 0.35	16-11 0.44	18-1 0.54	19-2 0.64	20-2 0.75	21-2 0.86	22-1 0.98	23-0 1.11	23-11 1.24	24-9 1.37	25-6 1.51	26-4 1.66	27-1 1.81	27-10 1.96
	16.0	12-4 0.23	13-6 0.30	14-8 0.38	15-8 0.46	16-7 0.55	17-6 0.65	18-4 0.75	19-2 0.85	19-11 0.96	20-8 1.07	21-5 1.19	22-1 1.31	22-10 1.44	23-5 1.56	24-1 1.70
	24.0	10-1 0.19	11-1 0.25	11-11 0.31	12-9 0.38	13-6 0.45	14-3 0.53	15-0 0.61	15-8 0.70	16-3 0.78	16-11 0.88	17-6 0.97	18-1 1.07	18-7 1.17	19-2 1.28	19-8 1.39
2x12	12.0	17-4 0.26	19-0 0.35	20-6 0.44	21-11 0.54	23-3 0.64	24-7 0.75	25-9 0.86	26-11 0.98	28-0 1.11	29-1 1.24	30-1 1.37	31-1 1.51	32-0 1.66	32-11 1.81	33-10 1.96
	16.0	15-0 0.23	16-6 0.30	17-9 0.38	19-0 0.46	20-2 0.55	21-3 0.65	22-4 0.75	23-3 0.85	24-3 0.97	25-2 1.07	26-0 1.19	26-11 1.31	27-9 1.44	28-6 1.56	29-4 1.70
	24.0	12-3 0.19	13-5 0.25	14-6 0.31	15-6 0.38	16-6 0.45	17-4 0.53	18-2 0.61	19-0 0.70	19-10 0.78	20-6 0.88	21-3 0.97	21-11 1.07	22-8 1.17	23-3 1.28	23-11 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)	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 0.27	8-2 0.36	8-10 0.45	9-6 0.55	10-0 0.66	10-7 0.77	11-1 0.89	11-7 1.01	12-1 1.14	12-6 1.28	13-0 1.41	13-5 1.56	13-10 1.71	14-2 1.86	14-7 2.02
	16.0	6-6 0.24	7-1 0.31	7-8 0.39	8-2 0.48	8-8 0.57	9-2 0.67	9-7 0.77	10-0 0.88	10-5 0.99	10-10 1.10	11-3 1.22	11-7 1.35	11-11 1.48	12-4 1.61	12-8 1.75
	24.0	5-4 0.19	5-10 0.25	6-3 0.32	6-8 0.39	7-1 0.46	7-6 0.54	7-10 0.63	8-2 0.72	8-6 0.81	8-10 0.90	9-2 1.00	9-6 1.10	9-9 1.21	10-0 1.31	10-4 1.43
2x8	12.0	9-10 0.27	10-10 0.36	11-8 0.45	12-6 0.55	13-3 0.66	13-11 0.77	14-8 0.89	15-3 1.01	15-11 1.14	16-6 1.28	17-1 1.41	17-8 1.56	18-2 1.71	18-9 1.86	19-3 2.02
	16.0	8-7 0.24	9-4 0.31	10-1 0.39	10-10 0.48	11-6 0.57	12-1 0.67	12-8 0.77	13-3 0.88	13-9 0.99	14-4 1.10	14-10 1.22	15-3 1.35	15-9 1.48	16-3 1.61	16-8 1.75
	24.0	7-0 0.19	7-8 0.25	8-3 0.32	8-10 0.39	9-4 0.46	9-10 0.54	10-4 0.63	10-10 0.72	11-3 0.81	11-8 0.90	12-1 1.00	12-6 1.10	12-10 1.21	13-3 1.31	13-7 1.43
2x10	12.0	12-7 0.27	13-9 0.36	14-11 0.45	15-11 0.55	16-11 0.66	17-10 0.77	18-8 0.89	19-6 1.01	20-4 1.14	21-1 1.28	21-10 1.41	22-6 1.56	23-3 1.71	23-11 1.86	24-6 2.02
	16.0	10-11 0.24	11-11 0.31	12-11 0.39	13-9 0.48	14-8 0.57	15-5 0.67	16-2 0.77	16-11 0.88	17-7 0.99	18-3 1.10	18-11 1.22	19-6 1.35	20-1 1.48	20-8 1.61	21-3 1.75
	24.0	8-11 0.19	9-9 0.25	10-6 0.32	11-3 0.39	11-11 0.46	12-7 0.54	13-2 0.63	13-9 0.72	14-4 0.81	14-11 0.90	15-5 1.00	15-11 1.10	16-5 1.21	16-11 1.31	17-4 1.43
2x12	12.0	15-4 0.27	16-9 0.36	18-1 0.45	19-4 0.55	20-6 0.66	21-8 0.77	22-8 0.89	23-9 1.01	24-8 1.14	25-7 1.28	26-6 1.41	27-5 1.56	28-3 1.71	29-1 1.86	29-10 2.02
	16.0	13-3 0.24	14-6 0.31	15-8 0.39	16-9 0.48	17-9 0.57	18-9 0.67	19-8 0.77	20-6 0.88	21-5 0.99	22-2 1.10	23-0 1.22	23-9 1.35	24-5 1.48	25-2 1.61	25-10 1.75
	24.0	10-10 0.19	11-10 0.25	12-10 0.32	13-8 0.39	14-6 0.46	15-4 0.54	16-1 0.63	16-9 0.72	17-5 0.81	18-1 0.90	18-9 1.00	19-4 1.10	20-0 1.21	20-6 1.31	21-1 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 (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-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. par sq. ft. dead load plus 20 lbs. per sq. ft. live load determinea 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	9-2 0.33	10-0 0.44	10-10 0.55	11-7 0.67	12-4 0.80	13-0 0.94	13-7 1.09	14-2 1.24	14-9 1.40	15-4 1.56	15-11 1.73	16-5 1.91	16-11 2.09	17-5 2.28	17-10 2.47
	16.0	7-11 0.29	8-8 0.38	9-5 0.48	10-0 0.58	10-8 0.70	11-3 0.82	11-9 0.94	12-4 1.07	12-10 1.21	13-3 1.35	13-9 1.50	14-2 1.65	14-8 1.81	15-1 1.97	15-6 2.14
	24.0	6-6 0.24	7-1 0.31	7-8 0.39	8-2 0.48	8-8 0.57	9-2 0.67	9-7 0.77	10-0 0.88	10-5 0.99	10-10 1.10	11-3 1.22	11-7 1.35	11-11 1.48	12-4 1.61	12-8 1.75
2x8	12.0	12-1 0.33	13-3 0.44	14-4 0.55	15-3 0.67	16-3 0.80	17-1 0.94	17-11 1.09	18-9 1.24	19-6 1.40	20-3 1.56	20-11 1.73	21-7 1.91	22-3 2.09	22-11 2.28	23-7 2.47
	16.0	10-6 0.29	11-6 0.38	12-5 0.48	13-3 0.58	14-0 0.70	14-10 0.82	15-6 0.94	16-3 1.07	16-10 1.21	17-6 1.35	18-2 1.50	18-9 1.65	19-4 1.81	19-10 1.97	20-5 2.14
	24.0	8-7 0.24	9-4 0.31	10-1 0.39	10-10 0.48	11-6 0.57	12-1 0.67	12-8 0.77	13-3 0.88	13-9 0.99	14-4 1.10	14-10 1.22	15-3 1.35	15-9 1.48	16-3 1.61	16-8 1.75
2x10	12.0	15-5 0.33	16-11 0.44	18-3 0.55	19-6 0.67	20-8 0.80	21-10 0.94	22-10 1.09	23-11 1.24	24-10 1.40	25-10 1.56	26-8 1.73	27-7 1.91	28-5 2.09	29-3 2.28	30-1 2.47
	16.0	13-4 0.29	14-8 0.38	15-10 0.48	16-11 0.58	17-11 0.70	18-11 0.82	19-10 0.94	20-8 1.07	21-6 1.21	22-4 1.35	23-2 1.50	23-11 1.65	24-7 1.81	25-4 1.97	26-0 2.14
	24.0	10-11 0.24	11-11 0.31	12-11 0.39	13-9 0.48	14-8 0.57	15-5 0.67	16-2 0.77	16-11 0.88	17-7 0.99	18-3 1.10	18-11 1.22	19-6 1.35	20-1 1.48	20-8 1.61	21-3 1.75
2x12	12.0	18-9 0.33	20-6 0.44	22-2 0.55	23-9 0.67	25-2 0.80	26-6 0.94	27-10 1.09	29-1 1.24	30-3 1.40	31-4 1.56	32-6 1.73	33-6 1.91	34-7 2.09	35-7 2.28	36-7 2.47
	16.0	16-3 0.29	17-9 0.38	19-3 0.48	20-6 0.58	21-9 0.70	23-0 0.82	24-1 0.94	25-2 1.07	26-2 1.21	27-2 1.35	28-2 1.50	29-1 1.65	29-11 1.81	30-10 1.97	31-8 2.14
	24.0	13-3 0.24	14-6 0.31	15-8 0.39	16-9 0.48	17-9 0.57	18-9 0.67	19-8 0.77	20-6 0.88	21-5 0.99	22-2 1.10	23-0 1.22	23-9 1.35	24-5 1.48	25-2 1.61	25-10 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 struetures 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 0.32	8-8 0.43	9-5 0.54	10-0 0.66	10-8 0.78	11-3 0.92	11-9 1.06	12-4 1.21	12-10 1.36	13-3 1.52	13-9 1.69	14-2 1.86	14-8 2.04	15-1 2.22	15-6 2.41
	16.0	6-11 0.28	7-6 0.37	8-2 0.47	8-8 0.57	9-3 0.68	9-9 0.80	10-2 0.92	10-8 1.05	11-1 1.18	11-6 1.32	11-11 1.46	12-4 1.61	12-8 1.76	13-1 1.92	13-5 2.08
	24.0	5-7 0.23	6-2 0.30	6-8 0.38	7-1 0.46	7-6 0.55	7-11 0.65	8-4 0.75	8-8 0.85	9-1 0.96	9-5 1.08	9-9 1.19	10-0 1.31	10-4 1.44	10-8 1.57	10-11 1.70
2x8	12.0	10-6 0.32	11-6 0.43	12-5 0.54	13-3 0.66	14-0 0.78	14-10 0.92	15-6 1.06	16-3 1.21	16-10 1.36	17-6 1.52	18-2 1.69	18-9 1.86	19-4 2.04	19-10 2.22	20-5 2.41
	16.0	9-1 0.28	9-11 0.37	10-9 0.47	11-6 0.57	12-2 0.68	12-10 0.80	13-5 0.92	14-0 1.05	14-7 1.18	15-2 1.32	15-8 1.46	16-3 1.61	16-9 1.76	17-2 1.92	17-8 2.08
	24.0	7-5 0.23	8-1 0.30	8-9 0.38	9-4 0.46	9-11 0.55	10-6 0.65	11-0 0.75	11-6 0.85	11-11 0.96	12-5 1.08	12-10 1.19	13-3 1.31	13-8 1.44	14-0 1.57	14-5 1.70
2x10	12.0	13-4 0.32	14-8 0.43	15-10 0.54	16-11 0.66	17-11 0.78	18-11 0.92	19-10 1.06	20-8 1.21	21-6 1.36	22-4 1.52	23-2 1.69	23-11 1.86	24-7 2.04	25-4 2.22	26-0 2.41
	16.0	11-7 0.28	12-8 0.37	13-8 0.47	14-8 0.57	15-6 0.68	16-4 0.80	17-2 0.92	17-11 1.05	18-8 1.18	19-4 1.32	20-0 1.46	20-8 1.61	21-4 1.76	21-11 1.92	22-6 2.08
	24.0	9-5 0.23	10-4 0.30	11-2 0.38	11-11 0.46	12-8 0.55	13-4 0.65	14-0 0.75	14-8 0.85	15-3 0.96	15-10 1.08	16-4 1.19	16-11 1.31	17-5 1.44	17-11 1.57	18-5 1.70
2x12	12.0	16-3 0.32	17-9 0.43	19-3 0.54	20-6 0.66	21-9 0.78	23-0 0.92	24-1 1.06	25-2 1.21	26-2 1.36	27-2 1.52	28-2 1.69	29-1 1.86	29-11 2.04	30-10 2.22	31-8 2.41
	16.0	14-1 0.28	15-5 0.37	16-8 0.47	17-9 0.57	18-10 0.68	19-11 0.80	20-10 0.92	21-9 1.05	22-8 1.18	23-6 1.32	24-4 1.46	25-2 1.61	25-11 1.76	26-8 1.92	27-5 2.08
	24.0	11-6 0.23	12-7 0.30	13-7 0.38	14-6 0.46	15-5 0.55	16-3 0.65	17-0 0.75	17-9 0.85	18-6 0.96	19-3 1.08	19-11 1.19	20-6 1.31	21-2 1.44	21-9 1.57	22-5 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 0.20	5-11 0.26	6-5 0.33	6-10 0.40	7-3 0.48	7-8 0.56	8-0 0.65	8-4 0.74	8-8 0.83	9-0 0.93	9-4 1.03	9-8 1.14	9-11 1.24	10-3 1.36	10-6 1.47
	16.0	4-8 0.17	5-1 0.23	5-6 0.28	5-11 0.35	6-3 0.41	6-7 0.49	6-11 0.56	7-3 0.64	7-6 0.72	7-10 0.80	8-1 0.89	8-4 0.98	8-7 1.08	8-10 1.17	9-1 1.27
	24.0	3-10 0.14	4-2 0.18	4-6 0.23	4-10 0.28	5-1 0.34	5-5 0.40	5-8 0.46	5-11 0.52	6-2 0.59	6-5 0.66	6-7 0.73	6-10 0.80	7-0 0.88	7-3 0.96	7-5 1.04
2x6	12.0	8-6 0.20	9-4 0.26	10-0 0.33	10-9 0.40	11-5 0.48	12-0 0.56	12-7 0.65	13-2 0.74	13-8 0.83	14-2 0.93	14-8 1.03	15-2 1.14	15-8 1.24	16-1 1.36	16-7 1.47
	16.0	7-4 0.17	8-1 0.23	8-8 0.28	9-4 0.35	9-10 0.41	10-5 0.49	10-11 0.56	11-5 0.64	11-10 0.72	12-4 0.80	12-9 0.89	13-2 0.98	13-7 1.08	13-11 1.17	14-4 1.27
	24.0	6-0 0.14	6-7 0.18	7-1 0.23	7-7 0.28	8-1 0.34	8-6 0.40	8-11 0.46	9-4 0.52	9-8 0.59	10-0 0.66	10-5 0.73	10-9 0.80	11-1 0.88	11-5 0.96	11-8 1.04
2x8	12.0	11-2 0.20	12-3 0.26	13-3 0.33	14-2 0.40	15-0 0.48	15-10 0.56	16-7 0.65	17-4 0.74	18-0 0.83	18-9 0.93	19-5 1.03	20-0 1.14	20-8 1.24	21-3 1.36	21-10 1.47
	16.0	9-8 0.17	10-7 0.23	11-6 0.28	12-3 0.35	13-0 0.41	13-8 0.49	14-4 0.56	15-0 0.64	15-7 0.72	16-3 0.80	16-9 0.89	17-4 0.98	17-10 1.08	18-5 1.17	18-11 1.27
	24.0	7-11 0.14	8-8 0.18	9-4 0.23	10-0 0.28	10-7 0.34	11-2 0.40	11-9 0.46	12-3 0.52	12-9 0.59	13-3 0.66	13-8 0.73	14-2 0.80	14-7 0.88	15-0 0.96	15-5 1.04
2x10	12.0	14-3 0.20	15-8 0.26	16-11 0.33	18-1 0.40	19-2 0.48	20-2 0.56	21-2 0.65	22-1 0.74	23-0 0.83	23-11 0.93	24-9 1.03	25-6 1.14	26-4 1.24	27-1 1.36	27-10 1.47
	16.0	12-4 0.17	13-6 0.23	14-8 0.28	15-8 0.35	16-7 0.41	17-6 0.49	18-4 0.56	19-2 0.64	19-11 0.72	20-8 0.80	21-5 0.89	22-1 0.98	22-10 1.08	23-5 1.17	24-1 1.27
	24.0	10-1 0.14	11-1 0.18	11-11 0.23	12-9 0.28	13-6 0.34	14-3 0.40	15-0 0.46	15-8 0.52	16-3 0.59	16-11 0.66	17-6 0.73	18-1 0.80	18-7 0.88	19-2 0 96	19-8 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 0.20	5-3 0.27	5-8 0.34	6-0 0.41	6-5 0.49	6-9 0.58	7-1 0.67	7-5 0.76	7-8 0.86	8-0 0.96	8-3 1.06	8-6 1.17	8-9 1.28	9-0 1.39	9-3 1.51
	16.0	4-1 0.18	4-6 0.23	4-11 0.29	5-3 0.36	5-6 0.43	5-10 0.50	6-1 0.58	6-5 0.66	6-8 0.74	6-11 0.83	7-2 0.92	7-5 1.01	7-7 1.11	7-10 1.21	8-0 1.31
	24.0	3-4 0.14	3-8 0.19	4-0 0.24	4-3 0.29	4-6 0.35	4-9 0.41	5-0 0.47	5-3 0.54	5-5 0.61	5-8 0.68	5-10 0.75	6-0 0.83	6-3 0.90	6-5 0.99	6-7 1.07
2x6	12.0	7-6 0.20	8-2 0.27	8-10 0.34	9-6 0.41	10-0 0.49	10-7 0.58	11-1 0.67	11-7 0.76	12-1 0.86	12-6 0.96	13-0 1.06	13-5 1.17	13-10 1.28	14-2 1.39	14-7 1.51
	16.0	6-6 0.18	7-1 0.23	7-8 0.29	8-2 0.36	8-8 0.43	9-2 0.50	9-7 0.58	10-0 0.66	10-5 0.74	10-10 0.83	11-3 0.92	11-7 1.01	11-11 1.11	12-4 1.21	12-8 1.31
	24.0	5-4 0.14	5-10 0.19	6-3 0.24	6-8 0.29	7-1 0.35	7-6 0.41	7-10 0.47	8-2 0.54	8-6 0.61	8-10 0.68	9-2 0.75	9-6 0.83	9-9 0.90	10-0 0.99	10-4 1.07
2x8	12.0	9-10 0.20	10-10 0.27	11-8 0.34	12-6 0.41	13-3 0.49	13-11 0.58	14-8 0.67	15-3 0.76	15-11 0.86	16-6 0.96	17-1 1.06	17-8 1.17	18-2 1.28	18-9 1.39	19-3 1.51
	16.0	8-7 0.18	9-4 0.23	10-1 0.29	10-10 0.36	11-6 0.43	12-1 0.50	12-8 0.58	13-3 0.66	13-9 0.74	14-4 0.83	14-10 0.92	15-3 1.01	15-9 1.11	16-3 1.21	16-8 1.31
	24.0	7-0 0.14	7-8 0.19	8-3 0.24	8-10 0.29	9-4 0.35	9-10 0.41	10-4 0.47	10-10 0.54	11-3 0.61	11-8 0.68	12-1 0.75	12-6 0.83	12-10 0.90	13-3 0.99	13-7 1.07
2x10	12.0	12-7 0.20	13-9 0.27	14-11 0.34	15-11 0.41	16-11 0.49	17-10 0.58	18-8 0.67	19-6 0.76	20-4 0.86	21-1 0.96	21-10 1.06	22-6 1.17	23-3 1.28	23-11 1.39	24-6 1.51
	16.0	10-11 0.18	11-11 0.23	12-11 0.29	13-9 0.36	14-8 0.43	15-5 0.50	16-2 0.58	16-11 0.66	17-7 0.74	18-3 0.83	18-11 0.92	19-6 1.01	20-1 1.11	20-8 1.21	21-3 1.31
	24.0	8-11 0.14	9-9 0.19	10-6 0.24	11-3 0.29	11-11 0.35	12-7 0.41	13-2 0.47	13-9 0.54	14-4 0.61	14-11 0.68	15-5 0.75	15-11 0.83	16-5 0.90	16-11 0.99	17-4 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. par 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	6-2 0.29	6-9 0.38	7-3 0.49	7-9 0.59	8-3 0.71	8-8 0.83	9-1 0.96	9-6 1.09	9-11 1.23	10-3 1.37	10-8 1.52	11-0 1.68	11-4 1.84	11-8 2.00	12-0 2.17
	16.0	5-4 0.25	5-10 0.33	6-4 0.42	6-9 0.51	7-2 0.61	7-6 0.72	7-11 0.83	8-3 0.94	8-7 1.06	8-11 1.19	9-3 1.32	9-6 1.45	9-10 1.59	10-1 1.73	10-5 1.88
	24.0	4-4 0.21	4-9 0.27	5-2 0.34	5-6 0.42	5-10 0.50	6-2 0.59	6-5 0.68	6-9 0.77	7-0 0.87	7-3 0.97	7-6 1.08	7-9 1.19	8-0 1.30	8-3 1.41	8-6 1.53
2x6	12.0	9-8 0.29	10-7 0.38	11-5 0.49	12-3 0.59	13-0 0.71	13-8 0.83	14-4 0.96	15-0 1.09	15-7 1.23	16-2 1.37	16-9 1.52	17-3 1.68	17-10 1.84	18-4 2.00	18-10 2.17
	16.0	8-4 0.25	9-2 0.33	9-11 0.42	10-7 0.51	11-3 0.61	11-10 0.72	12-5 0.83	13-0 0.94	13-6 1.06	14-0 1.19	14-6 1.32	15-0 1.45	15-5 1.59	15-11 1.73	16-4 1.88
	24.0	6-10 0.21	7-6 0.27	8-1 0.34	8-8 0.42	9-2 0.50	9-8 0.59	10-2 0.68	10-7 0.77	11-0 0.87	11-5 0.97	11-10 1.08	12-3 1.19	12-7 1.30	13-0 1.41	13-4 1.53
2x8	12.0	12-9 0.29	13-11 0.38	15-1 0.49	16-1 0.59	17-1 0.71	18-0 0.83	18-11 0.96	19-9 1.09	20-6 1.23	21-4 1.37	22-1 1.52	22-9 1.68	23-6 1.84	24-2 2.00	24-10 2.17
	16.0	11-0 0.25	12-1 0.33	13-1 0.42	13-11 0.51	14-10 0.61	15-7 0.72	16-4 0.83	17-1 0.94	17-9 1.06	18-5 1.19	19-1 1.32	19-9 1.45	20-4 1.59	20-11 1.73	21-6 1.88
	24.0	9-0 0.21	9-10 0.27	10-8 0.34	11-5 0.42	12-1 0.50	12-9 0.59	13-4 0.68	13-11 0.77	14-6 0.87	15-1 0.97	15-7 1.08	16-1 1.19	16-7 1.30	17-1 1.41	17-7 1.53
2x10	12.0	16-3 0.29	17-10 0.38	19-3 0.49	20-7 0.59	21-10 0.71	23-0 0.83	24-1 0.96	25-2 1.09	26-2 1.23	27-2 1.37	28-2 1.52	29-1 1.68	30-0 1.84	30-10 2.00	31-8 2.17
	16.0	14-1 0.25	15-5 0.33	16-8 0.42	17-10 0.51	18-11 0.61	19-11 0.72	20-10 0.83	21-10 0.94	22-8 1.06	23-7 1.19	24-5 1.32	25-2 1.45	25-11 1.59	26-8 1.73	27-5 1.88
	24.0	11-6 0.21	12-7 0.27	13-7 0.34	14-6 0.42	15-5 0.50	16-3 0.59	17-1 0.68	17-10 0.77	18-6 0.87	19-3 0.97	19-11 1.08	20-7 1.19	21-2 1.30	21-10 1.41	22-5 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 (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-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 (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	5-3 0.27	5-9 0.36	6-3 0.45	6-8 0.55	7-1 0.66	7-5 0.77	7-9 0.89	8-2 1.02	8-6 1.15	8-9 1.28	9-1 1.42	9-5 1.57	9-8 1.72	10-0 1.87	10-3 2.03
	16.0	4-7 0.24	5-0 0.31	5-5 0.39	5-9 0.48	6-1 0.57	6-5 0.67	6-9 0.77	7-1 0.88	7-4 0.99	7-7 1.11	7-11 1.23	8-2 1.36	8-5 1.49	8-8 1.62	8-10 1.76
	24.0	3-9 0.19	4-1 0.25	4-5 0.32	4-8 0.39	5-0 0.47	5-3 0.55	5-6 0.63	5-9 0.72	6-0 0.81	6-3 0.91	6-5 1.01	6-8 1.11	6-10 1.21	7-1 1.32	7-3 1.43
2x6	12.0	8-3 0.27	9-1 0.36	9-9 0.45	10-5 0.55	11-1 0.66	11-8 0.77	12-3 0.89	12-9 1.02	13-4 1.15	13-10 1.28	14-4 1.42	14-9 1.57	15-3 1.72	15-8 1.87	16-1 2.03
	16.0	7-2 0.24	7-10 0.31	8-5 0.39	9-1 0.48	9-7 0.57	10-1 0.67	10-7 0.77	11-1 0.88	11-6 0.99	12-0 1.11	12-5 1.23	12-9 1.36	13-2 1.49	13-7 1.62	13-11 1.76
	24.0	5-10 0.19	6-5 0.25	6-11 0.32	7-5 0.39	7-10 0.47	8-3 0.55	8-8 0.63	9-1 0.72	9-5 0.81	9-9 0.91	10-1 1.01	10-5 1.11	10-9 1.21	11-1 1.32	11-5 1.43
2x8	12.0	10-11 0.27	11-11 0.36	12-10 0.45	13-9 0.55	14-7 0.66	15-5 0.77	16-2 0.89	16-10 1.02	17-7 1.15	18-2 1.28	18-10 1.42	19-6 1.57	20-1 1.72	20-8 1.87	21-3 2.03
	16.0	9-5 0.24	10-4 0.31	11-2 0.39	11-11 0.48	12-8 0.57	13-4 0.67	14-0 0.77	14-7 0.88	15-2 0.99	15-9 1.11	16-4 1.23	16-10 1.36	17-4 1.49	17-11 1.62	18-4 1.76
	24.0	7-8 0.19	8-5 0.25	9-1 0.32	9-9 0.39	10-4 0.47	10-11 0.55	11-5 0.63	11-11 0.72	12-5 0.81	12-10 0.91	13-4 1.01	13-9 1.11	14-2 1.21	14-7 1.32	15-0 1.43
2x10	12.0	13-11 0.27	15-2 0.36	16-5 0.45	17-7 0.55	18-7 0.66	19-8 0.77	20-7 0.89	21-6 1.02	22-5 1.15	23-3 1.28	24-1 1.42	24-10 1.57	25-7 1.72	26-4 1.87	27-1 2.03
	16.0	12-0 0.26	13-2 0.34	14-3 0.43	15-2 0.53	16-2 0.63	17-0 0.74	17-10 0.85	18-7 0.97	19-5 1.09	20-1 1.22	20-10 1.35	21-6 1.49	22-2 1.63	22-10 1.78	23-5 1.93
	24.0	9-10 0.19	10-9 0.25	11-7 0.32	12-5 0.39	13-2 0.47	13-11 0.55	14-7 0.63	15-2 0.72	15-10 0.81	16-5 0.91	17-0 1.01	17-7 1.11	18-1 1.21	18-7 1.32	19-2 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 (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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Chapter 26
CONCRETE

NOTE: This chapter has been revised in its entirety.

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

Sec. 2602. The following terms are defined for general use in this code. Specialized definitions appear in individual chapters.

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 inert material that is mixed with hydraulic cement and water to produce concrete.

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. See Section 2612. Also, the means by which the prestress force is permanently transferred to the 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.

CONCRETE is a mixture of portland cement or any other hydraulic cement, fine aggregate, coarse aggregate and water, with or without admixtures.

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

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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 concrete due to prestressing after all calculated losses have been deducted, excluding effects of superimposed loads and weight of member; stress remaining in prestressing tendons after all losses have occurred, excluding effects of dead loads and superimposed load.

EMBEDMENT LENGTH is the length of embedded reinforcement provided beyond a critical section.

EMBEDMENT LENGTH, EQUIVALENT (l_e), is the length of embedded reinforcement that can develop the same stress as that which can be developed by a hook or mechanical anchorage.

END ANCHORAGE is the length of reinforcement, or mechanical anchor, or hook, or combination thereof, beyond point of zero stress in reinforcement; mechanical device to transmit prestressing force to concrete in a posttensioned member.

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.

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

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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).

SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE (f'_c) is the specified compressive strength of concrete in pounds per square inch (see Section 2604). Wherever this quantity is under a radical sign, the square root of the numerical value only is intended, and the resultant is in pounds per square inch.

SPIRAL REINFORCEMENT is continously 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 ϕ. 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 used to impart prestress to concrete when element is tensioned.

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 an element used to enclose or separate spaces and may act as a structural member.

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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 a manner acceptable to the building official or in compliance with Section 2603 (f).

Specifications for Tests and Materials

Sec. 2603. (a) **Notations.**

d_b = nominal diameter of bar, inches.

f_y = specified yield strength of nonprestressed reinforcement, psi.

(b) **Tests of Materials.** 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 aeeordance with the standards listed in Section 2603 (i).

A complete record of tests of materials and of eoncrete shall be available for inspection during progress of work and for two years thereafter. and shall be preserved by inspecting engineer or arehitect for that purpose.

(c) **Cements.** 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 (e)].

(d) **Aggregates.** Concrete aggregates shall conform to U.B.C. Standard No. 26-2 or U.B.C. Standard No. 26-3, exeept that aggregates failing to meet these specifieations but which have been shown by special test or actual 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 offieial, workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

(e) **Water.** 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 eonerete or reinforcement.

In addition, mixing water for prestressed concrete or for concrete that will contain aluminum embedments, ineluding that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ions.

Nonpotable water shall not be used in eoncrete unless the following are satisfied:

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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.** 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, except as follows:

A. For A615, A616 and A617, yield strength shall correspond to that determined by tests on full-size bars.

B. For A615, A616 and A617, bend test requirements for all bar sizes No. 3 through No. 11 shall be based upon 180-degree bends of full-size bars around pins with diameters specified in Table No. 26-C-1. If No. 14 or No. 18 bars meeting these specifications are to be bent, full-size bar specimens shall be bend tested 90 degrees, at a minimum temperature of 60°F. around a $9d_b$ pin without cracking of the bar. However, if No. 14 and No. 18 bars as used in the structure are required to have bends exceeding 90 degrees, specimens shall be bend tested 180 degrees with other criteria the same as for 90 degrees.

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; including additional requirements of Section 2603 (f) 2 A and the first paragraph of Section 2603 (f) 2 B. See Section 2609 (e).

Bar and rod mats for concrete reinforcement shall conform to U.B.C. Standard No. 26-5.

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 welded intersections shall be spaced not farther apart than 12 inches in direction of primary flexural reinforcement 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 deformed wire fabric for concrete reinforcement shall conform to U.B.C. Standard No. 26-6, except that welded intersections shall be spaced not

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farther apart than 16 inches in direction of primary flexural reinforcement 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.

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, including additional requirements of Section 2603 (f) 2 A and the first paragraph of Section 2603 (f) 2 B.

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.** 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).

Admixtures containing chloride ions shall not be used in prestressed concrete or in concrete containing aluminum embedments if their use will produce a deleterious concentration of chloride ions in the mixing water.

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.** 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.

(i) **Material and Test Standards.** 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.

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Construction Requirements—Concrete Quality

Sec. 2604. (a) **Notations.**

f'_c = specified compressive strength of concrete, psi

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi

(b) **General.** Concrete shall be proportioned and produced to provide an average compressive strength sufficiently high to minimize frequency of strength tests below the value of the specified compressive strength of concrete, f'_c. See Sections 2604 (d) 1 and 2604 (i) 2 C.

Requirements for f'_c shall be based on tests of cylinders made and tested as prescribed in Section 2604 (i).

Unless otherwise specified, f'_c shall be based on 28-day tests. For high-early-strength concrete, the test age for f'_c shall be as indicated in the plans or specifications.

Plans submitted for approval shall show the specified compressive strength of concrete f'_c for which each part of the 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 value of f'_c. Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

(e) **Selection of Concrete Proportions.** 1. Proportions of materials for concrete shall be established to provide:

A. Adequate workability and proper consistency to permit concrete to be worked readily into the forms and around reinforcement under conditions of placement to be employed, without excessive segregation or bleeding.

B. Resistance to freezing and thawing and other aggressive actions, as required by Section 2604 (g).

C. Conformance with strength test requirements of Section 2604 (i).

2. Where different materials are to be used for different portions of the work, each combination shall be evaluated separately.

3. Concrete proportions, including water-cement ratio, shall be established on the basis of field experience [Section 2604 (d)] or laboratory trial batches [Section 2604 (e)] with materials to be employed, except as permitted in Section 2604 (f) or required by Section 2604 (g).

(d) **Proportioning on the Basis of Field Experience.** 1. Where a concrete production facility has a record, based on at least 30 consecutive strength tests that represent similar materials and conditions to those expected, required average compressive strength used as the basis for selecting concrete proportions shall exceed required f'_c at designated test age by at least:

400 psi if standard deviation is less than 300 psi
550 psi if standard deviation is 300 to 400 psi
700 psi if standard deviation is 400 to 500 psi
900 psi if standard deviation is 500 to 600 psi

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If standard deviation exceeds 600 psi, concrete proportions shall be selected to produce an average strength at least 1200 psi greater than required f'_c.

2. Strength test data for determining standard deviation shall be considered to comply with Section 2604 (d) 1 if data represent either a group of at least 30 consecutive tests or a statistical average for two groups totaling 30 or more tests.

3. Strength tests used to establish standard deviation shall represent concrete produced to meet a specified strength or strengths within 1000 psi of that specified for the proposed work.

4. Changes in materials and proportions within the population of background tests used to establish standard deviation shall not have been more closely restricted than for the proposed work.

(e) **Proportioning by Laboratory Trial Batches.** 1. When laboratory trial batches are used as the basis for selecting concrete proportions, strength tests shall be made in accordance with U.B.C. Standard No. 26-10.

2. When laboratory trial batches are made, air content shall be within ± 0.5 percent and slump within ± 0.75 inch of maximums permitted by the specifications.

3. A curve shall be established showing relationship between water-cement ratio (or cement content) and compressive strength. Curve shall be based on at least three points representing batches which produce strengths above and below required average compressive strength specified in Section 2604 (d) 1. If concrete construction facility does not have a record based on 30 consecutive strength tests representing similar materials and conditions to those expected, required average compressive strength shall be 1200 psi greater than f'_c. Each point shall represent the average of at least three cylinders tested at 28 days or the specified earlier age.

4. Maximum permissible water-cement ratio (or minimum cement content) for concrete to be used in the structure shall be that shown by the curve to produce the average strength indicated in Section 2604 (d) 1 or 2604 (e) 3 unless a lower water-cement ratio or higher strength is required by Section 2604 (g).

(f) **Proportioning by Water-Cement Ratio.** 1. If suitable data from a record of 30 consecutive tests [Section 2604 (d)] or from laboratory trial batches [Section 2604 (e)] are not available, permission may be granted to base concrete proportions on water-cement ratio limits in Table No. 26-A.

2. Table No. 26-A shall be used only for concrete to be made with cements meeting strength requirements for Types I, IA, II, IIA, III, IIIA, V; or Types IS, IS-A, IS(MS), IS-A(MS), IP, IP-A 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.

3. Concrete proportioned by water-cement ratio limits prescribed in Table No. 26-A shall also conform to special exposure requirements of Section 2604 (g) and to compressive strength test criteria of Section 2604 (*i*).

(g) **Special Exposure Requirements.** 1. Concrete that, after curing, will be exposed to freezing temperatures while wet shall contain entrained air within limits of Table No. 26-B and, in addition:

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A. For concrete made with normal-weight aggregate, water-cement ratio shall not exceed 0.53 by weight.

B. For concrete made with lightweight aggregate, specified compressive strength f'_c shall be at least 3000 psi.

2. Concrete that is intended to be watertight shall conform to the following:

A. For concrete made with normal-weight aggregate, water-cement ratio shall not exceed 0.50 by weight for exposure to fresh water and 0.45 by weight for exposure to seawater.

B. For concrete made with lightweight aggregate, specified compressive strength f'_c shall be at least 3750 psi for exposure to fresh water and 4000 psi for exposure to seawater.

3. Concrete that will be exposed to injurious concentrations of sulfate-containing solutions shall be made with sulfate-resisting cement and, in addition:

A. For concrete made with normal-weight aggregate, water-cement ratio shall not exceed 0.50 by weight.

B. For concrete made with lightweight aggregate, specified compressive strength f'_c shall be at least 3750 psi.

(h) **Average Strength Reduction.** After sufficient compressive test data become available from the job, methods of U.B.C. Standard No. 26-11 may be used to reduce the amount by which the average strength must exceed f'_c below that indicated in Section 2604 (d) 1, provided:

1. Probable frequency of strength tests more than 500 psi below f'_c will not exceed 1 in 100.

2. Probable frequency of an average of three consecutive strength tests below f'_c will not exceed 1 in 100, and

3. Special exposure requirements of Section 2604 (g) are met.

(i) **Evaluation and Acceptance of Concrete.** 1. **Frequency of testing.** 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 as required by Section 2604 (i) 1 A 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, adequate evidence of satisfactory strength is provided.

D. Average strength of two cylinders from the same sample, tested at 28 days or the specified earlier age, is required for each strength test.

2. **Tests of laboratory-cured specimens.** 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 and laboratory cured in accordance with U.B.C. Standard No. 26-10.

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C. Strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:

(i) The average of all sets of three consecutive strength tests equals or exceeds required f'_c.

(ii) No individual strength test (average of two cylinders) falls below required f'_c by more than 500 psi.

D. If either of the requirements of Section 2604 (i) 2 C are not met, steps shall be taken immediately to increase the average of subsequent strength test results. Additionally, requirements of Section 2604 (j) shall be observed if the requirement of Section 2604 (i) 2 C (ii) is not met.

3. **Tests of field-cured specimens.** 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. Field-cured cylinders shall be cured under field conditions in accordance with U.B.C. Standard No. 26-10.

Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at the test age designated for measuring f'_c is less than 85 percent of that of companion laboratory-cured cylinders. When laboratory-cured cylinder strengths are appreciably higher than f'_c, field-cured cylinder strengths need not exceed f'_c by more than 500 psi even though the 85 percent criterion is not met.

(j) **Investigation of Low-strength Test Results.** If any strength test [Section 2604 (i) 1 D] of laboratory-cured cylinders falls below required f'_c by more than 500 psi [Section 2604 (i) 2 C (ii)] 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.

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 required f'_c.

If concrete in the structure will be dry under service conditions, cores shall be air dried (temperature 60°F. to 80°F., relative humidity less than 60 percent) for 7 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 48 hours and be tested wet.

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.

If criteria of the preceding paragraph are not met, and if structural adequacy remains in doubt, the building official may order load tests as outlined in Section 2620 for the questionable portion of the structure, or take other action appropriate to the circumstances.

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Mixing and Placing Concrete

Sec. 2605. (a) **Preparation of Equipment and Place of Deposit.** 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.** 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 set forth in U.B.C. Standard No. 26-13.

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 1½ 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.

(c) **Conveying.** 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.** Concrete shall be deposited as nearly as practicable in its final position to avoid segregation due to rehandling or flowing.

Concreting 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 place-

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ment and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

(e) **Curing.** 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 (i) 3 may be required to assure that curing is satisfactory.

(f) **Cold Weather Requirements.** 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 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.** 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

Sec. 2606. (a) **Design of Formwork.** 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.** Construction loads shall not be supported on, nor any shoring removed from, any part of the structure under construction

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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 may be demonstrated by field-cured test cylinders and by a structural analysis considering proposed loads in relation to field-cured cylinder strengths and strength of the forming and shoring system. Such analysis and strength test data shall be furnished by the contractor 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 prestessed members to carry their dead load and anticipated construction loads.

(c) **Conduits and Pipes Embedded in Concrete.** 1. Conduits, pipes and sleeves of any material not harmful to concrete and within limitations of this subsection may be embedded in conerete 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 effeetively eoated 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 thiekness of slab, wall or beam in which they are embedded.

B. They shall be spaeed not eloser than three diameters or widths on eenter.

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 eonerete, 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.

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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 percent 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.

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 1½ inches for concrete exposed to earth or weather, nor ¾ 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.** Where a construction joint is to be made, the surface of concrete shall be thoroughly cleaned and all laitance and standing water removed. Vertical construction joints shall be thoroughly wetted immediately before new concrete placement.

Construction joints not indicated on the design drawings shall be so made and located as not to impair significantly the strength of the structure.

Construction joints in floors shall be located near the middle of spans of slabs, beams or girders, unless a beam intersects a girder at the middle location, in which case joints in the girders shall be offset a distance equal to twice the width of the beam. Provision shall be made for transfer of shear and other forces through construction joints.

Beams, girders or slabs supported by columns or walls shall not be cast or

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erected until concrete in the vertical support members is no longer plastic. Beams, girders, column capitals and haunches shall be considered as part of a slab system and shall be placed monolithically therewith.

Details of Reinforcement

Sec. 2607. (a) **Notations.**

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.** The term "standard hook" as used in this code shall mean either:

1. A 180-degree bend plus an extension of at least $4d_b$ but not less than 2½ inches at free end of bar, or

2. A 90-degree bend plus an extension of at least $12d_b$ at free end of bar, or

3. For stirrup and tie hooks only, either a 90-degree or a 135-degree bend plus an extension of a least $6d_b$ but not less than 2½ inches at free end of bar.

4. For stirrup and tie hooks only, in Seismic Zones No. 2, No. 3 and No. 4, 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.

(c) **Minimum Bend Diameters.** Diameter of bend measured on the inside of the bar, other than for stirrups and ties, shall be not less than the values in Table No. 26-C-2, except that for Grade 40 bars in sizes No. 3 through No. 11 with 180-degree bends only, diameter of bend shall be not less than $5d_b$.

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-2.

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.** All reinforcement shall be bent cold, unless otherwise permitted by the building official. Reinforeement 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.** 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.

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(f) **Placing Reinforcement.** 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.	$\pm$ ⅜ in.	− ⅜ in.
$d > 8$ in.	$\pm$ ½ in.	− ½ in.

except that tolerance for the clear distance to formed soffits shall be minus ¼ 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 $\pm$ 2 inches except at discontinuous ends of members where tolerance shall be $\pm$ ½ 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.** 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 1½ 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 inches in one bundle. Bundled bars shall be enclosed within stirrups or ties. Bars larger than No. 11 shall not be bundled in beams.

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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 satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

(h) **Concrete Protection for Reinforcement.** 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	1½
C. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
No. 14 and No. 18 bar	1½
No. 11 bar and smaller	¾
Beams, columns:	
Primary reinforcement, ties, stirrups, spirals	1½
Shells, folded plate members:	
No. 6 bar and larger	¾
No. 5 bar, W31 or D31 wire, and smaller	½

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	1½
No. 11 bar and smaller	¾
Other members:	
No. 14 and No. 18 bar	2
No. 6 through No. 11 bar	1½
No. 5 bar, W31 or D31 wire, and smaller	1¼

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B. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
No. 14 and No. 18 bar	1¼
No. 11 bar and smaller	⅝
Beams, columns:	
Primary reinforcement	d_b but not less than ⅝ and need not exceed 1½
Ties, stirrups, spirals	⅜
Shells, folded plate members:	
No. 6 bar and larger	⅝
No. 5 bar, W31 or D31 wire, and smaller	⅜

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	1½
(iii) Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	¾
Beams, columns:	
Primary reinforcement	1½
Ties, stirrups, spirals	1
Shells, folded plate members:	
No. 5 bars, W31 or D31 wire, and smaller	⅜
Other reinforcement	d_b but not less than ¾

B. For prestressed concrete members exposed to earth, weather or corrosive environments, minimum concrete cover shall be increased 50 percent if the tensile stress of Section 2618 (e) 2 B is exceeded.

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

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concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other proteetion 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.** 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 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 (s).

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.** 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.** 1. **General.** Lateral

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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.

B. For cast-in-place construction, size of spirals shall be not less than ⅜-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 ⅝-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 ⅝-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

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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 (f) 4, supplementary crossties engaging the hoops only may be considered as meeting this requirement.

C. Ties shall be arranged sueh 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 inehes elear on each side along the tie from such a laterally supported bar. Where longitudinal bars are located around the perimeter of a circle, a eomplete circular tie may be used.

D. In Seismic Zones Nos 0 and 1, column lateral ties shall be as specified in Section 2607 (b) 3. In Seismic Zones Nos. 2, 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 into all sides of a column, ties may be terminated not more than 3 inches below the lowest reinforcement in such beams or brackets.

(l) **Lateral Reinforcement for Flexural Members.** 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.** Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural floor and roof slabs where the flexural reinforcement extends in one direction only.

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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:

Slabs where Grade 40 or Grade 50 deformed bars are used	0.0020
Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) are used	0.0018
Slabs where reinforcement with yield strength exceeding 60,000 psi measured at a yield strain of 0.35 percent is used	$\frac{0.0018 \times 60{,}000}{f_y}$

Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness nor 18 inches. At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength f_y in tension in accordance with Subsection 2612 (b) or 2612 (q).

Analysis and Design

Sec. 2608. (a) **Notations.**

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.

β_1 = factor defined in Section 2610 (e) 7.

ρ = ratio of nonprestressed tension reinforcement.
= A_s/bd.

ρ' = ratio of nonprestressed compression reinforcement.
= A'_s/bd.

ρ_b = reinforcement ratio producing balanced strain conditions. See Section 2610 (d) 2.

ϕ = strength reduction factor. See Section 2609 (d).

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(b) **Design Methods.** In design of reinforced concrete struetures, members shall be proportioned for adequate strength in accordance with provisions of this code, using load faetors and strength reduction factors ϕ 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 Seetion 2628, Alternate Design Method.

(c) **Loading.** 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.** 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 threc 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 ..... $w_u l_n^2/10$

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 wherc ratio of sum of column stiffnesses to beam stiffness exceeds eight at each end of the span ..... $w_u l_n^2/12$

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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.** 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 ρ or $\rho - \rho'$ is not greater than $0.50\,\rho_b$, where

$$\rho_b = \frac{0.85\,\beta_1 f'_c}{f_y} \quad \frac{87{,}000}{87{,}000 + f_y} \qquad (8\text{-}1)$$

For criteria on moment redistribution for prestressed concrete members, see Section 2618.

(f) **Modulus of Elasticity.** 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.** 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.

(h) **Span Length.** 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.

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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.** 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.** 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.** 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.

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:

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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.** 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.

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.** 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.

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Strength and Serviceability Requirements

Sec. 2609. (a) **Notations.**

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 = lateral pressure of liquids, or related internal moments and forces.

h = overall thickness of member, inches.

H = lateral earth pressure, 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.

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 = cumulative effects of temperature, creep, shrinkage and differential settlement.

U = required strength to resist factored loads or related internal moments and forces.

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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.

α = 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.

α_m = average value of α for all beams on edges of a panel.

β = ratio of clear spans in long-to-short direction of two-way slabs.

β_s = ratio of length of continuous edges to total perimeter of a slab panel.

ϕ = strength reduction factor. See Section 2609 (d).

(b) **General.** 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.** 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

$$U = 0.75(1.4D + 1.7L + 1.7W) \quad \text{(9-2)}$$

where load combinations shall include both full value and zero value of L to determine the more severe condition, and

$$U = 0.9D + 1.3W \quad \text{(9-3)}$$

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.

4. If resistance to lateral earth pressure H is included in design, required strength U shall be at least equal to

$$U = 1.4D + 1.7L + 1.7H \quad \text{(9-4)}$$

except that where D or L reduces the effect of H, $0.9D$ shall be substituted for

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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 lateral liquid pressure F is included in design, load combinations of Section 2609 (c) 4 shall apply, except that 1.4F shall be substituted for 1.7H. Vertical liquid pressure shall be considered as dead load D, with due regard to variation in liquid depth.

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

$$U = 0.75\,(1.4D + 1.4T + 1.7L) \quad \text{(9-5)}$$

but required strength U shall be not less than

$$U = 1.4\,(D + T) \quad \text{(9-6)}$$

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.** 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 ϕ.

Strength reduction factor ϕ shall be as follows:

1. Flexure, with or without axial tension 0.90
2. Axial tension 0.90
3. Axial compression, with or without flexure:
   A. Members with spiral reinforcement conforming to Section 2610 (j) 3 ..... 0.75
   B. Other reinforced members 0.70

except that for low values of axial load, ϕ 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, ϕ may be increased linearly to 0.90 as ϕP_n decreases from $0.10 f'_c A_g$ to zero.

For other reinforced members, ϕ may be increased linearly to 0.90 as ϕP_n deereases from $0.10 f'_c A_g$ or ϕP_b, whichever is smaller, to zero.

4. Shear and torsion 0.85
5. Bearing on concrete [See also Section 2618 (n)] 0.70
6. Flexure in plain concrete 0.65

Development lengths specified in Section 2612 do not require a ϕ factor.

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(e) **Design Strength for Reinforcement.** 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.** 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 effeets.

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.

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \quad \text{.....(9-7)}$$

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 spans, 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.

E. Unless values are obtained by a more comprehensive analysis, additional long-time deflection for flexural members (normal-weight or lightweight con-

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crete) shall be obtained by multiplying the immediate deflection caused by the sustained load considered, by the factor.

$$[2 - 1.2\,(A'_s/A_s)] \geqslant 0.6$$

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 (9-10), (9-11) and (9-12) and the other provisions of this section.

$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000 + 5000\beta\left[\alpha_m - 0.5\,(1 - \beta_s)\left(1 + \frac{1}{\beta}\right)\right]} \quad \ldots\ldots (9\text{-}10)$$

but not less than

$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000 + 5000\beta\,(1 + \beta_s)} \quad \ldots\ldots (9\text{-}11)$$

and need not be more than

$$h = \frac{l_n\,(800 + 0.005f_y)}{36{,}000} \quad \ldots\ldots (9\text{-}12)$$

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 α_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 (9-10), (9-11) or (9-12) may be reduced by 10 percent.

At discontinuous edges, an edge beam shall be provided with a stiffness ratio α not less than 0.80; or the minimum thickness required by Formula (9-10), (9-11), (9-12) 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

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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 long-time 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 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

Sec. 2610. (a) **Notations.**

a = depth of equivalent rectangular stress block as defined in Section 2610 (e) 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.

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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 = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area.

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 Formulas (10-9) and (10-10).

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 moment on 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.

P_b = nominal axial load strength at balanced strain conditions. See Section 2610 (d) 2.

P_c = critical load. See Formula (10-7).

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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).

β_1 = factor defined in Section 2610 (c).

β_d = ratio of maximum factored dead load moment to maximum factored total load moment, always positive.

δ = moment magnification factor. See Section 2610 (l) 5, 6 and 7.

ρ = ratio of nonprestressed tension reinforcement.

$= A_s/bd$.

ρ_b = reinforcement ratio producing balanced strain conditions. See Section 2610 (d) 2.

ρ_s = ratio of volume of spiral reinforcement to total volume of core (out-to-out of spirals) of a spirally reinforced compression member.

ϕ = strength reduction factor. See Section 2609 (d).

(b) **Scope.** 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.** 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 (e).

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

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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 β_1 shall be taken as 0.85 for concrete strengths f'_c up to and including 4000 psi. For strengths above 4000 psi, β_1 shall be reduced continuously at a rate of 0.05 for each 1000 psi of strength in excess of 4000 psi, but β_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 ϕP_n is less than the smaller of $0.10 f'_c A_g$ or ϕP_b, the ratio of reinforcement ρ provided shall not exceed 0.75 of the ratio ρ_b that would produce balanced strain conditions for the section under flexure without axial load. For members with compression reinforcement, the portion of ρ_b equalized by compression reinforcement 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 ϕP_n of compression members shall not be taken greater than the following:

A. For nonprestressed members with spiral reinforcement conforming to Section 2607 (k) 2 or composite members conforming to Section 2610 (o):

$$\phi P_{n\,(max.)} = 0.85\phi[0.85 f'_c (A_g - A_{st}) + f_y A_{st}] \quad \text{(10-1)}$$

B. For nonprestressed members with tie reinforcement conforming to Section 2607 (k) 3:

$$\phi P_{n\,(max.)} = 0.80\phi[0.85 f'_c (A_g - A_{st}) + f_y A_{st}] \quad \text{(10-2)}$$

C. For prestressed members, design axial load strength ϕP_n shall not be taken 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 ϕP_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.** Spacing of

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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.** 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 ρ provided shall be not less than that given by:

$$\rho \, min. = \frac{200}{f_y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10\text{-}3)$$

In T-beams and joists where the web is in tension, the ratio ρ 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.** 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

$$z = f_s \sqrt[3]{d_c A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10\text{-}4)$$

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 k_s (kips per square inch) shall be computed as the moment divided by the product of steel area 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

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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 reinforeement 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.** 1. Flexural members with overall depth to clear span ratios greater than two fifths for eontinuous spans, or four fifths for simple spans, shall be designed as deep flexural members, taking into account nonlinear distribution of strain and lateral buekling.

2. Design of deep flexural members for shear effects shall be in aeeordance with Seetion 2611 (i).

3. Minimum flexural tension reinforcement shall conform to Section 2610 (f).

4. Minimum horizontal and vertical reinforeement in the side faces of deep flexural members shall be the greater of the requirements of Section 2611 (i) 8 or Section 2614 (c) 9.

(i) **Design Dimensions for Compression Members.** 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 eonerete cover required by Section 2607 (h).

2. **Compression member built monolithically with wall.** Outer limits of the effeetive eross section of a spirally reinforced compression member built monolithieally with a concrete wall or pier shall be taken either as a circle at least 1½ inches outside the spiral, or as a square or reetangle with sides at least 1½ inehes outside the spiral.

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 cireular section with a diameter equal to the least lateral dimension of the actual shape. Cross area eonsidered, 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.

(j) **Limits for Reinforcement of Compression Members.** 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 reinforcing bars in eompression members shall be six for bars in a circular arrangement and four for bars in a rectangular arrangement.

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3. Ratio of spiral reinforcement ρ_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.** 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.** 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 $34 - 12M_1/M_2$.

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. Compression members shall be designed using the factored axial load P_u from a conventional frame analysis and a magnified

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factored moment M_c defined by:

$$M_c = \delta M_2 \quad \text{(10-6)}$$

WHERE:

$$\delta = \frac{C_m}{1 - (P_u/\phi P_c)} \geq 1.0 \quad \text{(10-7)}$$

AND

$$P_c = \frac{\pi^2 EI}{(kl_u)^2} \quad \text{(10-8)}$$

B. In lieu of a more accurate calcuation, EI in Formula (10-8) may be taken either as

$$EI = \frac{(E_c I_g/5) + E_s I_{se}}{1 + \beta_d} \quad \text{(10-9)}$$

or conservatively

$$EI = \frac{E_c I_g/2.5}{1 + \beta_d} \quad \text{(10-10)}$$

C. In Formula (10-7), for members braced against sidesway and without transverse loads between supports, C_m may be taken as

$$C_m = 0.6 + 0.4 \frac{M_1}{M_2} \quad \text{(10-11)}$$

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 compression member or that computed end eccentricities are less than $(0.6 + 0.03h)$ inches, M_2 in Formula (10-6) shall be based on a minimum eccentricity of $(0.6 + 0.03h)$ inches about each principal axis separately. Ratio M_1/M_2 in Formula (10-11) 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_1/M_2 in Formula (10-11).

(ii) If computations show that there is essentially no moment at both ends of a compression member, the ratio M_1/M_2 shall be taken equal to one.

6. **Moment magnifier δ for unbraced frames.** A. In frames not braced against sidesway, the value of δ shall be computed for an entire story, assuming all columns to be loaded.

B. In Formula (10-7), P_u and P_c shall be replaced by the summations ΣP_u and ΣP_c for all columns in a story.

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C. For design of each column within a story, δ shall be taken as the larger of the values computed for the entire story according to Section 2610 (l) 6 B or as computed for the individual column assuming column ends to be braced against sidesway.

D. 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 δ for biaxial bending.** For compression members subject to bending about both principal axes, moment about each axis shall be magnified by δ, computed from corresponding conditions of restraint about that axis.

(m) **Axially Loaded Members Supporting Slab System.** 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.** 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 about the column for an area four times the column area. Column concrete shall be well integrated into floor concrete and shall be placed in accordance with Section 2606 (d).

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 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.** 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:

$$r = \sqrt{\frac{(E_c I_g/5) + E_s I_t}{(E_c A_g/5) + E_s A_t}} \qquad (10\text{-}12)$$

For computing P_c in Formula (10-8), EI of the composite section shall be not

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greater than

$$EI = \frac{E_c I_g/5}{1 + \beta_d} + E_s I_t \quad \text{.....(10-13)}$$

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

$$h\sqrt{\frac{f_y}{8E_s}}, \text{ for circular sections of diameter } h$$

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 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. 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 be at least No. 5 bars, or smaller bars with a diameter not less than 1/50 times the greatest side dimension of the composite member, but not smaller than No. 3. 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

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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_s for strength but not in computing I_s for evaluation of slenderness effects.

(p) **Special Provisions for Walls.** 1. Walls may be designed by provisions of Section 2610 with limitations and exceptions of this subsection or by provisions of Section 2614.

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. Vertical reinforcement shall be spaced not farther apart than three times the wall thickness, nor 18 inches.

4. 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.

5. 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.

6. Horizontal reinforcement shall be spaced not farther apart than three times the wall thickness, nor 18 inches.

7. The minimum requirements for horizontal and vertical steel of Section 2610 (p) 2 and 2610 (p) 5 may be interchanged for precast panels which are not restrained along vertical edges to inhibit temperature expansion contraction.

(q) **Bearing Strength.** 1. Design bearing strength on concrete shall not exceed $\phi(0.85f'_c A_1)$, except as follows:

A. 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.

B. When the supporting surfaee 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. Section 2610 (q) does not apply to posttensioning anchorages.

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Shear and Torsion

Sec. 2611. (a) **Notations.**

a = shear span, distance between concentrated load and face of supports.

A_c = area of concrete section resisting shear transfer, square inches.

A_g = gross area of section, square inches.

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_{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.

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_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_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)

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at centroid of cross section resisting externally applied loads or at junction of web and flange when the centroid lies within the flange, psi. (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.

l_n = clear span measured face-to-face of supports.

l_v = length of shearhead arm from centroid of concentrated load or reaction, inches.

l_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 on bracket or corbel acting simultaneously with V_u, 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.

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V_c = nominal shear strength provided by concrete.

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.

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.

α = angle between included stirrups and longitudinal axis of member.

α_t = coefficient as a function of y_1/x_1. See Section 2611 (g) 9 A.

α_v = ratio of stiffness of shearhead arm to surrounding composite slab section. See Section 2611 (l) 4 E.

β_c = ratio of long side to short side of concentrated load or reaction area.

μ = coefficient of friction. See Section 2611 (h) 5.

γ_f = fraction of unbalanced moment transferred by flexure at slab-column connections. See Section 2613 (d) 4.

γ_v = fraction of unbalanced moment tranferred by eccentricity of shear at slab-column connections. See Section 2611 (m) 2 C.

$= 1 - \gamma_f$.

ρ = ratio of nonprestressed tension reinforcement.

$= A_s/bd$.

ρ_h = ratio of horizontal shear reinforcement area to gross concrete area of vertical section.

ρ_n = ratio of vertical shear reinforcement area to gross concrete area of horizontal section.

$\rho_v = (A_s + A_h)/bd$.

$\rho_w = A_s/b_w d$.

ϕ = strength reduction factor. See Section 2609 (d).

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(b) **Shear Strength.** 1. Design of cross sections subject to shear shall be based on

$$V_u \leq \phi V_n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11\text{-}1)$$

where V_u is factored shear force at section considered and V_n is nominal shear strength computed by

$$V_n = V_c + V_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11\text{-}2)$$

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. When the reaction, in direction of applied shear, introduces compression into the end regions of a member, calculation of maximum factored shear force V_u shall be as follows:

A. 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.

B. 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 $h/2$.

4. 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.** 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 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.** 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,

$$V_c = 2\sqrt{f'_c}\, b_w d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11\text{-}3)$$

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B. For members subjeet to axial compression,

$$V_c = 2\left(1 + \frac{N_u}{2000A_g}\right)\sqrt{f'_c}b_w d \quad \text{.....(11-4)}$$

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 $\phi(0.5\sqrt{f'_c}\Sigma x^2 y)$,

$$V_c = \frac{2\sqrt{f'_c}b_w d}{\sqrt{\left[1 + \left(2.5C_t\frac{T_u}{V_u}\right)^2\right]}} \quad \text{.....(11-5)}$$

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,

$$V_c = \left(1.9\sqrt{f'_c} + 2500\rho_w\frac{V_u d}{M_u}\right)b_w d \quad \text{.....(11-6)}$$

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 occuring 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

$$M_m = M_u - N_u\frac{(4h-d)}{8} \quad \text{.....(11-7)}$$

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).

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C. For members subject to significant axial tension,

$$V_c = 2\left(1 + \frac{N_u}{500A_g}\right)\sqrt{f'_c}\,b_w d \quad \ldots\ldots\ldots\ldots (11\text{-}9)$$

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.** 1. For members with effective prestress foree not less than 40 percent of the tensile strength of flexural reinforcement, unless a more detailed calculation is made in aecordance with Section 2611 (e) 2.

$$V_c = \left(0.6\sqrt{f'_c} + 700\frac{V_u d}{M_u}\right) b_w d \quad \ldots\ldots\ldots (11\text{-}10)$$

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) 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

$$V_{ci} = 0.6\sqrt{f'_c}\,b_w d + V_d + \frac{V_i M_{cr}}{M_{max}} \quad \ldots\ldots\ldots\ldots (11\text{-}11)$$

but V_{ci} need not be taken less than $1.7\sqrt{f'_c}\,b_w d$, where

$$M_{cr} = (I/y_t)(6\sqrt{f'_c} + f_{pe} - f_d) \quad \ldots\ldots\ldots\ldots (11\text{-}12)$$

and values of M_{max} and V_i shall be computed from the load combination causing maximum moment to occur at the section.

B. Shear strength V_{cw} shall be computed by

$$V_{cw} = (3.5\sqrt{f'_c} + 0.3f_{pc})\,b_w d + V_p \quad \ldots\ldots\ldots\ldots (11\text{-}13)$$

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

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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 of $0.8h$, 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.

(f) **Shear Strength Provided by Shear Reinforcement.** 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) Combinations 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 (o) to develop the design yield strength of reinforcement.

4. **Spacing limits for shear reinforcement.** A. Spacing of shear reinforcement placed perpendicular to axis of member shall not exceed $d/2$ 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 spacings given in Section 2611 (f) 4 A and B shall be reduced 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 ϕV_c, except:

(i) Slabs and footings.

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(ii) Concrete joist construction defined by Section 2608 (l).

(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 reinforcement requirements of Section 2611 (f) 5 A may be waived if shown by test that required ultimate flexural and shear strength can be developed when shear reinforcement is omitted.

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 Section 2611 (f) 5 D] and nonprestressed members shall be computed by

$$A_v = 50\,\frac{b_w s}{f_y} \qquad \text{.....(11-14)}$$

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, minimum area of shear reinforcement may be computed by Formula (11-14) or (11-15).

$$A_v = \frac{A_{ps}}{80}\,\frac{f_{pu}}{f_y}\,\frac{s}{d}\sqrt{\frac{d}{b_w}} \qquad \text{.....(11-15)}$$

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

$$A_v + 2A_t = 50\,\frac{b_w s}{f_y} \qquad \text{.....(11-16)}$$

6. **Design of shear reinforcement.** A. Where factored shear force V_u exceeds shear strength ϕV_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,

$$V_s = \frac{A_v f_y d}{s} \qquad \text{.....(11-17)}$$

where A_v is the area of shear reinforcement within a distance s.

C. When inclined stirrups are used as shear reinforcement,

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$$V_s = \frac{A_v f_y (\sin\alpha + \cos\alpha) d}{s} \quad \text{.....(11-18)}$$

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.** 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.

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 $\phi(4\sqrt{f'_c}\Sigma x^2 y/3)$.

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

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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

$$T_c = \frac{0.8\sqrt{f'_c}\,\Sigma x^2 y}{\sqrt{1 + \left(\dfrac{0.4 V_u}{C_t T_u}\right)^2}} \quad \text{(11-22)}$$

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.

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 (o) 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

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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 ϕT_c, torsion reinforcement shall be provided to satisfy Formulas (11-20) and (11-21), where torsional moment strength T_s shall be computed by

$$T_s = \frac{A_t \alpha_t x_1 y_1 f_y}{s} \quad \text{.....(11-23)}$$

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

$$A_l = 2A_t \left(\frac{x_1 + y_1}{s} \right) \quad \text{.....(11-24)}$$

or by

$$A_l = \left| \frac{400xs}{f_y} \left(\frac{T_u}{T_u + \frac{V_u}{3C_t}} \right) - 2A_t \right| \left(\frac{x_1 + y_1}{s} \right) \quad \text{.....(11-25)}$$

whichever is greater. Value of A_l computed by Formula (11-25) need not exceed that obtained by substituting

$$\frac{50b_w s}{f_y} \text{ for } 2A_t.$$

D. Torsional moment strength T_s shall not exceed $4T_c$.

(h) **Shear Friction.** Provisions of this section may 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.

1. A crack shall be assumed to occur along the shear plane, with relative displacement along the assumed crack resisted by friction maintained by shear-friction reinforcement across the assumed crack. Shear-friction reinforcement shall be placed approximately perpendicular to the assumed crack.

2. Design of cross sections subject to shear transfer shall be based on Formula

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(11-1) where shear strength V_n shall be computed by

$$V_n = A_{vf} f_y \mu \quad \text{.....(11-26)}$$

where A_{vf} is area of shear-friction reinforcement, and μ is coefficient of friction in accordance with Section 2611 (h) 4.

3. Shear strength V_n shall not be taken greater than $0.2 f'_c A_c$ nor $800 A_c$, where A_c is area of concrete section resisting shear transfer. Quantity $800 A_c$ is in pounds.

4. Coefficient of friction μ in Formula (11-26) shall be

Concrete placed monolithically 1.4

Concrete placed against hardened concrete. [See Section 2611 (h) 8] 1.0

Concrete placed against as-rolled structural steel. [See Section 2611 (h) 9] 0.7

5. Design yield strength of shear-friction reinforcement shall not exceed 60,000 psi.

6. Direct tension across the assumed crack shall be provided for by additional reinforcement.

7. Shear-friction reinforcement shall be well distributed across the assumed crack and shall be adequately anchored on both sides by embedment, hooks or welding to special devices.

8. For the purpose of Section 2611 (h), when concrete is placed against previously hardened concrete, the interface for shear transfer shall be clean, free of laitance and intentionally roughened to a full amplitude of approximately ¼ inch.

9. When shear is transferred between as-rolled steel and concrete, steel shall be clean and free of paint.

(i) **Special Provisions for Deep Flexural Members.** Provisions of this section shall apply for members with l_n/d less than 5 and loaded at top or compression face.

1. Design of 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) 4 or 2611 (i) 5, and shear strength V_s shall be in accordance with Section 2611 (i) 6.

2. Shear strength V_n for deep flexural members shall not be taken greater than $8\sqrt{f'_c} b_w d$ when l_n/d is less than 2. When l_n/d is between 2 and 5,

$$V_n = \frac{2}{3}\left(10 + \frac{l_n}{d}\right)\sqrt{f'_c} b_w d \quad \text{.....(11-27)}$$

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3. 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.

4. Unless a more detailed calculation is made in accordance with Section 2611 (i) 5,

$$V_c = 2\sqrt{f'_c}\,b_w d \quad \text{(11-28)}$$

5. Shear strength V_c may be computed by

$$V_c = \left(3.5 - 2.5\frac{M_u}{V_u d}\right)\left(1.9\sqrt{f'_c} + 2500\rho_w\frac{V_u d}{M_u}\right) b_w d \quad \text{(11-29)}$$

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) 3.

6. Where factored shear force V_u exceeds shear strength ϕV_c, shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength V_s shall be computed by

$$V_s = \left[\frac{A_v}{s}\left(\frac{1 + \frac{l_n}{d}}{12}\right) + \frac{A_{vh}}{s_2}\left(\frac{11 - \frac{l_n}{d}}{12}\right)\right] f_y d \quad \text{(11-30)}$$

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.

7. Area of shear reinforcement A_v shall be not less than $0.0015\,bs$, and s shall not exceed $d/5$ nor 18 inches.

8. Area of shear reinforcement A_{vh} shall be not less than $0.0025\,bs_2$, and s_2 shall not exceed $d/3$ nor 18 inches.

9. Shear reinforcement required at the critical section defined in Section 2611 (i) 3 shall be used throughout the span.

(j) **Special Provisions for Brackets and Corbels.** Provisions of this section shall apply to brackets and corbels with a shear-span-to-depth ratio a/d of unity or less. Distance d shall be measured at a section adjacent to face of support, but

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shall not be taken greater than twice the depth of bracket or corbel at outside edge of bearing area.

Brackets and corbels with a shear-span-to-depth ratio a/d of one half or less, may be designed in accordance with provisions of Section 2611 (h), except that all limitations on quantity and spacing of reinforcement in this section shall apply.

1. Design of brackets and corbels shall be based on Formula (11-1), where shear strength V_n shall be computed in accordance with Section 2611 (j) 2 or 2611 (j) 3.

2. For brackets and corbels subject to tension due to restrained creep and shrinkage,

$$V_n = \left[6.5 - 5.1\sqrt{\frac{N_{uc}}{V_u}}\right]\left[1 - 0.5\frac{a}{d}\right] \times \left(1 + \left[64 + 160\sqrt{\left(\frac{N_{uc}}{V_u}\right)}\right]\rho\right)\sqrt{f'_c}\,b_w d \quad \text{.....(11-31)}$$

where ρ shall not exceed $0.13 f'_c/f_y$ and N_{uc}/V_u shall not be taken less than 0.20. Tensile force N_{uc} shall be regarded as a live load even when tension results from creep, shrinkage or temperature change.

3. When provisions are made to avoid tension due to restrained creep and shrinkage, so that bracket or corbel is subject to shear and moment only,

$$V_n = 6.5\left(1 - 0.5\,\frac{a}{d}\right)\left(1 + 64\,\rho_v\right)\sqrt{f'_c}\,b_w d \quad \text{.....(11-32)}$$

where

$$\rho_v = \frac{A_s + A_h}{bd}$$

but not greater than

$$0.20\,\frac{f'_c}{f_y}$$

and A_h shall not exceed A_s.

4. Closed stirrups of ties parallel to flexural tension reinforcement with a total area A_h not less than $0.50 A_s$ shall be uniformly distributed within two thirds of the effective depth adjacent to flexural tension reinforcement.

5. Ratio $\rho = A_s/bd$ shall be not less than $0.04 (f'_c/f_y)$.

(k) **Special Provisions for Walls.** 1. Design for shear forces perpendicular to face of wall shall be in accordance with provisions for slabs in Section 2611 (l).

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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 (11-33) and (11-34), where V_c shall be the lesser of Formula (11-33) or (11-34).

$$V_c = 3.3\sqrt{f'_c}hd + \frac{N_u d}{4l_w} \qquad \text{(11-33)}$$

or

$$V_c = \left[0.6\sqrt{f'_c} + \frac{l_w\left(1.25\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right] hd \qquad \text{(11-34)}$$

where N_u is negative for tension. When $(M_u/V_u - l_w/2)$ is negative, Formula (11-34) shall not apply.

EXCEPTION: N_u when in compression shall be taken as zero for buildings located in Seismic Zones No. 3 and No. 4 when considering earthquake load.

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 ϕV_c, horizontal shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength V_s shall be computed by

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$$V_s = \frac{A_v f_y d}{s_2} \quad \text{(11-35)}$$

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 ρ_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 ρ_n of vertical shear reinforcement area to gross concrete area of horizontal section shall be not less than

$$\rho_n = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_h - 0.0025) \quad \text{(11-36)}$$

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.

(l) **Special Provisions for Slabs and Footings.** 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 given by Formula (11-37), unless shear reinforcement is provided in accordance with Section 2611 (l) 3 or 4.

$$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d \quad \text{(11-37)}$$

but not greater than $4\sqrt{f'_c}\, b_o d$. β_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).

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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.

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 distant 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 ϕV_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 (o).

4. Shear reinforcement consisting of steel I or channel shapes (shearheads) may be used in slabs. Provisions of Section 2611 (l) 4 A through I shall apply where shear is transferred at interior column supports. Where shear is transferred at edge or corner column supports, special designs are required.

A. Each shearhead shall consist of steel shapes fabricated by welding into four identical arms at right angles. Shearhead arms shall be continuous through the column section.

B. Shearhead shall be not 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 α_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

$$\phi M_p = \frac{V_u}{8}\left[h_v + \alpha_v\left(l_v - \frac{c_1}{2}\right)\right] \qquad (11\text{-}38)$$

where ϕ is strength reduction factor for flexure and l_v is minimum length of each shearhead arm required to comply with requirements of Section 2611 (l) 4 G and 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

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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 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

$$M_v = \frac{\phi \alpha_v V_u}{8}\left(l_v - \frac{c_1}{2}\right) \quad \text{.....(11-39)}$$

where ϕ is the strength reduction factor for flexure 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).

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.** 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.

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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

$$\gamma_v = 1 - \frac{1}{1 + 2/3\sqrt{\frac{c_1 + d}{c_2 + d}}} \quad \text{.....(11-40)}$$

shall be considered transferred by eccentricity of shear about centroid of 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 column.

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 $\phi(2 + 4/\beta_c)\sqrt{f'_c}$ nor $\phi 4\sqrt{f'_c}$.

Development and Splices of Reinforcement

Sec. 2612. (a) **Notations.**

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.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches.

d_b = nominal diameter of barn 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_h = tensile stress developed by standard hook, 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.

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l_e = equivalent embedment length of a hook, 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.

β_b = ratio of area of reinforcement cut off to total area of tension reinforcement at section.

ξ = constant for standard hook.

(b) **Development of Reinforcement—General.** 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 or end anchorage or a combination thereof. Hooks may be used in developing bars in tension.

(c) **Development of Deformed Bars and Deformed Wire in Tension.** 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 (q) and development of web reinforcement by Section 2612 (o).

Basic development length shall be:

No. 11 bar and smaller	$0.04A_b f_y/\sqrt{f'_c}$*
but not less than	$0.0004d_b f_y$†
No. 14 bar	$0.085f_y/\sqrt{f'_c}$‡
No. 18 bar	$0.11f_y/\sqrt{f'_c}$‡
Deformed wire	$0.03d_b f_y/\sqrt{f'_c}$

*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

§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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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 required)/(A_s provided)

Reinforcement enclosed within spiral reinforcement not less than ¼-inch diameter and not more than 4-inch pitch 0.75

(d) **Development of Deformed Bars in Compression.** 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.

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 applicable factors for:

Reinforcement in excess of that required by analysis . . . . . (A_s required)/(A_s provided)

Reinforcement enclosed within spiral reinforcement not less than ¼-inch diameter and not more than 4-inch pitch 0.75

(e) **Development of Bundled Bars.** 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) **Standard Hooks in Tension.** Standard hooks shall be considered to develop a tensile stress in bar reinforcement

$$f_h = \xi \sqrt{f'_c}$$

where ξ is not greater than values in Table No. 26-E.

An equivalent embedment length l_e of a standard hook may be computed using provisions of Section 2612 (c) by substituting f_h for f_y and l_e for l_d.

Hooks shall not be considered effective in developing reinforcement in compression.

(g) **Mechanical Anchorage.** Any mechanical device capable of developing the strength of reinforcement without damage to concrete may be used as anchorage.

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Test results showing adequacy of such mechanical devices shall be presented to the building official.

(h) **Combination Development Length.** Development length l_d in tension may consist of a combination of equivalent embedment length of a hook or mechanical anchorage plus additional embedment length of reinforcement.

(i) **Development of Welded Deformed Wire Fabric in Tension.** 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 (t) and development of web reinforcement by Section 2612 (o).

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

$$0.03 d_b (f_y - 20{,}000) / \sqrt{f'_c} \text{ *}$$

*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.

(j) **Development of Welded Smooth Wire Fabric in Tension.** 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 $(A_s \text{ required})/(A_s \text{ provided})$ 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 Seetion 2612 (u).

(k) **Development of Prestressing Strand.** 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.

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where d_b is strand diameter in inches, and f_{ps} and f_{se} are expressed in kips per square inch.

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 the end of a member, bonded development length specified in above shall be doubled.

(l) **Development of Flexural Reinforcement—General.** 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 (m) 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 β_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.

(m) **Development of Positive Moment Reinforcement.** 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 Section 2612 (m) 1 shall be anchored to develop the specified yield strength f_y in

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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) satisifies the following:

$$l_d \leq \frac{M_n}{V_u} + l_a \quad \text{.....(12-1)}$$

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 sum of the embedment length beyond the center of support and the equivalent embedment length of any hook or mechanical anchorage provided.

l_a at a point of inflection shall be limited to the effective depth or member of 12 d_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.

(n) **Development of Negative Moment Reinforcement.** 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 Sections 2612 (b) and 2612 (l) 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.

(o) **Development of Web Reinforcement.** 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 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

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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 (11-18).

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, sueh 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.

(p) **Splices of Reinforcement—General.** 1. 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. Lap splices shall not be used for bars larger than No. 11, except as provided in Section 2615 (i) 6.

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.

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 (p) 3 C or D may be used in accordance with Section 2612 (q) 4.

(q) **Splices of Deformed Bars and Deformed Wire in Tension.** 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:

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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 accordance with Section 2612 (c).

2. Lap splices of deformed bars and deformed wire in tension shall conform to Table No. 26-H .

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 (p) 3 C and D.

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 (p) 3 C and D and be staggered at least 1.7 l_d.

(r) **Splices of Deformed Bars in Compression.** 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.

In tied reinforced 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 device.

Bar ends shall terminate in flat surfaces within 1½ 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 Section 2612 (p) 3 C and D.

(s) **Special Splice Requirements for Columns.** 1. Where factored load stress in longitudinal bars in a column, calculated for various loading combinations,

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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 each face of the column by splices alone or by spliees 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 eolumn but not less than required by Seetion 2612 (s) 3.

2. Where factored load stress in longitudinal bars in a column, calculated for any loading eombination, exceeds one half f_y in tension, lap spliees designed to develop the specified yield strength f_y in tension, or full-welded splices or full mechanical connections in accordance with Section 2612 (p) 3 C and D.

3. At horizontal cross sections of columns where splices are located, a minimum tensile strength in each face of the column equal to one fourth the area of vertical reinforcement in that face multiplied by f_y shall be provided.

(t) **Splices of Welded Deformed Wire Fabric in Tension.** 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 each fabric sheet shall be not less than 2 inches, l_d shall be the development length for the specified yield strength f_y in accordance with Section 2612 (i).

Lap splices of welded deformed wire fabric, with no cross wires within the lap splice length, shall be determined as for deformed wire.

(u) **Splices of Welded Smooth Wire Fabric in Tension.** Minimum 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 (j).

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 $1.5\,l_{d2}$, nor 2 inches, l_d shall be the development length for the specified yield strength f_y in accordance with Section 2612 (j).

Slab Systems with Multiple Square or Rectangular Panels

Sec. 2613. (a) **Notations:**

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_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 (13-8).

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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 α and β_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.

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.

α = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by centerlines of adjacent panels (if any) on each side of the beam:

$$= \frac{E_{cb}I_b}{E_{cs}I_s}$$

α_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.

$$= \frac{\Sigma K_c}{\Sigma (K_s + K_b)}$$

α_{ec} = ratio of flexural stiffness of equivalent column to combined flexural

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stiffness of the slabs and beams at a joint taken in the direction of the span for which moments are being determined.

$= \dfrac{K_{ec}}{\Sigma (K_s + K_b)}$

α_{min} = minimum α_c to satisfy Section 2613 (h) 10 A.

α_1 = α in direction of l_1.

α_2 = α in direction of l_2

β_a = ratio of dead load per unit area to live load per unit area (in each case without load factors).

β_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.

$= \dfrac{E_{cb}C}{2E_{cs}I_s}$

δ_s = factor defined by Formula (13-5). See Section 2613 (h) 10.

γ_f = fraction of unbalanced moment transferred by flexure at slab-column connections. See Section 2613 (d) 6.

(b) **Scope.** 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 shall be considered for structural purposes that lies outside the largest right circular cone or pyramid with a 90-degree vertex that can be included within the outlines of a supporting element.

3. Solid slabs and slabs with recesses or pockets made by permanent or removable fillers between ribs or joists in two directions are included within the scope of this section.

4. Slabs with paneled ceilings are included within the scope of this section, provided the panel of reduced thickness lies entirely within middle strips, and is not less than two thirds the thickness of the remainder of the slab, exclusive of the drop panel, nor less than 4 inches thick.

5. Minimum thickness of slabs designed in accordance with this section shall be as required by Section 2609 (f) 3.

(c) **Definitions.** 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.** 1. A slab system may be designed by any procedure satisfying conditions of equilibrium and geometrical compatibility if shown that

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the design strength at every section is at least equal to the required strength considering Section 2609 (c), and that all serviceability conditions, including specified limits on deflections, are met.

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) 5.

The fraction of unbalanced moment not transferred by flexure shall be transferred by eccentricity of shear in accordance with Section 2611 (m) 2.

5. The fraction of the unbalanced moment given by

$$\gamma_f = \frac{1}{1 + \frac{2}{3}\sqrt{\frac{c_1 + d}{c_2 + d}}} \qquad (13\text{-}1)$$

shall be considered transferred by flexure over 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.

Concentration of reinforcement over the column by closer spacing or additional reinforcement 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.** 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 α greater than 1.0, special top and bottom slab reinforcement shall be provided at exterior corners in accordance with the following:

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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 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.** 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

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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.** 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 within a panel not greater than 2.

C. Successive span lengths 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.

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

$$M_o = \frac{w l_2 l_n^2}{8} \quad \text{.....(13-3)}$$

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

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walls. Value of l_n used in Formula (13-3) shall be not less than $0.65l_1$. 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

In an end span, total static moment M_o shall be distributed as follows:

Interior negative factored moment ..... $0.75 - \dfrac{0.10}{1 + \dfrac{1}{\alpha_{ec}}}$

Positive factored moment ..... $0.63 - \dfrac{0.28}{1 + \dfrac{1}{\alpha_{ec}}}$

Exterior negative factored moment ..... $\dfrac{0.65}{1 + \dfrac{1}{\alpha_{ec}}}$

where α_{ec} is computed in accordance with Section 2613 (i) 7 for the exterior column.

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.

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:

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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

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 according to this paragraph, beams shall be proportioned to resist moments caused by loads applied directly on beams.

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

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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.

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.

$$M = \frac{0.08\ [(w_d + 0.5w_l)\ l_2 l_n^2 - w'_d\ l'_2\ (l'_n)^2]}{1 + \frac{1}{\alpha_{ec}}} \quad \ldots\ldots\ldots (13\text{-}4)$$

where w'_d, l'_2 and l'_n refer to shorter span.

10. **Provisions for effects of pattern loadings.** Where ratio β_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 α_c is not less than α_{min} specified in Table No. 26-F.

B. If α_c for the columns above and below the slab is less than α_{min} specified in Table No. 26-F, positive factored moments in panels supported by such columns shall be multiplied by the coefficient δ_s determined from Formula (13-5).

$$\delta_s = 1 + \frac{2 - \beta_{ta}}{4 + \beta_{ta}} \left(1 - \frac{\alpha_c}{\alpha_{min}}\right) \quad \ldots\ldots\ldots\ldots\ldots (13\text{-}5)$$

where β_a is ratio of dead load to live load, per unit area (in each case without load factors).

(i) **Equivalent Frame Method.** 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

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equivalent frames on column lines taken longitudinally and transversely through the building. Each frame shall consist of a row of equivalent 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.

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 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. **Equivalent columns.** An equivalent column shall be assumed to consist of the actual columns above and below the slab-beam plus an attached torsional member [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 column. Flexibility (inverse of stiffness) of an equivalent column shall be taken as the sum of the flexibilities of the actual columns above and below the slab-beam and the flexibility of the attached torsional member as expressed by Formula (13-6).

$$\frac{1}{K_{ec}} = \frac{1}{\Sigma K_c} + \frac{1}{K_t} \quad \text{.....(13-6)}$$

In computing stiffness of columns K_c, 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 shall be assumed infinite from top to bottom of the slab-beam at a joint.

5. **Attached torsional members.** Attached 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.

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Stiffness K_t of an attached torsional member shall be calculated by the following expression:

$$K_t = \Sigma \frac{9E_{cs}C}{l_2\left(1 - \frac{c_2}{l_2}\right)^3} \quad \text{.....(13-7)}$$

where c_2 and l_2 relate to the transverse spans on each side of column. The constant C in Formula (13-7) may be evaluated for the cross section by dividing it into separate rectangular parts and carrying out the following summation:

$$C = \Sigma \left(1 - 0.063\frac{x}{y}\right)\frac{x^3y}{3} \quad \text{.....(13-8)}$$

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.

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 sections across the slab-beam strip of each frame may be

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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.

Moments determined for the equivalent columns in the frame analysis shall be used in design of the actual columns above and below the slab beams.

Walls

Sec. 2614. (a) **Notations.**

A_g = gross area of section, square inches.
f'_c = specified compressive strength of concrete, psi.
h = overall thickness of member, inches.
l_c = vertical distance between supports, inches.
P_{nw} = nominal axial load strength of wall designed by Section 2614 (c).
ϕ = strength reduction factor. See Section 2609 (o).

(b) **Structural Design.** Walls shall be designed for any lateral or other loads to which they are subjected. Proper provisions shall be made for eccentric loads and lateral forces.

Unless designed in accordance with Section 2614 (c), walls subject to combined flexure and axial loads shall be designed under the provisions of Section 2610 (p).

(c) **Empirical Design Method.** 1. Walls may be designed by the empirical provisions under this section if resultant of the factored axial load is located within the middle third of the overall thickness of wall and all limits of this section are satisfied.

EXCEPTION: Limits of thickness and quantity of reinforcement required by this section may be waived where structural analysis shows adequate strength and stability.

2. Design axial load strength ϕP_{nw} of a wall within limitations of Section 2614 (c) 1 shall be computed by

$$\phi P_{nw} = 0.55\phi f'_c A_g \left[1 - \left(\frac{l_c}{40h}\right)^2\right] \quad \text{(14-1)}$$

where $\phi = 0.70$.

3. Length of wall to be considered as effective for each concentrated load or reaction shall not exceed center-to-center distance between loads, nor width of bearing plus four times the wall thickness.

4. Overall thickness of bearing walls shall be not less than $\frac{1}{25}$ the unsupported height or width, whichever is shorter.

5. Bearing walls shall be not less than 6 inches thick for uppermost 15 feet of wall height; and for each successive 25 feet downward (or fraction thereof), minimum thickness shall be increased 1 inch. Bearing walls of two-story dwellings may be 6 inches thick for total wall height, provided the factored axial load P_u does not exceed the design axial load strength ϕP_{nw} computed by Formula (14-1).

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6. Exterior basement walls, foundation walls, fire walls and party walls shall be not less than 8 inches thick.

7. Overall thickness of panel and enclosure walls shall be not less than 4 inches, nor less than 1/30 the distance between supporting or enclosing members.

8. Walls shall be anchored to floors, roofs, or to columns, pilasters, buttresses and intersecting walls.

9. Area of horizontal reinforcement shall be not less than 0.0025 times gross area of wall. For reinforcement with specified yield strength of 60,000 psi or greater, and not larger than No. 5 bar or W31 or D31 welded wire fabric, reinforcement ratio may be reduced to 0.0020.

Area of vertical reinforcement shall be not less than 0.0015 times gross area of wall. For reinforcement with specified yield strength of 60,000 psi or greater, and not larger than No. 5 bar or W31 or D31 welded wire fabric, reinforcement ratio may be reduced to 0.0012.

10. Walls greater 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 the 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 ¾ inch nor more than one third the thickness of wall from interior surface.

C. Bars, if used, shall be not less than No. 3 and spaced not more than 18 inches on centers. Welded wire fabric, if used, shall be in flat sheet form.

11. In addition to the minimum reinforcement required by Section 2614 (c) 9, not less than two No. 5 bars shall be provided around all (window or door) openings. Such bars shall extend at least 24 inches beyond the corners of openings.

12. Where bearing walls consist of studs or ribs tied together by other reinforced concrete members at each floor or roof level, such studs or ribs may be considered as columns.

(d) **Walls as Grade Beams.** Walls designed as grade beams shall have top and bottom reinforcement as required for moment in accordance with provisions of Section 2610 (c) through (h). Design for shear shall be in accordance with provisions of Section 2611.

Portions of grade beam walls exposed above grade also shall meet requirements of Section 2610 (p) or Section 2614 (c).

Footings

Sec. 2615. (a) **Notations.**

d_p = diameter of pile at footing base.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi.

β = ratio of long side to short side of footing.

ϕ = strength reduction factor. See Section 2609 (d).

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(b) **Scope.** 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.** 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.

(d) **Footings Supporting Circular or Regular Polygon-shaped Columns or Pedestals.** 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.** 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

*External forces and moments are those resulting from unfactored loads (D, L, W and E) specified in Chapter 23.

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shall be distributed uniformly outside center band width of footing.

$$\frac{\text{Reinforcement in band width}}{\text{Total reinforcement in short direction}} = \frac{2}{(\beta+1)} \quad \ldots\ldots\ldots (15\text{-}1)$$

(f) **Shear in Footings.** 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) 4 B.

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.

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.** 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 (l) 6.

(h) **Minimum Footing Depth.** 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 or Reinforced Pedestal.** 1. All forces and moments applied at base of column or pedestal shall be transferred to top of supporting pedestal or footing by bearing on concrete and by reinforcement. If required loading conditions include uplift, the total tensile force shall be resisted by reinforcement.

2. Lateral forces shall be transferred to footings by shear keys, or other means.

3. Bearing on concrete at contact surface between supporting and supported member shall not exceed concrete bearing strength for either surface as given in Section 2610 (q).

4. Reinforcement shall be provided across interface between supporting and

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supported member either by extending longitudinal bars into supporting member, or by dowels.

A. Reinforcement across interface shall be sufficient to satisfy both of the following:

(i) Reinforcement shall be provided to transfer all force that exceeds concrete bearing strength in supporting or supported member.

(ii) Area of reinforcement shall be not less than 0.005 times the gross area of supported member, with a minimum of four bars.

B. Diameter of dowels, if used, shall not exceed diameter of longitudinal bars by more than 0.15 inch, except as required by Section 2615 (i) 6.

5. For transfer of force by reinforcement, development of reinforcement in supporting and supported member shall be in accordance with Section 2612.

6. At footings, No. 14 and No. 18 longitudinal bars, in compression only, may be lap spliced with footing dowels to provide the required area, but not less than that required by Section 2615 (i) 4. Dowels shall be not larger than No. 11 and shall extend into the column a distance not less than the development length of the 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.

(j) **Sloped or Stepped Footings.** 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.** 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. Design stresses 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	$4\phi\sqrt{f'_c}$

2. Maximum compressive stress in plain concrete pedestals shall not exceed concrete bearing strength as given in Section 2610 (q). Where concrete bearing strength is exceeded, reinforcement shall be provided and the pedestal designed as a reinforced concrete member.

3. Plain concrete shall not be used for footings on piles.

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4. Depth of plain concrete footings shall not be less than 8 inches.

Precast Concrete

Sec. 2616. (a) **Scope.** 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.** 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.** 1. Precast bearing and nonbearing walls shall be designed in accordance with provisions of Section 2610 (p) or 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-Δ effects) and deflections are provided for in the design. See Section 2610 (h) and 2610 (k).

(d) **Details.** 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.** 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.** During curing, form removal, storage, transportation and erection, precast members shall not be overstressed, warped or otherwise damaged or have camber adversely affected.

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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

Sec. 2617. (a) **Notations.**

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.

ϕ = strength reduction factor. See Section 2609 (d).

(b) **Scope.** 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.** 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.

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.** 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.** 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 (o).

3. Extended and anchored shear reinforcement may be included as ties for horizontal shear.

(f) **Horizontal Shear Strength.** 1. In a composite member, full transfer of

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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 ¼ 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

$$V_u \leq \phi V_{nh} \quad \text{.....(17-1)}$$

where V_u is factored shear foree 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 aceordance with Section 2617 (g) and contact surfaces are clean and free of laitanee, but not intentionally roughened, shear strength V_{nh} shall not be taken greater than $80b_v d$.

C. When minimum ties are provided in accordanee with Section 2617 (g) and contact surfaces are clean, free of laitance, and intentionally roughened to a full amplitude of approximately ¼ inch, shear strength V_{nh} shall not be taken greater than $350b_v d$.

D. When faetored shear foree 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 ϕV_{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 contaet may be assumed only when minimum ties are provided in aeeordance with Seetion 2617 (g).

(g) **Ties for Horizontal Shear.** 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 intereonnected elements in accordance with Section 2612 (o).

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Prestressed Concrete

Sec. 2618. (a) **Notations.**

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 prestressed reinforcement, or to combined centroid when nonprestressed tension reinforcement is included, inches.

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.

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 (18-7).

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.

α = total angular change of prestressing tendon profile in radians from tendon jacking end to any point x.

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μ = curvature friction coefficient.

ρ = ratio of nonprestressed tension reinforcement.
$= A_s/bd$.

ρ' = ratio of compression reinforcement.
$= A'_s/bd$.

ρ_p = ratio of prestressed reinforcement.
$= A_{ps}/bd$.

ϕ = strength reduction factor. See Section 2609 (d).

$\omega = \rho f_y/f'_c$.

$\omega' = \rho' f_y/f'_c$.

$\omega_p = \rho_p f_{ps}/f'_c$.

ω_w, ω_{pw}, ω'_w
= reinforcement indices for flanged sections computed as for ω, ω_p, and ω' except that b shall be the web width, and reinforcement area shall be that required to develop compressive strength of web only.

(b) **Scope.** 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 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.

(c) **General.** 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.** 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

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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.** 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 ..... $3\sqrt{f'_{ci}}$

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 uncracked 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 Stresses in Prestressing Tendons.** Tensile stress in prestressing tendons shall not exceed the following:

1. Due to tendon jacking force ..... $0.80f_{pu}$ or $0.94f_{py}$ whichever is smaller, but not greater than maximum value recommended by the manufacturer of the prestressing tendons or anchorages.

2. Pretensioning tendons immediately after prestress transfer ..... $0.70f_{pu}$

3. Posttensioning tendons immediately after tendon anchorage ..... $0.70f_{pu}$

(g) **Loss of Prestess.** 1. To determine effective prestress f_{se}, allowance for the following sources of loss of prestress shall be considered:

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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

$$P_s = P_x e^{(Kl + \mu\alpha)} \quad \text{.....(18-1)}$$

When $(Kl + \mu\alpha)$ is not greater than 0.3, effect of friction loss may be computed by

$$P_s = P_x(1 + Kl + \mu\alpha) \quad \text{.....(18-2)}$$

B. Friction loss shall be based on experimentally determined wobble K and curvature μ 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 a member may occur due to connection of member to adjoining construction, such loss of prestress shall be allowed for in design.

(h) **Flexural Strength.** 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:

$$f_{ps} = f_{pu}\left(1 - 0.5\,\rho_p \frac{f_{pu}}{f'_c}\right) \quad \text{.....(18-3)}$$

B. For members with unbonded prestressing tendons:

$$f_{ps} = f_{se} + 10{,}000 + \frac{f'_c}{100\,\rho_p} \quad \text{.....(18-4)}$$

but f_{ps} in Formula (18-4) shall not be taken greater than f_{py} nor $(f_{se} + 60{,}000)$.

3. Nonprestressed reinforcement conforming to Section 2603 (f) 2, if used with prestressing tendons, may be considered to contribute to the tensile force and

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may be included in moment strength computations at a stress equal to the specified 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.** 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 ω_p, $(\omega + \omega_p - \omega')$, or $(\omega_w + \omega_{pw} - \omega'_w)$, is not greater than 0.30.

2. When a reinforcement ratio in excess 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.

(j) **Minimum Bonded Reinforcement.** 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

$$A_s = 0.004A \quad \text{.....(18-5)}$$

A. Bonded reinforeement required by Formula (18-5) shall be uniformly distributed over precompressed tensile zone as close as practicable to extreme tension fiber.

B. Bonded reinforcement shall be required regardless of servicc load stress conditions.

One-way, unbonded, posttensioned slabs and beams shall be designed to carry the dead load of the 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.

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 service load exceeds $2\sqrt{f'_c}$, minimum area of bonded reinforcement shall be computed by

$$A_s = \frac{N_c}{0.5f_y} \quad \text{.....(18-6)}$$

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where design yield strength f_y shall not exceed 60,000 psi. Bonded reinforcement shall be uniformly distributed over precompressed tensile zone as close as practicable to extreme tension fiber.

C. In negative moment areas at column supports, minimum area of bonded reinforcement in each direction shall be computed by

$$A_s = 0.00075hl \quad \text{(18-7)}$$

where l is length of span in direction parallel to that of the reinforcement being determined. Bonded reinforcement required by Formula (18-7) 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 B, minimum length also shall conform to provisions of Section 2612.

(k) **Frames and Continuous Construction.** 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 elastic theory for any assumed loading arrangement, may be increased or decreased by not more than

$$20\left(1 - \frac{\omega + \omega_p - \omega'}{0.30}\right) \text{ percent}$$

B. The modified negative moments shall be used for calculating moments at sections within spans for the same loading arrangement.

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C. Redistribution of negative moments shall be made only when the section at which moment is reduced is so designed that ω_p, $(\omega + \omega_p - \omega')$, or $(\omega_w + \omega_{pw} - \omega'_w)$, whichever is applicable, is not greater than 0.20.

(l) **Compression Members—Combined Flexure and Axial Loads.** 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 2610 (p) 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 2610 (p) may be waived where structural analysis shows adequate strength and stability.

(m) **Slab Systems.** Prestressed slab systems reinforced for flexure in more than one direction may be designed by any procedure satisfying conditions of equilibrium and geometric compatibility. Column stiffnesses, rigidity of slab-column connections, and effects of prestressing in accordance with Section 2618 (k) shall be considered in the analysis method.

Moment and shear coefficients used for design of slab systems reinforced with nonprestressed reinforcement shall not be applied for prestressed slab systems.

(n) **Tendon Anchorage Zones.** 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.

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4. Posttensioning anchorage zones shall be designed to develop the guaranteed ultimate tensile strength of prestressing tendons using a strength reduction factor ϕ of 0.90 for concrete.

(o) **Corrosion Protection for Unbonded Prestressing Tendons.** 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.** 1. Ducts for grouted or unbonded tendons shall be mortar-tight and nonreactive with concrete, tendons or filler material.

2. Ducts for grouted single wire, strand or bar tendons shall have an inside diameter at least ¼-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.

(q) **Grout for Bonded Prestressing Tendons.** 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 grout 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.

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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.** 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.** 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.

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.** 1. Anchorages for unbonded prestressing tendons and couplers shall develop the specified ultimate strength of the tendons without exceeding anticipated set.

2. Anchorages for bonded prestressing tendons shall develop at least 90 percent of the specified ultimate strength of the tendons, when tested in an unbonded condition, without exceeding anticipated set. However, 100 percent of the specified ultimate strength of the tendons shall be developed after tendons are bonded in member.

3. Couplers shall be placed in areas approved by the building official and enclosed in housing long enough to permit necessary movements.

4. In unbonded construction subject to repetitive loads, special attention shall be given to the possibility of fatigue in anchorages and couplers.

5. Anchorage and end fittings shall be permanently protected against corrosion.

Shells and Folded Plate Members

Sec. 2619. (a) **Notations.**

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.

h = overall thickness of member, inches

ϕ = strength reduction factor. See Section 2609 (d).

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(b) **Scope and Definitions.** 1. Provisions of this section shall apply to design of thin-shell concrete structures and only to the thin-shell portions of such structures.

2. All provisions of this code not specifically excluded, and not in conflict with provisions of this section shall apply to thin-shell structures.

3. Thin shells are curved or folded slabs whose thicknesses are small compared to other dimensions. Thin shells are characterized by three-dimensional load-carrying behavior, determined by geometrical shape, boundary conditions and nature of applied load.

4. Thin shells are usually bounded by supporting members and edge members provided to stiffen the shell and distribute or carry load in composite action with that shell.

5. Elastic analysis of thin shells is any structural analysis involving assumptions that are suitable approximations of three-dimensional elastic behavior.

(c) **General.** 1. Elastic behavior shall be the accepted basis for determining internal forces, displacements and stability of thin shells. Equilibrium checks of internal forces and external loads shall be made to ensure consistency of results.

2. Approximate methods of analysis that do not satisfy compatibility of strains or stresses in thin shells may be used where experience has shown such analyses to provide safe designs.

3. Thin-shell elements shall be proportioned for the required strength in accordance with provisions of this code.

4. Investigation of thin shells for stability shall include consideration of possible reduction in buckling capacity caused by large deflections, creep effects and deviation between actual and theoretical shell surface.

5. **Supporting members.** A. Supporting members shall be designed in accordance with applicable provisions of this chapter.

B. A portion of the shell equal to the effective flange width as specified in Section 2608 (k) may be assumed to act with supporting members.

C. Within the effective flange width of shell assumed to act with supporting members, reinforcement perpendicular to supporting member shall be at least equal to that required for a T-beam flange as specified in Section 2608 (k) 5.

6. **Model analysis.** A. Analyses based on results of elastic model tests approved by the building official shall be considered as valid elastic analyses.

B. When model analysis is used, only those portions of the thin shell structure that significantly affect items under study need be simulated.

C. Every attempt shall be made to ensure that elastic model tests reveal quantitative behavior of prototype structure.

(d) **Design Assumptions.** In elastic analysis of thin shells, material may be assumed to be ideally elastic, homogeneous and isotropic.

Poisson's ratio may be assumed equal to zero.

(e) **Design Strength of Materials.** 1. Specified compressive strength of concrete f'_c at 28 days shall be not less than 3000 psi.

2. Specified yield strength of reinforcement f_y shall not exceed 60,000 psi.

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(f) **Shell Reinforcement.** 1. Area of shell reinforcement in square inches per foot of shell width shall not exceed $7.2hf'_c/f_y$ nor $29{,}000h/f_y$.

2. If deviation of shell reinforcement from lines of principal stress is greater than 10 degrees, area of shell reinforcement shall not exceed one half the value shown above.

3. Shell reinforcement shall not be spaced farther apart than five times the shell thickness, nor 18 inches.

4. Where computed principal tensile stresses in concrete due to factored loads exceed $4\phi\sqrt{f'_c}$, shell reinforcement shall not be spaced farther apart than 3 times the shell thickness.

5. Shell reinforcement shall be provided to resist the total principal tensile stress, but shall be not less than required by Section 2607 (m).

6. Shell reinforcement, assumed to act at middle surfaces of shell, may be placed either parallel to lines of principal tensile stress, or in two or three component directions.

7. In regions of high tension, shell reinforcement shall be placed in general direction of principal stresses.

8. Shell reinforcement may be considered parallel to a line of principal stress when its direction does not deviate from the line of principal stress by more than 15 degrees.

9. Where excess shell reinforcement is provided, the 15-degree deviation limit of Section 2619 (f) 8 may be increased 1 degree for each 5 percent decrease in stress below specified yield strength f_y.

10. Variations in direction of principal stress over cross section of shell due to moments need not be considered for determination of maximum deviation.

11. Nonprestressed shell reinforcement placed in more than one direction shall be proportioned to resist the components of principal tensile stresses in each direction.

12. Where tensile stresses vary greatly in magnitude over the shell (as for long barrel shells and domes), reinforcement resisting the total tension may be concentrated in regions of maximum tensile stress. However, area of shell reinforcement in any portion of the tensile zone shall be not less than 0.0035 times gross cross-sectional area of shell.

13. Shell reinforcement required for flexure shall be proportioned with due regard to axial forces.

14. Splices in principal tensile reinforcement shall conform to provisions of Section 2612.

15. Shell reinforcement at junction of shell and supporting members or edge members shall be anchored in or through supporting members by embedment length, hooks or mechanical anchorage in accordance with Section 2612.

(g) **Prestressing.** 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.

(h) **Construction.** 1. When removal of formwork is based on a specific modulus of elasticity of concrete for stability or deflection considerations,

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required modulus of elasticity shall be determined by tests of field-cured beams.

2. Dimensions of test beams and test procedures shall be specified by the building official.

3. Proportions and loading of test beams shall ensure action that is primarily flexure.

Strength Evaluation of Existing Structures

Sec. 2620. (a) **Notations.**

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.** 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.** 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.

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.** 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.** 1. When flexural members, including beams and slabs, are load tested, the additional provisions of this subsection shall apply.

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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 (e) 8 A and B, l_t for cantilevers shall be taken as two times 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.** Members other than flexural members preferably shall be investigated by analysis.

(g) **Provision for Lower Load Rating.** 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.** Load tests shall be conducted in such a manner as to provide for safety of life and structure during the test.

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No safety measures shall interfere with load test procedures or affect results.

Pneumatically Placed Concrete

Sec. 2621. (a) **General.** For the purpose of this chapter all pneumatically placed concrete shall consist of a mixture of fine aggregate and cement pneumatically applied by suitable mechanism and to which water is added immediately prior to discharge from the applicator.

Except as specified in the following subsections of this section, all pneumatically placed concrete shall conform to the regulations of this chapter for concrete.

(b) **Proportions.** The proportion of cement to aggregate, in loose dry volumes, shall be not less than one to four and one half.

(c) **Water.** The water content at the time of discharge, including any moisture in the fine aggregate, shall not exceed 3½ gallons per sack of cement.

(d) **Mixing.** The cement and aggregate shall be thoroughly mixed prior to the addition of water. At the time of mixing, the fine aggregate shall contain not less than 3 percent moisture.

(e) **Rebound.** Any rebound or accumulated loose aggregate shall be removed from the surface to be covered prior to placing the initial or any succeeding layers of pneumatically placed concrete. Rebound may be reused if it conforms to the requirements for aggregate, but not in excess of 25 percent of the total aggregate in any batch.

(f) **Joints.** Unfinished work shall not be allowed to stand for more than 30 minutes unless all abrupt edges are sloped to a thin edge. Before resuming work, this sloped portion shall be cleaned and wetted.

(g) **Damage.** Any pneumatically placed concrete which subsides after placement shall be removed.

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.

(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.

(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

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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 3½ inches.

Bolts

Sec. 2624. Bolts shall be solidly embedded in plain or reinforced concrete, and the connection shall be designed so that the shear or tension on every bolt is no more than the value set forth in Table No. 26-G.

Ductile Moment-resisting Space Frames

Sec. 2625. (a) **General.** Design and construction of cast-in-place, monolithic reinforced concrete framing members and their connections in ductile moment-resisting space frames shall conform to the requirements of this chapter and all the requirements of this section.

EXCEPTIONS: 1. Precast concrete frame members may be used, if the resulting construction complies with all the provisions of this section.

2. Ductile moment-resisting space frames in Seismic Zones Nos. 1 and 2 may be designed in accordance with the alternate provisions of Section 2626.

All lateral load-resisting frame members shall be designed by the strength method of design except that the alternate design method of Section 2608 (j) may be used, provided that it is shown that the factor of safety is equivalent to that achieved with the strength design method.

Formulas (9-2) and (9-3) of Section 2609 (d) for earthquake loading shall be modified to:

$$U = 1.40\,(D + L + E) \quad \text{(25-1)}$$

$$U = .90\,D + 1.40E \quad \text{(25-2)}$$

Members of space frames which are designed to resist seismic forces shall be designed, in accordance with the provisions of this section, so that shear failures will not occur if the frame is subjected to lateral displacements in excess of yield displacements.

(b) **Definitions.**

CONFINED CONCRETE is concrete which is confined by closely spaced special transverse reinforcement which is provided to restrain the concrete in directions perpendicular to the applied stresses.

SPECIAL TRANSVERSE REINFORCEMENT is spirals, stirrup ties or hoops and supplementary cross ties provided to restrain the concrete to make it qualify as confined concrete.

STIRRUP TIES OR HOOPS are continuous reinforcing steel of not less than a No. 3 bar bent to form a closed hoop which encloses the longitudinal reinforcing

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and the ends of which have a standard 135-degree bend with a 10-bar-diameter extension or equivalent.

(c) **Symbols and Notations.** The following symbols and notations apply only to the provisions of this section:

A_{ch} = area of rectangular or circular core of column measured out-to-out of hoop or spiral, square inches.

A_g = gross area of column, square inches.

A_s = effective cross-sectional area of nonprestressed reinforcement, square inches.

A'_s = effective cross-sectional area of nonprestressed compression reinforcement, square inches.

A_{sh} = total cross-sectional area of hoop reinforcement, including supplementary cross ties having a spacing of s_h and crossing a section with a core dimension of h_c, square inches.

b_w = web width, or diameter of circular section, inches.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches.

d_b = nominal diameter of bar, inches.

f'_c = specified compressive strength of concrete, psi.

f_y = specified yield strength of nonprestressed reinforcement, psi.

f_{yh} = specified yield strength of hoop reinforcement, psi.

h = largest core dimension of rectangular tied column, inches.

P_e = maximum design axial load on a column during an earthquake.

$\rho = A_s/bd$ = ratio of nonprestressed tension reinforcement.

$\rho' = A'_s/bd$ = ratio of nonprestressed compression reinforcement.

s_h = center-to-center spacing of hoops, inches.

V_d = applied shear force at section due to dead load.

V_l = applied shear force at section due to live load.

V_u = total applied design shear force at section.

(d) **Physical Requirements for Concrete and Reinforcing Steel.** 1. **Concrete.** The minimum specified 28-day strength of the concrete f'_c, shall be 3000 pounds per square inch. The maximum specified strength for lightweight concrete shall be limited to 4000 psi.

2. **Reinforcement.** All longitudinal reinforcing steel in columns and beams shall comply with U.B.C. Standard No. 26-4. Reinforcing not conforming to the low-alloy steel requirements of U.B.C. Standard No. 26-4 shall comply with the following additional requirements:

A. Reinforcing shall be limited to billet steel, Grade 40 or 60 bars.

B. The actual yield stress, based on mill tests, shall not exceed the minimum specified yield stress, f_y, by more than 18,000 psi. Retests shall not exceed

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this value by more than 3000 psi.

C. The ultimate tensile stress shall be not less than 1.33 times the actual yield stress, based on mill tests.

Grades other than those specified for design shall not be used.

(e) **Flexural Members.** 1. **General.** Flexural members shall not have a width-depth ratio of less than 0.3, nor shall the width be less than 10 inches nor more than the supporting column width plus a distance on each side of the column of three fourths the depth of the flexural member. Flexural members framing into columns shall be subject to a rational joint analysis.

2. **Reinforcement.** All flexural members shall have a minimum reinforcement ratio, for top and for bottom reinforcement, of

$$\frac{200}{f_y}$$

throughout their length. The reinforcement ratio, ρ, shall not exceed 0.025. The positive moment capacity at the face of columns shall be not less than 50 percent of the negative moment capacity provided. A minimum of one fourth of the larger amount of the negative reinforcement required at either end shall continue throughout the length of the beam. At least two bars shall be provided both top and bottom.

3. **Splices.** Tensile steel shall not be spliced by lapping in a region of tension or reversing stress unless the region is confined by stirrup-ties. Splices shall not be located within the column or within a distanee of twice the member depth from the face of the column. At least two stirrup-ties shall be provided at all splices.

4. **Anchorage.** Flexural members terminating at a column, in any vertical plane, shall have top and bottom reinforcement extending, without horizontal offsets, to the far face of a confined concrete region terminating in a standard 90-degree hook. Length of required anchorage shall be computed beginning at the near face of the column. Length of anchorage in confined regions, including hook and vertical extension, shall be not less than 56 percent of the development length computed by Section 2612 (f) 1, A, B or C, but not less than 24 inches.

> **EXCEPTION:** Where the column resists less than 25 percent of the story-bent shear, at least 50 percent of such top and bottom reinforcement shall be anchored within such column cores and the remainder shall be anchored in regions outside the column core confined as specified herein for columns.

5. **Web reinforcement.** Vertical web reinforcement of not less than No. 3 bars shall be provided in accordance with the requirements of Section 2611, except that:

A. Web reinforcement shall be provided to develop the shears resulting from shear forces at the end of the member computed as

$$V_u \geq \frac{M_a + M_b}{L_{ab}} + 1.4\,(V_d + V_l) \quad \text{.....(25-3)}$$

where M_a and M_b are the ultimate moment capacities of opposite sense at each hinge location of the member and $V_d + V_l$ is the simple span shear. L_{ab} is the

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distance between M_a and M_b. The ultimate moment capacities shall be computed without the ϕ factor reduction and assuming the maximum reinforcing yield strength based on 25 percent over specified yield.

Ultimate shear capacities shall be computed with the ϕ factor reduction.

B. Stirrups shall be spaced at no more than $d/2$ throughout the length of the member.

C. Stirrup-ties, at a maximum spacing of not over $d/4$, eight bar diameters, 24 stirrup-tie diameters or 12 inches, whichever is least, shall be provided in the following locations:

(i) At each end of all flexural members. The first stirrup-tie shall be located not more than 2 inches from the face of the column and the last, a distance of at least twice the member depth from the face of the columns.

(ii) Wherever ultimate moment capacities or plastic hinges may be developed in the flexural members under inelastic lateral displacement of the frame.

(iii) Wherever required compression reinforcement occurs in the flexural members.

D. In regions where stirrup-ties are required, longitudinal bars shall have lateral support conforming to the provisions of ties for tied columns. Single or overlapping stirrup-ties and supplementary cross-ties may be used.

(f) **Columns Subject to Direct Stress and Bending.** 1. **Dimensional limitations.** The ratio of minimum to maximum column thickness shall be not less than 0.4 nor shall any dimension be less than 12 inches.

2. **Vertical reinforcement.** The reinforcement ratio, ρ, in tied columns shall be not less than 0.01 nor greater than 0.06.

3. **Splices.** Lap splices shall be made within the center half of column height, and the splice length shall be not less than 30 bar diameters. Continuity may also be effected by welding or by approved mechanical devices, provided not more than alternate bars are welded or mechanically spliced at any level and the vertical distance between these welds or splices of adjacent bars is not less than 24 inches.

4. **Special transverse reinforcement.** The cores of columns shall be confined by special transverse reinforcement as specified herein or as required to meet shear requirements.

A. The volumetric ratio of spiral reinforcement shall be not less than that required by Formula (10-3) of Section 2610 (j) nor

$$0.12\frac{f'_c}{f_{yh}} \quad \text{(25-4)}$$

whichever is greater.

B. The total cross-section area (A_{sh}) of rectangular hoop reinforcement shall be not less than the greater of

$$A_{sh} = 0.30 s_h h_c \frac{f'_c}{f_{yh}} \left(\frac{A_g}{A_{ch}} - 1\right) \quad \text{(25-5)}$$

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or

$$0.12 s_h h_c \frac{f'_c}{f_{yh}} \quad \text{.....(25-6)}$$

The center-to-center spacing of hoops; s_h, shall not exceed 4 inches.

Single or overlapping hoops may be provided to meet this requirement.

Supplementary cross ties of the same size and spacing as hoops using 135-degree minimum hooks engaging the periphery hoop and secured to a longitudinal bar may be used. Supplementary cross ties or legs of overlapping hoops shall be spaced not more than 14 inches on center transversely.

EXCEPTION: Formula (25-5) need not be complied with if the column design is based on the column core only.

C. Special transverse reinforcement shall be provided in that portion of the column over a length equal to the maximum column dimension or one sixth of the clear height of the column, but not less than 18 inches from either face of the joint.

D. At any section where the ultimate capacity of the column is less than the sum of the shears (ΣV_u) computed by Formula (25-3) for all the beams framing into the column above the level under consideration, special transverse reinforcement shall be provided. For beams framing into opposite sides of the column, the moment components of Formula (25-3) may be assumed to be of opposite sign. For the purpose of this determination the factor 1.4 in Formula (25-3) may be changed to 1.1. For determination of the ultimate capacity of the column, the moments resulting from Formula (25-3) may be assumed to result from deformation of the frame in any one principal axis.

E. Columns which support discontinuous members, such as shear walls, braced frames or other rigid elements, shall have special transverse reinforcement for the full height of the supporting columns.

5. **Column shear.** The transverse reinforcement in columns subjected to bending and axial compression shall satisfy the following requirement:

$$A_v f_y \frac{d_c}{s} = \frac{V_u}{\phi} - V_c \quad \text{.....(25-7)}$$

V_u shall be computed by using the ultimate moment capacity in the ends of either the beams or columns framing into the connection.

Ultimate moment capacities shall be computed without ρ or other reduction factors and under all possible vertical loading conditions and assuming the maximum reinforcing yield strength based on 25 percent over specified yield. Shear strength shall be computed based on the column core area.

WHERE:

$V_c = v_c A_{ch}$, where v_c shall be in accordance with Section 2611 (e) except that v_c shall be considered zero when

$$\frac{P_c}{A_g} < 0.12 f'_c$$

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s = spacing, ≤ ½ minimum column dimension.

d_c = dimension of the column core in the direction of load, in inches.

A_v = total cross-sectional area of special transverse reinforcement in tension within a distance s, except that two thirds of such area shall be used in the case of circular spirals.

(g) **Beam-column Connection.** Special transverse reinforcement shall be provided through the beam-column connection.

1. **Analysis.** The transverse reinforcement through the connection shall be proportioned according to the requirements of Section 2626 (f) 4. The transverse reinforcement thus selected shall be checked according to the provisions specified in Section 2626 (f) 5, with the exception that the V_u acting on the connection shall be equal to the maximum shears in the connection computed by a rational analysis taking into account the column shear and the concentrated shears developed from the forces in the beam reinforcement at a stress assumed at f_y.

Special transverse column reinforcement of one half the amount otherwise required by Section 2626 (g) 1 shall be required within the connection, determined by the depth of the shallowest framing member, where such members frame into all four sides of a column and whose width is at least three fourths the column width. When a corner of a tied column, unconfined by flexural members, exceeds 4 inches, the full special transverse reinforcement shall be provided through the connection and around bars outside of the connection.

Special transverse beam reinforcing shall be provided through the beam column connection to provide confinement for longitudinal reinforcement outside the column core where sueh confinement is not provided by another beam framing into the connection.

2. **Design limitations.** At any beam-column connection where $P_e/A_g \geq 0.12 f'_c$ the sum of the moment strengths of the columns, at the design earthquake axial load, shall be greater than the sum of the moment strengths of the beam, along their principal planes at that connection.

> **EXCEPTION:** Where certain beam-column connections at any level do not comply with the above limitations, the remaining columns and connected flexural members shall comply and, further, shall be capable of resisting the entire shear at that level accounting for the altered relative rigidities and torsion resulting from the omission of elastic action of the nonconforming beam-column connections.

(h) **Inspection.** For buildings designed under this section, a specially qualified inspector under the supervision of 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.

Ductile Moment-resisting Space Frames—Alternate Provisions for Seismic Zones No. 1 and No. 2

Sec. 2626. (a) **General.** Design and construction of earthquake-resisting reinforced concrete framing members and their conneetions conforming to the general requirements of this chapter and the special requirements of this section

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shall be deemed to meet the requirements for a ductile moment-resisting space frame of Section 2312 (j) for buildings in Seismic Zones No. 1 and No. 2, provided the horizontal force factor, K, is not taken less than unity when computing seismic forces under Section 2312 (d).

(b) **Flexural Members.** Web reinforcement shall be required throughout the length of the member. It shall be designed according to Section 2611 except that such web reinforcement shall be not less than 0.15 percent of the area computed as the product of the width of the web and the spacing of web reinforcement along the longitudinal axis of the member. The first stirrup shall be located 2 inches from the column face. The next six stirrups shall be spaced not over $d/4$.

Positive moment reinforcement at the supports of flexural members subject to reversal of moments shall be anchored by bond, hooks or mechanical anchors in or through the supporting member to develop the yield strength of the bar.

Lapped splices located in a region of tension or reversing stress shall be confined by at least two stirrups at each splice.

(c) **Columns.** Additional lateral reinforcement shall be provided for columns as prescribed in this subsection. The spacing of ties at the ends of tied columns shall not exceed 4 inches for a distance equal to the maximum column dimension but not less than one sixth of the clear height of the column from the face of the joint. The first such tie shall be located 2 inches from the face of the joint. Joints of exterior and corner columns shall be confined by lateral reinforcement through the joint. Such lateral reinforcement shall consist of spirals or ties as required at the ends of columns.

Earthquake-resisting Concrete Shear Walls and Braced Frames

Sec. 2627. (a) **General.** Design and construction of earthquake-resisting reinforced concrete shear walls and reinforced concrete braced frames subjected primarily to axial stresses for all buildings shall conform to the requirements of this chapter.

Shear walls and vertical bracing frames shall be designed by the strength design method except that the alternate design method of Section 2608 (j) may be used, provided that the factor of safety in shear is equivalent to that achieved with the strength design method.

Formulas (9-2) and (9-3) of Section 2609 (d) for earthquake loading shall be modified to:

$$U = 1.4\,(D + L) + 1.4E \quad \text{(27-1)}$$

$$U = 0.9\,D + 1.4E \quad \text{(27-2)}$$

provided, further, that $2.0E$ shall be used in Formulas (27-1) and (27-2) in calculating shear and diagonal tension stresses in shear walls of buildings other than those complying with requirements for buildings with $K = 0.67$.

(b) **Braced Frames.** Reinforced concrete members of braced frames subjected primarily to axial stresses shall have special transverse reinforcing as specified in Section 2626 (f) 4 throughout the full length of the member. Tension members shall additionally meet the requirements for compression members.

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(c) **Vertical Boundary Members for Shear Walls.** Special vertical boundary elements shall be provided at the edges of concrete shear walls in buildings whose lateral force resisting system is as described in Table No. 23-I for a K of .80. These elements shall be composed of concrete-encased structural steel elements of A36, A441, A500 Grades B and C, A501, A572 (except Grades 60 and 65) or A588, or shall be concrete reinforced as required for columns in Section 2626 (f) with special transverse reinforcement as described in Section 2626 (f) 4 for the full length of the element. The longitudinal reinforcing in these concrete boundary elements shall conform to the requirements of Section 2626 (d) 2.

EXCEPTION: The special transverse reinforcement may be omitted in Seismic Zones No. 1 and No. 2 when the combined dead load, live load and seismic stresses are not over one half of those otherwise allowed.

The boundary vertical elements and such other similar vertical elements as may be required shall be designed to carry all the vertical stresses resulting from the wall loads in addition to tributary dead and live loads and from the horizontal forces as prescribed in Section 2312. Horizontal reinforcing in the walls shall be fully anchored to the vertical elements.

EXCEPTION: In Seismic Zones No. 1 and No. 2 the vertical boundary elements may be designed to carry all vertical stresses resulting from tributary dead and live loads not supported by the shear walls acting as bearing walls.

Similar confinement of horizontal and vertical boundaries at wall openings also shall be provided unless it can be demonstrated that the unit compressive stresses at the opening have a load factor two times that required by Formulas (27-1) and (27-2) above.

(d) **Wall Reinforcement.** Wall reinforcement required to resist wall shear shall be terminated with not less than a 90-degree bend plus a six-bar-diameter extension beyond the boundary reinforcing at vertical and horizontal end faces of wall sections. Wall reinforcement terminating in boundary columns or beams shall be fully anchored into the boundary elements.

Alternate Design Method

Sec. 2628. (a) **Notation.** 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.

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).

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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.

β_c = ratio of long side to short side of concentrated load or reaction area.

α = angle between inclined stirrups and longitudinal axis of member.

ρ = ratio of tension reinforcement.

$= A_s/bd$.

ϕ = strength reduction factor. See Section 2628 (c).

(b) **Scope.** 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.** Load factors and strength reduction factors ϕ 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 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.** 1. Stresses in concrete shall not exceed the following:

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A. Flexure.	
Extreme fiber stress in compression	$0.45f'_c$
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**	$0.3f'_c$

+For more detailed calculation of shear stress carried by concrete v_c and shear values for lightweight aggregate concrete, see Section 2628 (i).

*Designed in accordance with Section 2608 (l) of this code.

‡If shear reinforcement is provided, see Sections 2628 (l) 4 and 2628 (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, ⅜ inch or less in diameter, in one-way slabs of not more than 12-foot span	$0.50f_y$
but not greater than	30,000 psi

(e) **Development and Splices of Reinforcement.** Development and splices of reinforcement shall be as required in Section 2612. In satisfying requirements of Section 2612 (m), 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.

(f) **Flexure.** 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.

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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 $2E_s/E_c$ 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.** 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 Sections 2610 (k) and 2610 (l). In Formula (10-7), the term P_u shall be replaced by 2.5 times the design axial load, and ϕ shall be taken equal to 1.0.

Walls shall be designed in accordance with Section 2614 with combined flexure and axial load capacity taken as 40 percent of that computed in accordance with Section 2614 (c) or Section 2610 (p). In Formula (14-1), ϕ shall be taken equal to 1.0.

(h) **Shear and Torsion.** Design shear stress v shall be computed by:

$$v = \frac{V}{b_w d} \quad \text{.....(28-1)}$$

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 2628 (i) 4.

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 2628 (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

$$v_c = 1.1\left(1 + 0.004\frac{N}{A_g}\right)\sqrt{f'_c} \quad \text{.....(28-2)}$$

where N is negative for tension. Quantity N/A_g shall be expressed in psi.

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4. For members subject to shear and flexure only, v_c may be computed by

$$v_c = \sqrt{f'_c} + 1300\,\rho_w \frac{Vd}{M} \quad \text{(28-3)}$$

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 occuring simultaneously with V at section considered.

5. For members subject to axial compression, v_c may be computed by

$$v_c = 1.1\left(1 + 0.0006\frac{N}{A_g}\right)\sqrt{f'_c} \quad \text{(28-4)}$$

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 inelined 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.

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 (o) 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

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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 ean 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

$$A_v = 50\frac{b_w s}{f_y} \quad \text{.....(28-5)}$$

where b_w and s are in inehes.

6. **Design of shear reinforcement.** Where design shear stress v exeeeds 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,

$$A_v = \frac{(v - v_c)\, b_w s}{f_s} \quad \text{.....(28-6)}$$

When included stirrups are used as shear reinforcement,

$$A_v = \frac{(v - v_c)\, b_w s}{f_s (\sin\alpha + \cos\alpha)} \quad \text{.....(28-7)}$$

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,

$$A_v = \frac{(v - v_c)\, b_w d}{f_s \sin\alpha} \quad \text{.....(28-8)}$$

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 (28-7).

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

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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 $4\sqrt{f'_c}$.

(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) 3. Permissible stress in shear friction reinforcement shall be that given in Section 2628 (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 2628 (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 2628 (l) 2 and 2628 (l) 3.

2. Design shear stress v shall be computed by

$$v = \frac{V}{b_o d} \quad \text{.....(28-9)}$$

where V and b_o shall be taken at the critical section defined in Section 2628 (l) 1 B.

3. Design shear stress v shall not exceed v_c given by Formula (28-10) unless shear reinforcement is provided.

$$v_c = \left(1 + \frac{2}{\beta_c}\right)\sqrt{f'_c} \quad \text{.....(28-10)}$$

but v_c shall not exceed $2\sqrt{f'_c}$. β_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 2628 (i) 6 shall apply.

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 2628 (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

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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.

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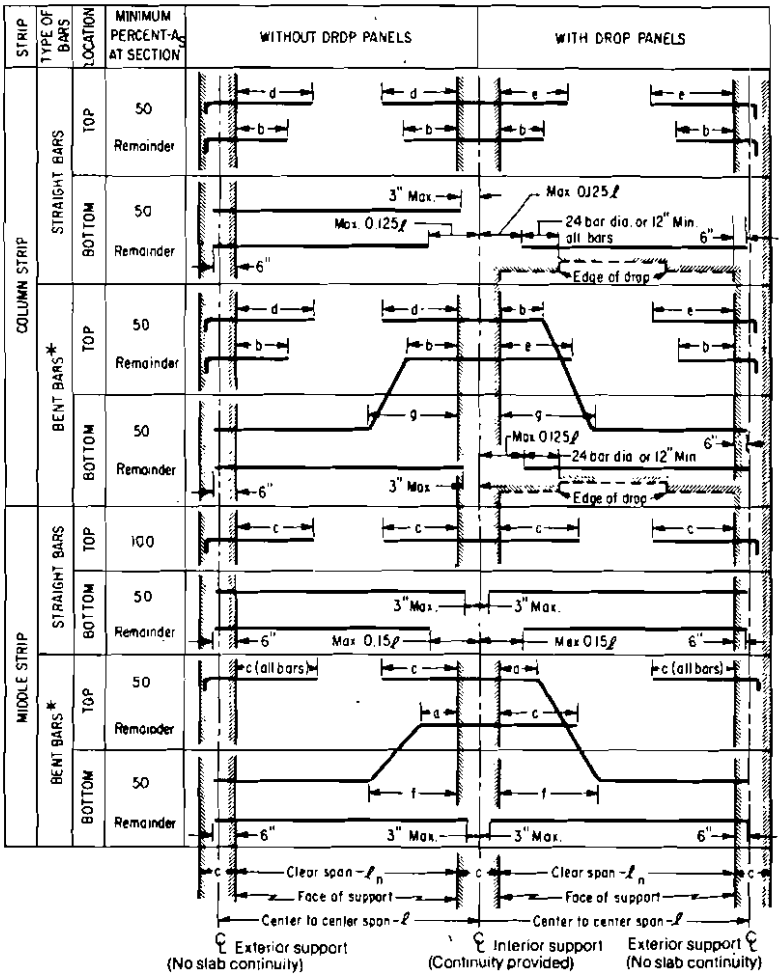

* Bent bars at exterior supports may be used if a general analysis is made

	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 (m) 1 for reinforcement extension into supports.]

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TABLE NO. 26-A—MAXIMUM PERMISSIBLE WATER-CEMENT RATIOS FOR CONCRETE WHEN STRENGTH DATA FROM TRIAL BATCHES OR FIELD EXPERIENCE ARE NOT AVAILABLE

Specified Compressive Strength, f'_c, psi[1]	MAXIMUM PERMISSIBLE WATER-CEMENT RATIO			
	Nonair-entrained Concrete		Air-entrained Concrete	
	Absolute Ratio by Weight	U.S. Gal. Per 94-lb. Bag of Cement	Absolute Ratio by Weight	U.S. Gal. Per 94-lb. Bag of Cement
2500	0.67	7.6	0.54	6.1
3000	0.58	6.6	0.46	5.2
3500	0.51	5.8	0.40	4.5
4000	0.44	5.0	0.35	4.0
4500	0.38	4.3	[2]	[2]
5000	[2]	[2]	[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) 1 as being required.

[2]For strengths above 4500 psi (nonair-entrained concrete) and 4000 psi (air-entrained concrete), proportions shall be established by methods of Section 2604 (d) or (e).

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
⅜	6 to 10
½	5 to 9
¾	4 to 8
1	3.5 to 6.5
1½	3 to 6
2	2.5 to 5.5
3	1.5 to 4.5

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TABLE NO. 26-C-1—BEND TEST REQUIREMENTS

BAR DESIGNATION	PIN DIAMETER FOR BEND TEST
Nos. 3, 4 and 5	$3\frac{1}{2}d_b$
Nos. 6, 7 and 8	$5d_b$
Nos. 9, 10 and 11	$7d_b$
Nos. 9, 10 and 11 (of Grade 40)	$5d_b$

TABLE NO. 26-C-2—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—ξ VALUES[1]

BAR SIZE	f_y = 60 ksi		f_y = 40 ksi
	TOP BARS	OTHER BARS	ALL BARS
Nos. 3 to 5	540	540	360
No. 6	450	540	360
Nos. 7 to 9	360	540	360
No. 10	360	480	360
No. 11	360	420	360
No. 14	330	330	330
No. 18	220	220	220

[1]Values of ξ may be increased 30 percent where enclosure is provided perpendicular to plane of hook. Enclosure may consist of external concrete or internal closed ties, spirals or stirrups. See Section 2607 (j).

TABLE NO. 26-F—VALUES OF α_{min}

β_a	ASPECT RATIO l_2/l_1	RELATIVE BEAM STIFFNESS, α				
		0	0.5	1.0	2.0	2.0
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-G—ALLOWABLE SHEAR AND TENSION ON 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
¼	2½	500	500	200
⅜	3	1100	1100	500
½	4	2000	2000	950
⅝	4	2750	3000	1500
¾	5	2940	3560	2250
⅞	6	3580	4150	3200
1	7	3580	4150	3200
1⅛	8	3580	4500	3200
1¼	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-H—TENSION LAP SPLICES[1]

A_s PROVIDED[2] / 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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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 shall be tested to determine conformity to such standard. The fabricator shall,

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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 = Nominal 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; equal to

$$\frac{\pi^2 E k \sqrt{3}}{12\ (1 - v^2)\ (h/t)^2 F_u}$$

or

$$\frac{190}{h/t}\sqrt{\frac{k}{F_u}}$$

[See Section 2707(e)].

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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.

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_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.

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M_1 = Smaller moment at end of unbraced length of beam-column.

M_2 = Larger moment at end of unbraced length of beam-column.

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.

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).

$P_{cr} = 1.70AF_a$.

$$P_e = \frac{\pi^2 EI}{l^2} \text{ (kips)}$$

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.

V'_h = Total horizontal shear to be resisted by connectors in providing partial composite action (kips). See Section 2708 (d).

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.

a = Clear distance between transverse stiffeners.

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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.

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.

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t_f = 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.

α = Ratio of hybrid girder web yield stress to flange yield stress.

Δ = Displacement of the neutral axis of a loaded member from its position when the member is not loaded.

β = 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 effective slenderness ratio of any unbraced segment as defined in Section 2705, is less than C_c.

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right]F_y}{\text{F.S.}} \qquad \text{.....(2-1)}$$

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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.

$$F_a = \frac{12\pi^2 E}{23(Kl/r)^2} \quad \text{(2-2)}$$

On the gross section of axially loaded bracing and secondary members, when l/r exceeds 120 (for this case K is taken as unity).

$$F_{as} = \frac{F_a \text{ [by Formula (2-1) or (2-2)]}}{1.6 - \frac{l}{200r}} \quad \text{(2-3)}$$

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:

$$\frac{190}{\sqrt{F_u}}$$

(iv) The depth-thickness ratio of the web or webs does not exceed:

$$\frac{640\,(1 - 3.74\,\frac{f_u}{F_u})}{\sqrt{F_u}} \text{ when } \frac{f_u}{F_u} \leq 0.16 \qquad \text{(2-4)}$$

nor:

$$\frac{257}{\sqrt{F_u}} \text{ when } \frac{f_u}{F_u} > 0.16$$

(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[1]

$$F_p = \left(\frac{F_y - 13}{20}\right) 0.66d$$

where d is the diameter of roller or rocker in inches.

[1]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).

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(d) **Welds.** Except as modified by Section 2704, weld stresses shall comply with Table No. 27-B.

(e) **Effective Areas of Weld Metal.** The effective area of groove and fillet welds shall be considered as the effective length of the weld times the effective throat thickness.

The effective 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 surface.

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 ⅜ inch and smaller fillet welds and equal to the theoretical throat plus 0.11 inch for fillet welds over ⅜ 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 ⅛ inch for grooves having an included 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 effective throat of a partial joint penetration groove weld shall be the depth 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 metal arc, flux-cored arc or electrogas 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 arc welding.

The effective throat thickness 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 sections 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 consistently larger effective throats than those shown in Table No. 27-F can be provided, such larger effective throats may be established by qualification.

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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 construction.

(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, $C_m = 1$.

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(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.

(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	$F_v \leq 22.0\ (1 - f_t A_b / T_b)$

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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.

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.

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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	$127/\sqrt{F_y}$

(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 (Assumes net area of plate at widest hole in computing compression stress.)	$317/\sqrt{F_y}$
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

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$0.15F_y$ 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

$$\frac{14{,}000\ (t)}{\sqrt{F_y\ (F_y + 16.5)}}$$

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 (c) 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

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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 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:

$$F_v = \frac{F_y\,(C_v)}{2.89} \leqq 0.4F_y \quad \ldots\ldots\ldots\ldots\ldots\ldots (7\text{-}1)$$

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:

$$F_v = \frac{F_y}{2.89}\left[C_v + \frac{1 - C_v}{1.15\sqrt{1 + (a/h)^2}}\right] \leqq 0.4F_y \quad \ldots\ldots\ldots\ldots (7\text{-}2)$$

(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

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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:

$$\left(\frac{260}{h/t}\right)^2 \text{ nor } 3.0.$$

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).

$$A_{st} = \frac{1 - C_v}{2}\left[\frac{a}{h} - \frac{(a/h)^2}{\sqrt{1 + (a/h)^2}}\right] YDht \quad \ldots\ldots\ldots\ldots (7\text{-}3)$$

(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

$$f_{vs} = h\sqrt{\left(\frac{F_y}{340}\right)^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7\text{-}4)$$

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

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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.

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:

$$F'_b \leqq F_b \left[1.0 - 0.0005 \frac{A_w}{A_f}\left(\frac{h}{t} - \frac{760}{\sqrt{F_b}}\right)\right] \quad \ldots\ldots\ldots\ldots\ldots (7\text{-}5)$$

The maximum stress in either flange of a hybrid girder shall not exceed F'_b in Formula (7-5) nor

$$F'_b \leqq F_b \left[\frac{12 + \left(\frac{A_w}{A_f}\right)(3\alpha - \alpha^3)}{12 + 2\,(A_w/A_f)}\right] \quad \ldots\ldots\ldots\ldots\ldots (7\text{-}6)$$

WHERE:

a = 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:

$$0.6F_y \text{ nor } \left(0.825 - 0.375\,\frac{f_v}{F_v}\right)F_y \quad \ldots\ldots\ldots\ldots\ldots (7\text{-}7)$$

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

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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 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.

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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 beam nor more than eight times the slab thickness. When the slab is present on only one side of the beam, the effective width 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

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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.

Where shear connectors in conformance with Section 2708 (d) are not provided, the effective section modulus used in stress calculations shall not exceed:

$$S_{eff} = S_s + \sqrt{\frac{V'_h}{V_h}}\,(S_{tr} - S_s) \qquad (8\text{-}1)$$

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.

$$S_{tr} = \left(1.35 + 0.35\,\frac{M_L}{M_D}\right) S_s \qquad (8\text{-}2)$$

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 $0.45f'_c$.

(c) **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

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composite action with concrete subject to flexural compression, the total horizontal 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

$$V_h = \frac{A_s F_u}{2} \quad \text{(8-4)}$$

$A'_s F_{yr}/2$ 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:

$$\frac{V_h}{q} \quad \text{(8-6)}$$

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 multipled 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.

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

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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

$$\frac{s^2}{4g}$$

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 whieh 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. Unless a larger coefficient ean be justified by tests or by other recognized criteria, the effective net area A_e of axially loaded tension members whose profile consists of segments not in a common plane and which are connected by some, but not all, of these segments by rivets or bolts, shall be computed as follows:

A. *W, M,* or *S* shapes with flange width not less than two thirds the depth, and structural tees cut from these shapes, $A_e = 0.90A_n$, provided the connection is to the flanges and has no fewer than three fasteners per line.

B. For all other shapes, including built-up cross sections, $A_e = 0.85A_n$, provided the conneetion has no fewer than three fasteners per line.

C. All members whose connections have only two fasteners per line, $A_e = 0.75A_n$.

3. Riveted and bolted splice and gusset plates and other connection fittings subject to tensile force shall be designed in aceordance 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 eoncentrie 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 ½ inch. The net area of the head through the pinhole, transverse to the axis of the eyebar, shall be not less than 1.33 nor more than 1.50 times the eross-sectional area of the body of the eyebar. The

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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 contact. 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 connections shall be designed for eccentricity where the gravity axes of the connected 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. 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

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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.

$$A_{st} \geq \frac{P_{bf} - F_{yc}\, t\,(t_b + 5k)}{F_{yst}} \qquad (12\text{-}1)$$

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 ¾ 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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$$d_c > \frac{4100\, t_f^2 \sqrt{F_{yc}}}{P_{bf}} \quad \text{(12-2)}$$

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 2⅓:12. 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 critical 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 exeeed 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

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calculated stress across a joint or faying surfaces, when the strength required is 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 eenter-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

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U.B.C. Standard No. 27-13.

Built-up Members

Sec. 2715. (a) **Open Web Steel Joists, H, LH, and DLH Series, and Joist Girders.** Open web 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

$$\frac{127t}{\sqrt{F_u}}$$

but not more than 12 inches.

When rivets, bolts or welds are staggered

$$\frac{190t}{\sqrt{F_u}}$$

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 exeeed $0.85P_y$, 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 faetored 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:

$$P_{cr} = 1.7AF_a \quad \text{.....(21-1)}$$

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:

$$\frac{P}{P_{cr}} + \frac{C_m M}{\left(1 - \frac{P}{P_e}\right) M_m} \leqq 1.0 \quad \text{.....(21-2)}$$

$$\frac{P}{P_y} + \frac{M}{1.18M_p} \leqq 1.0; \; M \leqq M_p \quad \text{.....(21-3)}$$

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:

$$\frac{P}{P_u} \leqq 0.27$$

$$\frac{d}{t} = \frac{412}{\sqrt{F_u}}\left(1 - 1.4\,\frac{P}{P_u}\right) \quad \text{.....(21-6a)}$$

WHERE:

$$\frac{P}{P_u} > 0.27$$

$$\frac{d}{t} = \frac{257}{\sqrt{F_u}} \quad \text{.....(21-6b)}$$

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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:

$$+1.0 > \frac{M}{M_p} > -0.5$$

$$\frac{l_{cr}}{r_y} = \frac{1375}{F_y} + 25 \quad \text{.....(21-7a)}$$

WHERE:

$$-0.5 \geqq \frac{M}{M_p} > -1.0$$

$$\frac{l_{cr}}{r_y} = \frac{1375}{F_y} \quad \text{.....(21-7b)}$$

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 latcrally 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 Ductile Moment-resisting Space Frames—Seismic Zones Nos. 3 and 4

Sec. 2722. (a) **General.** Design and construction of steel framing in ductile moment-resisting space frames in Seismic Zones No. 3 and No. 4 shall conform to the requirements of the code and to all the requirements of this section. Welding shall comply with U.B.C. Standard No. 27-6.

(b) **Definitions.** 1. **Joints.** The joint is the entire assemblage at the intersections of the members.

2. **Connections.** The connection consists of only those elements that connect the member to the joint.

(c) **Materials.** Structural steel shall conform to A36, A441, A500 (Grades B and C), A501, A572 (Grades 42, 45, 50 and 55), or A588.

EXCEPTION: Structural steel A283 Grade D may be used for base plates and anchor bolts.

(d) **Connections.** Each beam or girder moment connection to a column shall be capable of developing in the beam the full plastic capacity of the beam or girder.

EXCEPTION: The connection need not develop the full plastic capacity of the beam or girder if it can be shown that adequately ductile joint displacement capacity is provided with a lesser connection.

For steel whose specified ultimate strength is less than 1.5 of the specified yield strength, plastic hinges in beams formed during inelastic deformations of the frame shall not occur at locations in which the beam flange area has been reduced such as by holes for bolts.

(e) **Local Buckling.** Members in which hinges will form during inelastic displacement of the frames shall comply with the requirement for "plastic design sections."

(f) **Nondestructive Testing.** Welded connections between the primary members of ductile moment-resisting space frames shall be tested by nondestructive

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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 specifications.

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 splices shall be tested either by ultrasonic testing or radiography when required by the plans and specifications.

3. Base metal thicker than 1½ 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 Table No. 27-6-E of U.B.C. Standard No. 27-6.

Steel Ductile Moment-resisting Space Frames—Seismic Zones Nos. 1 and 2

Sec. 2723. (a) **General.** Compliance with this section shall be deemed to meet the requirements for a ductile moment-resisting space frame of Section 2312 (j) and Table No. 23-I for buildings in Seismic Zones No. 1 and No. 2.

(b) **Design and Construction.** The design and construction for steel ductile moment-resisting space frames for buildings located in Seismic Zones No. 1 and No. 2 shall conform to all applicable requirements of this code except 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[5,7]			BEARING TYPE CONNECTIONS
		Standard Size Holes	Oversize and Short-slotted	Long-slotted Holes[5]	
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, Section 27.305.

[5] When specified by the designer, the working stress, F_v, for friction-type shear connections may have the applicable value given U.B.C. Standard No. 27-7, Table No. 27-7-B.

[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 Table No. 27-6-E of 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 exeeed 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	

(Continued)

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TABLE NO. 27-B (Continued)

TYPE OF WELD AND STRESS[1]	ALLOWABLE STRESS	REQUIRED WELD STRENGTH LEVEL[2,3]
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 Table No. 27-6-E of 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.	4.3w	4.7w	5.0w
6. 4" channel, 5.4 lb.	4.6w	5.0w	5.3w
7. 5" channel, 6.7 lb.	4.9w	5.3w	5.6w

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	¼
⅝	1⅛	⅞
¾	1¼	1
⅞	1½	1⅛
1	1¾	1¼
1⅛	2	1½
1¼	2¼	1⅝
Over 1¼	1¼ x Diameter	1¼ x Diameter

[1]For oversized or slotted holes, see Section 2713 (e) 4.

[2]All edge distances 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.

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TABLE NO. 27-D-2—VALUES OF SPACING INCREMENT C, 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]
≤ ⅞	⅛	0	3/16	1½d − 1/16
1	3/16	0	¼	1 7/16
≥ 1⅛	¼	0	3/16	1½d − 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	Long Slots[1]	
≤ ⅞	1/16	⅛		
1	⅛	⅛	¼d	0
≥ 1⅛	⅛	3/16		

[1]When length of slot is less than maximum allowable, C_2 may be reduced by one half the differenee 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 ¼ inclusive	⅛
Over ¼ to ½	3/16
Over ½ to ¾	¼
Over ¾	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 ¼ inclusive	⅛
Over ¼ to ½	3/16
Over ½ to ¾	¼
Over ¾ to 1½	5/16
Over 1½ to 2¼	⅜
Over 2¼ to 6	½
Over 6	⅝

[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	½R[1]

NOTE: R = radius of bar.

[1]Except ⅝R 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, ineheS^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 (exeept 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.

s = spacing of transverse stiffeners (clear distance between stiffeners for

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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.

α = 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 ineh 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 meehanical 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 aecordance with the formulas of Tables Nos. 28-E and 28-G shall be calculated using the nonwelded mechanieal 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

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shall be calculated by the following formula:

$$F_{pw} = F_n - \frac{A_w}{A}(F_n - F_w)$$

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.

(b) **Fasteners.** Bolts and other fasteners shall be aluminum, stainless steel or

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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 ereetion, structural aluminum shall be adequately braeed 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

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 Stress is Considered to be Equal to the Load Divided by the 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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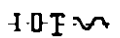
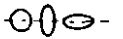
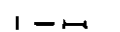
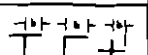
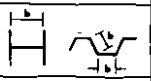
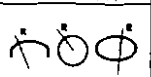
TABLE NO. 28-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES

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 $F_{su}/(k_s n_u)$				
TENSION IN BEAMS, extreme fiber, net section	Rectangular tubes, structural shapes bent about strong axis 	2	F_{tu}/n_u or $F_{su}/(k_s n_u)$				
	Round or oval tubes 	3	$1.17F_{tu}/n_u$ or $1.24F_{su}/(k_s n_u)$				
	Rectangular bars, plates, shapes bent about weak axis 	4	$1.30F_{tu}/n_u$ or $1.42F_{su}/(k_s n_u)$				
BEARING	On rivets and bolts	5	F_{bu}/n_u or $F_{bu}/(1.2n_u)$				
	On flat surfaces and pins	6	$F_{bu}/(1.5n_u)$ or $F_{bu}/(1.8n_u)$				
			ALLOWABLE STRESS, KSI, SLENDERNESS $\le S_1$	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	$\frac{F_{cy}}{k_c n_u}$	$\frac{b}{t} = \frac{B_p - n_u F_{cy}}{k_c n_y 5.1 D_p}$	$\frac{1}{n_u}\left(B_p - 5.1 D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{C_p}{5.1}$	$\frac{\pi^2 E}{n_u (5.1b/t)^2}$
	Flat plates with both edges supported 	9	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - n_u F_{cy}}{k_c n_y 1.6 D_p}$	$\frac{1}{n_u}\left(B_p - 1.6 D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{1.6 D_p}$	$\frac{k_4\sqrt{B_p E}}{n_u (1.6b/t)}$
	Curved plates supported on both edges, walls of round or oval tubes 	10	$\frac{F_{cy}}{k_c n_u}$	$\frac{R}{t} = \left(\frac{B_t - \frac{n_u F_{cy}}{k_c n_y}}{D_t}\right)^2$	$\frac{1}{n_u}\left(B_t - D_t\sqrt{\frac{R}{t}}\right)$	$\frac{R}{t} = C_t$	$\frac{\pi^2 E}{16 n_u \left(\frac{R}{t}\right)\left(1 + \frac{\sqrt{R/t}}{35}\right)^2}$

(Continued)

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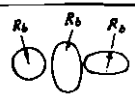
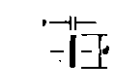
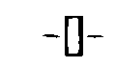
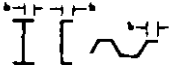
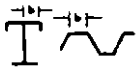
TABLE NO. 28-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES—(Continued)

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 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	$\frac{1.17F_{cy}}{n_y}$	$\frac{R_b}{t} = \left(\frac{B_{tb} - 1.17F_{cy}}{D_{tb}}\right)^2$	$\frac{1}{n_y}\left(B_{tb} - D_{tb}\sqrt{\frac{R_b}{t}}\right)$	$\frac{R_b}{t} = \left(\frac{\frac{n_w}{n_y} B_{tb} - B_t}{\frac{n_w}{n_y} D_{tb} - D_t}\right)^2$	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	$\frac{1.3F_{cy}}{n_y}$	$\frac{d}{t}\sqrt{\frac{L_b}{d}} = \frac{B_b - 1.3F_{cy}}{2.3D_b}$	$\frac{1}{n_y}\left(B_b - 2.3D_b\frac{d}{t}\sqrt{\frac{L_b}{d}}\right)$	$\frac{d}{t}\sqrt{\frac{L_b}{d}} = \frac{C_b}{2.3}$	$\frac{\pi^2 E}{5.29 n_y (d/t)^2 (L_b/d)}$
	Rectangular tubes and box sections 	14	$\frac{F_{cy}}{n_y}$	$\frac{L_b S_r}{I_y} = \left(\frac{B_r - F_{cy}}{1.6D_r}\right)^2$	$\frac{1}{n_y}\left(B_r - 1.6D_r\sqrt{\frac{L_b S_r}{I_y}}\right)$	$\frac{L_b S_r}{I_y} = \left(\frac{C_r}{1.6}\right)^2$	$\frac{\pi^2 E}{2.56 n_y (L_b S_r / I_y)}$
COMPRESSION IN COMPONENTS OF BEAMS, (component under uniform compression), gross section	Outstanding flanges 	15	$\frac{F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_p - F_{cy}}{5.1D_p}$	$\frac{1}{n_y}\left(B_p - 5.1D_p\frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{5.1D_p}$	$\frac{k_1\sqrt{B_p E}}{n_y (5.1b/t)}$
	Flat plates with both edges supported 	16	$\frac{F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_p - F_{cy}}{1.6D_p}$	$\frac{1}{n_y}\left(B_p - 1.6D_p\frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$	$\frac{k_1\sqrt{B_p E}}{n_y (1.6b/t)}$

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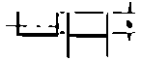
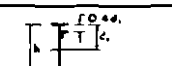
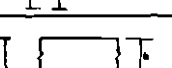
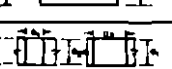
COMPRESSION IN COMPONENTS OF BEAMS, (component under bending in own plane), gross section	Flat plates with compressed edge free tension edge supported		17	$\frac{1.3F_{cy}}{n_a}$	$\frac{b}{t} = \frac{B_b - 1.3F_{cy}}{3.5D_b}$	$\frac{1}{n_a}\left(B_b - 3.5D_b\frac{b}{t}\right)$	$\frac{b}{t} = \frac{C_b}{3.5}$	$\frac{\pi^2 E}{n_a(3.5b/t)^2}$
	Flat plates with both edges supported		18	$\frac{1.3F_{cy}}{n_a}$	$\frac{h}{t} = \frac{B_b - 1.3F_{cy}}{0.67D_b}$	$\frac{1}{n_a}\left(B_b - 0.67D_b\frac{h}{t}\right)$	$\frac{h}{t} = \frac{k_1 B_b}{0.67D_b}$	$\frac{k_2\sqrt{B_b E}}{n_v(0.67h/t)}$
	Flat plates with horizontal stiffener, both edges supported		19	$\frac{1.3F_{cy}}{n_a}$	$\frac{h}{t} = \frac{B_b - 1.3F_{cy}}{0.29D_b}$	$\frac{1}{n_a}\left(B_b - 0.29D_b\frac{h}{t}\right)$	$\frac{h}{t} = \frac{k_1 B_b}{0.29D_b}$	$\frac{k_2\sqrt{B_b E}}{n_v(0.29h/t)}$
SHEAR IN WEBS, gross section	Unstiffened flat webs		20	$\frac{F_{sy}}{n_v}$	$\frac{h}{t} = \frac{B_s - F_{sy}}{1.25D_s}$	$\frac{1}{n_v}\left(B_s - 1.25D_s\frac{h}{t}\right)$	$\frac{h}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_v(1.25h/t)^2}$
	Stiffened flat webs $a_0 = a_1\sqrt{1+0.7(a_1/a_2)^2}$		21	$\frac{F_{sy}}{n_v}$	$\frac{a_c}{t} = \frac{B_s - \frac{n_a F_{sy}}{n_s}}{1.25D_s}$	$\frac{1}{n_a}\left(B_s - 1.25D_s\frac{a_c}{t}\right)$	$\frac{a_c}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_a(1.25a_c/t)^2}$

[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_u	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	$B_p = F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{7.6}\right]$	$D_p = \frac{B_p}{20}\left(\frac{6B_p}{E}\right)^{1/2}$	$C_p = \frac{2B_p}{3D_p}$
3. Compression in Round Tubes Under Axial End Load	$B_t = F_{cy}\left[1+\frac{(F_{cy})^{1/5}}{5.8}\right]$	$D_t = \frac{B_t}{3.7}\left(\frac{B_t}{E}\right)^{1/3}$	C_t *
4. Compressive Bending Stress in Solid Rectangular Bars	$B_b = 1.3F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{7}\right]$	$D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$	$C_b = \frac{2B_b}{3D_b}$
5. Compressive Bending Stress in Round Tubes	$B_{tb} = 1.5F_y\left[1+\frac{(F_y)^{1/5}}{5.8}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$	$C_{tb} = \left(\frac{B_{tb}-B_t}{D_{tb}-D_t}\right)^2$
6. Shear Stress in Flat Plates	$B_s = F_{sy}\left[1+\frac{(F_{cy})^{1/3}}{6.2}\right]$	$D_s = \frac{B_s}{20}\left(\frac{6B_s}{E}\right)^{1/2}$	$C_s = \frac{2B_s}{3D_s}$
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	$B_c = F_{cy}\left[1+\left(\frac{F_{cy}}{2250}\right)^{1/2}\right]$	$D_c = \frac{B_c}{10}\left(\frac{B_c}{E}\right)^{1/2}$	$C_c = 0.41\frac{B_c}{D_c}$
2. Compression in Flat Plates	$B_p = F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{11.4}\right]$	$D_p = \frac{B_p}{10}\left(\frac{B_p}{E}\right)^{1/2}$	$C_p = 0.41\frac{B_p}{D_p}$
3. Compression in Round Tubes Under Axial End Load	$B_t = F_{cy}\left[1+\frac{(F_{cy})^{1/5}}{8.7}\right]$	$D_t = \frac{B_t}{4.5}\left(\frac{B_t}{E}\right)^{1/3}$	C_t *
4. Compressive Bending Stress in Solid Rectangular Bars	$B_b = 1.3F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{7}\right]$	$D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$	$C_b = \frac{2B_b}{3D_b}$
5. Compressive Bending Stress in Round Tubes	$B_{tb} = 1.5F_y\left[1+\frac{(F_y)^{1/5}}{8.7}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$	$C_{tb} = \left(\frac{B_{tb}-B_t}{D_{tb}-D_t}\right)^2$
6. Shear Stress in Flat Plates	$B_s = F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{9.3}\right]$	$D_s = \frac{B_s}{10}\left(\frac{B_s}{E}\right)^{1/2}$	$C_s = 0.41\frac{B_s}{D_s}$
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.

Cut slopes for permanent excavations shall be not steeper than 2 horizontal to 1 vertical and slopes for permanent fills shall be not steeper than 2 horizontal to 1 vertical unless substantiating data justifying steeper slopes are submitted. Deviation from the foregoing limitations for 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 structure 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 person making or causing the excavation to be made shall notify in writing the

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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.

(d) **Expansive Soils.** When expansive soils are present, the building official

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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.

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 below finish grade 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 (f). 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 (h).

(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) **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.

(e) **Foundation Plates or Sills.** Foundation plates or sills shall be bolted to the foundation or foundation wall with not less than ½-inch nominal diameter steel

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bolts embedded at least 7 inches into the concrete or reinforced masonry or 15 inches into unreinforced grouted 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. Foundation plates and sills shall be the kind of wood specified in Section 2516 (c).

(f) **Designs Employing Lateral Bearing.** 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.

1. **Design criteria: 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:

$$A = \frac{2.34P}{S_1 b}$$

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.

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.

$$d^2 = 4.25\,\frac{Ph}{S_3 b}$$

Vertical load. The resistance to vertical loads is determined by the allowable soil-bearing pressure set forth in Table No. 29-B.

2. **Construction requirements: Backfill.** The backfill in the annular space around columns not embedded in poured footings shall be by one of the following methods:

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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.

3. **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.

(g) **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.

(h) **Bleacher Footings.** Footings for open-air seating facilities shall comply with Chapter 29.

EXCEPTION: 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) **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.

(c) **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 inerease 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 whieh 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.

(d) **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 offieial after a foundation investigation by an approved agency.

(e) **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.

(f) **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.

(g) **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.

(h) **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.

(i) **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 bearing resistance shall not be assumed to act simultaneously unless recommended after a foundation investigation as specified in Section 2905.

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(j) **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.** Conerete piles cast-in-place against earth in drilled or bored holes shall be made in sueh 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 pereent of the yield strength of the steel nor 25,500 psi.

(c) **Metal-cased Concrete Piles.** 1. **Material.** All conerete 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 contaet 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 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 exeeed the values specified

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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 ¼ 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 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 ¼ inch round or No. 3 gauge.

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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 (j), the allowable stresses may be increased to $0.50 F_y$.

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 ⅜ 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 ¼ 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 (j), 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.

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.

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	.79	
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

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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 ½-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.

TABLE NO. 29-C—CLASSIFICATION OF EXPANSIVE SOIL

EXPANSION INDEX	POTENTIAL EXPANSION
0-20	Very low
21-50	Low
51-90	Medium
91-130	High
Above 130	Very high

TABLE NO. 29-D—WEIGHTED EXPANSION INDEX[1]

DEPTH INTERVAL[2]	WEIGHT FACTOR
0-1	0.4
1-2	0.3
2-3	0.2
3-4	0.1
Below 4	0

[1]The weighted expansion index for nonuniform soils is determined by multiplying the expansion index for each depth interval by the weight factor for that interval and summing the products.

[2]Depth in feet below the ground surface.

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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 25 feet in height above the adjacent ground elevation except when approved by the building official considering special construction designed to provide for differential movement.

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.

Design

Sec. 3004. (a) **General.** The design of all veneer shall comply 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.

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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 ½ inch nor more than 1¼ 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 ⅜ 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. 30-A shall be applied to the backing as a setting bed. The setting bed shall be a minimum of ⅜ inch thick and a maximum of ¾ 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) **Plastic Veneer.** When used within a building, plastic veneer shall comply with the interior finish requirements of Chapter 42.

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Exterior plastic veneer shall be of approved plastics materials as defined in Chapter 52 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.
3. Sections of plastic veneer shall be separated by a minimum of 4 feet vertically.

(f) **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 veneer shall be supported on footings, foundations or other noncombustible support except as provided under Section 2515.

Where anchored veneer is applied more than 25 feet above the adjacent ground elevation, it shall be supported by noncombustible, corrosion-resistant, structural framing having horizontal supports spaced not over 12 feet vertically above the 25-foot height.

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 1/500 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 Sections 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 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.

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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 1⅛-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 ½ 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-ineh 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 1⅛-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.

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-

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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 1¼ 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 ¼-inch galvanized pencil 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.

TABLE NO. 30-A—CERAMIC TILE SETTING MORTARS

Coat		Volume Type 1 Portland Cement	Volume Type S Hydrated Lime	Volume UBC 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	⅛"	24 hrs.
		1	0	3	4	⅛"	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	⅛" 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 Construction and Materials

Sec. 3202. (a) **Roof Construction and Materials.** Roof coverings shall be securely fastened to the supporting roof construction and shall provide weather protection for the building at the roof.

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.

Plywood roof sheathing, unless of exterior type, shall have no surface or edge exposed to the weather.

Diagonal and sway bracing shall be used to brace all roof trusses.

(b) **Fire Retardancy, When Required.** Roof coverings shall be fire retardant except in Types III, IV and V buildings, where it may be as follows:

1. Ordinary roof coverings may be used on buildings of Group R, Division 3 or Group M Occupancies.

2. Ordinary roof coverings may be used on buildings of Group R, Division 1 Occupancies 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. Group A, Division 3; Group B, Divisions 1 and 2 and Group R, Division 1 Occupancies 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 which comply with U.B.C. Standard No. 32-7 and roofs of No. 1 cedar or redwood shakes and No. 1 shingles constructed in accordance with Section 3203 (g), Special Purpose Roofs.

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 attics, access and area, see Section 3205. For roof drainage, see Section 3207.

For solar energy collectors located above or upon a roof, see Section 1714.

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(c) **Quality of Materials.** The quality and design of roofing materials and their fastenings shall conform to the applicable standards listed in Chapter 60.

Roof Coverings

Sec. 3203. (a) **General.** Roof coverings shall be as specified in this section.

(b) **Definitions.** For purposes of this chapter certain terms are designated as follows:

BASE SHEET is one layer of felt or combination sheet secured to the deck over which may be applied additional felts, a cap sheet, organic or inorganic fiber shingles, smooth coating or mineral aggregate.

BUILT-UP ROOF COVERING is two or more layers of roofing consisting of a base sheet, felts and 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, cold 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.

FELT is matted organic or inorganic fibers, saturated with bituminous compound.

FELT, NONBITUMINOUS SATURATED, is matted asbestos fibers with binder for use with wood shingle and wood shake assemblies as specified in Section 3203 (g).

GLASS FIBER FELT is a glass fiber sheet coated on both sides with bituminous compound.

INTERLAYMENT is a layer of felt or nonbituminous saturated asbestos 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 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 solid roof surfaces or roof frameworks.

NON-NAILABLE DECK is any deck which is incapable of retaining an approved fastener.

PREPARED ROOFING is any manufactured or processed roofing material, other than untreated wood shingles and shakes, as distinguished from built-up coverings.

ROOFING SQUARE is 100 square feet of roofing surface.

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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 or nonbituminous saturated asbestos felt over which finish roofing is applied.

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; semi-split; 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.

WOOD SHINGLES are tapered pieces of approved durable wood, sawed both sides, of random widths ranging from 3 inches to 14 inches and in lengths of 16 inches, 18 inches or 24 inches.

(e) **Roofing Materials.** 1. **Materials.** Materials shall conform to the 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 prepared roofing and built-up roof covering 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 the label or identification mark of an approved inspection bureau or agency showing the grade.

Asphalt or pitch shall be delivered in cartons indicating the name of the manufacturer and the softening point of the product. Bulk shipments shall be accompanied by a certification of the softening point by the manufacturer.

3. **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 and shingles 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.

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4. **Fasteners.** Fasteners shall be as set forth herein or in Table No. 32-B and shall be long enough to penetrate into the sheathing ¾ inch or through the thickness of the sheathing, whichever is less.

Built-up roofing nails for wood board deck shall be No. 12 gauge, 7/16-inch head, driven through tin caps or approved nails with integral caps. For plywood, use No. 11 gauge ring shank nails driven through tin caps or approved nails with integral caps. For gypsum decks, insulating concrete, cementitious wood fiber and others, fasteners recommended by the deck manufacturer shall be used.

All fasteners except those used in built-up roofing installed on poured gypsum or insulating concrete roof decks shall be corrosion resistant complying with the requirements of U.B.C. Standard No. 25-17, Section 25.1716 (e), 25.1716 (h) or 25.1717 (a).

5. **Wire.** Attaching wire for slate shingle and clay or concrete tile shall be not smaller than No. 14 gauge and shall comply with U.B.C. Standards Nos. 32-6 and 32-13.

(d) **Application.** 1. **General.** Application of roof-covering materials listed in Table No. 32-B shall be in accordance with the provisions thereof.

2. **Built-up roofs.** Built-up roofing shall be applied on clean and dry decks in accordance with the manufacturer's instructions and this code. Wood nailers shall be installed at the perimeter of all non-nailable decks and at the top of all curbs. Adequate attachment shall be provided on all vertical surfaces. Reglets shall be provided in walls or parapets receiving metal counterflashing. Insulated decks shall have wood insulation stops at all edges of the deck. Suitable cant strips shall be used at all vertical intersections.

The base sheet shall be cemented or spot mopped to non-nailable decks as required by the type of deck material, using not less than 20 pounds per square of asphalt for solid mopping (10 pounds per square for spot mopping), or not less than 1½ gallons of cold bituminous compound in accordance with manufacturer's published specifications, or 30 pounds per square of coal tar pitch.

Over approved nailable decks, the base sheet shall be nailed using not less than one fastener per each 1⅓ square foot.

Successive layers shall be cemented using no less cementing material than that specified for a solidly cemented base sheet.

Mineral aggregate surfaced roofs shall be surfaced with not less than 60 pounds of asphalt or 70 pounds of pitch in which is embedded not less than 400 pounds of gravel or other approved surfacing materials or 300 pounds of crushed slag per roofing square. See Section 3203 (f) 3 for minimum amounts of mineral aggregate and asphalt or pitch on ordinary roofs. (See U.B.C. Standard No. 32-5 for mineral roofing aggregate weighing less than 60 pounds per cubic foot.)

Cap sheets shall be cemented to the base sheet or felts using no less cementing material than that specified for solidly cemented base sheets.

Asphalt for use as hot cement and mopping coat for built-up roof covering shall comply with U.B.C. Standard No. 32-2.

Asphalt shall be applied at a temperature not less than 375°F. nor more than 475°F. for high-melt types. Low-melt types shall not be applied at a temperature

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of less than 350°F. nor more than 400°F.

Asphalt shall not be heated to a temperature above 500°F. for a high-melt type nor 400°F. for low-melt types. Coal tar pitch shall not be heated to a temperature above 400°F. At no time shall the asphalt be heated to a temperature which will exceed its flash point at the kettle.

Built-up roofing shall be applied by starting at the low spots and working toward the ridges, with felts and cap sheets applied in shingle fashion to drain water. Felts and cap sheets shall be applied in solid uniform moppings of bitumen.

3. **Shingle, shake and tile roofs.** A. **General.** Installation shall be in accordance with Table No. 32-B. Underlayment, when required, shall be lapped horizontally and vertically so as to shed water.

In areas subject to roof ice buildup, underlayment consisting of two layers of Type 15 felt applied shingle fashion shall be installed and solid mopped together with approved cementing material between the plies extending from the eave up the roof to a point 24 inches inside the exterior wall line of the building.

EXCEPTIONS: 1. For wood shingle or wood shake roofs the underlayment shall extend 36 inches inside the exterior wall line of the building.

2. When interlocking tiles are used, the underlayment may consist of one layer of Type 40 or heavier asphalt-coated base sheet extending from the eave to a point 24 inches inside the exterior wall line of the building. When this method is used, all horizontal and vertical seams of the base sheet shall be lapped 6 inches and be continuously sealed with approved cementing material and shall be applied only over solid sheathing.

B. **Asphalt shingles.** Asphalt shingles shall comply with U.B.C. Standard No. 32-3. Asphalt shingles shall be fastened according to manufacturer's instructions to solidly sheathed roofs, but not less than four nails per each strip shingle not more than nominal 36 inches wide and two nails per each individual shingle not more than 18 inches wide shall be used.

Underlayment may be omitted over existing asphalt shingle roofs except where the roof slope is less than 4 inches in 12 inches.

C. **Slate shingles.** Slate shingles shall comply with U.B.C. Standard No. 32-10 and shall be installed in an approved manner.

D. **Asbestos-cement shingles.** Asbestos-cement shingles shall comply with U.B.C. Standard No. 32-9 and shall be installed in an approved manner.

E. **Metal shingles.** Metal shingles shall be applied in an approved manner.

F. **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 Table No. 32-B and fastened with corrosion-resistant nails or wire.

Noninterlocking tiles with projecting anchor lugs at the bottom of the tiles shall be held in position by means of 1-inch by 2-inch wood stripping nailed to the roof sheathing over the underlayment.

Interlocking tiles with projecting anchor lugs may be installed over spaced sheathing board, 1-inch by 2-inch wood stripping nailed to solid roof sheathing or directly to solid roof sheathing, provided in all cases each tile is attached in conformance with Table No. 32-B.

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Tile roofs shall have an underlayment of not less than two layers of Type 15 felt or one layer of Type 30 felt.

G. **Wood shingles.** Shingles may be applied to roofs with solid or spaced sheathing.

Shingles shall be laid with a side lap of not less than 1½ inches between joints in adjacent courses, and not in direct alignment in alternate courses. Spacing between shingles shall be not less than ¼ inch nor more than ⅜ inch. Each shingle shall be fastened with two nails only, positioned approximately ¾ inch from each edge and approximately 1 inch above the exposure line. Starter course at the eaves shall be doubled.

Weather exposures shall not exceed those set forth in Table No. 32-A. Hip and ridge weather exposures shall not exceed those permitted for the field of the roof.

H. **Wood shakes.** Shakes may be applied to roofs with solid or spaced sheathing. In wind-driven-snow areas sheathing shall be solid and the shakes shall be applied over an underlayment of not less than Type 15 felt.

Shakes shall be laid with a side lap of not less than 1½ inches between joints in adjacent courses. Spacing between shakes shall be not less than ⅜ inch nor more than ⅝ inch.

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 final course at the ridge.

Shakes shall be laid with not less than 18-inch-wide strips of not less than Type 30 felt shingled between each course in such a manner that no felt is exposed to the weather below the shake butts.

Weather exposures shall not exceed those set forth in Table No. 32-A. Hip and ridge weather exposures shall not exceed those permitted for the field of the roof.

4. **Other roof coverings.** A. **Asbestos-cement.** Corrugated asbestos-cement roofing shall be applied in an approved manner.

B. **Metal roofing.** Flat sheets shall be applied only to solidly sheathed roofs.

Metal roofing shall be applied in an approved manner.

C. **Sheet roofing.** Sheet roofing shall comply with the provisions of U.B.C. Standard No. 32-3.

5. **Flashing.** Roof valley flashings shall be provided for shingles as follows:

A. **Asphalt shingles.** The roof valley flashing shall be the same as required for wood shingles or shall be of laced asphalt shingles applied in an approved manner with an underlayment of not less than Type 15 felt extending 18 inches from the center line each way, or shall be of two layers of 90-pound mineral surfaced cap sheet cemented together with the bottom layer not less than 12 inches wide laid face down and the top layer not less than 24 inches wide laid face up.

B. **Metal shingles.** The roof valley flashing shall be provided of not less than No. 28 galvanized sheet gauge corrosion-resistant metal applied over an underlayment of not less than Type 15 felt. The metal shall extend at least 8 inches from the center line each way and shall have a splash diverter rib not less than ¾ inch

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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.

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 applied over an underlayment of not less than Type 15 felt. The metal 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.

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 applied over an underlayment of not less than Type 15 felt. The metal 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.

(e) **Fire-retardant Roof Coverings.** A fire-retardant roof covering shall be any one of the following roofings:

1. Any Class A or B built-up roofing assembly.
2. Any mineral aggregate surfaced built-up roof for application to roofs having a slope not more than 3 inches to 12 inches applied as specified in Section 3203 (d) 1 consisting of not less than the following:

   Roof Deck

   Solid surface on noncombustible materials or minimum of ½-inch plywood or 1-inch nominal boards or other material approved by the building official.

   Base Sheet and Plies

   Four layers of Type 15 perforated organic fiber felt, or
   Three layers of Type 15 organic or inorganic fiber felt, and

   Surfacing Material

   400 pounds per roofing square of gravel, crushed rock, ceramic or approved similar surfacing material, or
   300 pounds per roofing square of crushed slag.
   (See U.B.C. Standard No. 32-5 for mineral roofing aggregate weighing less than 60 pounds per cubic foot.)
3. Any built-up roof for application to roofs having a slope not less than ½ inch to 12 inches applied as specified in Section 3203 (d) 1, consisting of not less than the following:

   Roof Deck

   Solid surface on noncombustible materials or minimum of ½-inch plywood or 1-inch nominal boards or other material approved by the building official.

   Base Sheet and Plies

   Two layers of Type 15 organic fiber felt, or
   One layer of 14-pound glass fiber felt base sheet, or combination sheet, or

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One layer of Type 30 organic fiber felt, or
One layer of Type 45 asbestos fiber felt base sheet, and

Cap Sheets

One layer of 90-pound mineral surfaced organic fiber felt cap sheet (requires not less than two layers of organic fiber felt), or
Two layers of 55-pound mineral surfaced organic fiber felt split sheet, or
One layer of 80-pound mineral surfaced asbestos fiber felt cap sheet, or
One layer of 72-pound mineral surfaced glass fiber felt cap sheet, or
Two layers of Type 15 asbestos fiber finishing felts.

4. Any Class A or B prepared roofing.
5. Any Class C mineral surfaeed asphalt shingles laid so that there are not less than two thicknesses at any point and the total weight per roofing square is not less than 235 pounds.
6. Asbestos-cement shingles or sheets.
7. Concrete slab roof.
8. Metal roof covering.
9. Slate shingles.
10. Clay or concrete roof tile.
11. Any roof covering systems of wood shingles or shakes having a Class B rating.

(f) **Ordinary Roof Covering.** An ordinary roof covering shall be any one of the following roofings:

EXCEPTION: 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 55-pound smooth-surfaced organic cap sheet, or built-up roofing consisting of two layers of Type 15 organic fiber felt and one layer of surfacing material as specified in Section 3203 (f) 3.

1. Any roof covering listed in Section 3203 (e).
2. Any built-up roofing assembly not less than Class C roofing.
3. 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 speeified in Section 3203 (d) 2, consisting of not less than the following:

Base Sheet and Plies

Three layers of Type 15 organic or inorganic fiber 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 in 50 pounds of asphalt, or 60 pounds of pitch.

4. Any prepared roofing not less than Class C roofing.
5. Wood shingles (treated or untreated).
6. Wood shakes (treated or untreated).

(g) **Special Purpose Roofs.** 1. **Wood shakes.** Special purpose wood shake roofing shall conform to grading and application requirements of this chapter. In

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addition, the deck shall be constructed of ⅜-inch plywood with exterior glue or 1-inch nominal T and G boards, overlaid with a layer of approved asbestos felt lapped 2 inches on the horizontal and vertical joints. An 18-inch-wide strip of the same asbestos felt shall be shingled in between each course of shakes in such manner that no felt is exposed to the weather below the shake butts. As an alternate, an underlayment of ½-inch Type X gypsum board shall be placed under the solid or spaced sheathing.

2. **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 asbestos felt lapped 2 inches on the horizontal and vertical joints or an underlayment of ½-inch Type X gypsum board shall be placed under the solid or spaced sheathing.

3. **Asbestos felt.** Approved asbestos felt for special purpose roofing shall weigh not less than 12 pounds per 100 square feet, be not less than .022 inch in thickness, nonbituminous saturated, containing a fire- and water-retardant binder, and be reinforced with glass fibers running lengthwise of the sheet not more than ¼ inch apart.

(h) **Slope of Roof.** Roof covering materials shall be installed as set forth in Table No. 32-B except as follows:

EXCEPTIONS: 1. In addition to the application requirements of Table No. 32-B, built-up roofing on slopes greater than 1 inch in 12 inches for gravel surface or 2 inches in 12 inches for smooth or cap sheet surface shall be blind nailed through tin caps into the deck, wood nailers or wood insulation stops at not more than 18 inches on center to secure all underlying plies.

Built-up roofing on slopes exceeding 3 inches in 12 inches shall be installed with plies laid parallel to the slope of the deck, and the surfacing material shall be other than gravel or slag.

2. Asphalt shingles laid with double coverage 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 Type 15 felt applied shingle fashion.

3. Asbestos cement shingles may be installed on slopes as low as 3 inches in 12 inches where the underlayment consists of two layers of Type 15 asbestos felt applied shingle fashion.

4. Wood shakes may be installed on a slope not less than 3 inches in 12 inches when installed over an underlayment of not less than Type 15 felt and when approved by the building official.

5. Interlocking roof tiles may be installed on slopes below 3 inches in 12 inches where underlayment consists of two layers of Type 15 felt or heavier applied shingle fashion and solid-mopped together with approved cementing material between the plies.

Roof Insulation

Sec. 3204. The use of combustible roof insulation shall be permitted, provided it is covered with approved roof covering applied directly thereto. For foam plastic, see Section 1712.

Insulation shall be of a rigid type suitable for application of a roof covering.

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Where fire-retardant roof coverings are required, insulations shall be a type approved for the type of deck and the built-up roofing applied.

Where built-up roofing is to be applied, vapor barriers shall be installed between the deck and the insulation where the average January temperature is below 45°F. or where excessive moisture conditions are anticipated within the building.

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 shall be installed in accordance with the provisions of this section as follows:

1. In single-story Group B, Division 2 and 4 Occupancies having over 50,000 square feet in undivided area.

   EXCEPTIONS: 1. Office buildings and retail sales areas.

   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 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.

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(c) **Types of Vents.** Vents shall be fixed in the open position or shall open automatically in the event of fire and may consist of skylights, exterior wall windows or other openings leading directly to the exterior of the building. 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, provision shall be made to protect the occupants from glass breakage. In no case shall vents be located closer than 20 feet to an adjoining property line.

(d) **Releasing Devices.** Releasing devices for automatically opening vents shall be activated by temperature. The temperature-releasing device shall be operated normally at a maximum temperature of 165°F.; special circumstances warranting higher releasing temperatures may be approved by the building official. Noncorrodible materials shall be used for hinges, latches and related details to prevent sticking and consequent failure to open.

(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 2 feet.

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.

3. **Location and depth.** Curtain boards shall extend down from the ceiling for 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 not designed to support accumulated water shall be sloped for drainage. See Section 2305 (f).

(b) **Roof Drains.** Unless roofs are sloped to drain over roof edges or are

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designed to support accumulated water, roof drains shall be installed at each low point of the roof.

Roof drains shall be adequate in size to convey the water tributary to the roof drains.

(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.

Flashing

Sec. 3208. At the juncture of the roof and vertical surfaces, flashing and counterflashing shall be provided as required in Section 1707 (b).

For roof valley flashing see Section 3203 (d).

TABLE NO. 32-A—MAXIMUM WEATHER EXPOSURE

GRADE LENGTH	3" TO LESS THAN 4" IN 12"	4" IN 12" AND STEEPER
WOOD SHINGLES		
No. 1 16-inch	3¾"	5"
No. 2[1] 16-inch	3½"	4"
No. 3[1] 16-inch	3"	3½"
No. 1 18-inch	4¼"	5½"
No. 2[1] 18-inch	4"	4½"
No. 3[1] 18-inch	3½"	4"
No. 1 24-inch	5¾"	7½"
No. 2[1] 24-inch	5½"	6½"
No. 3[1] 24-inch	5"	5½"
WOOD SHAKES[2]		
18-inch	7½"[3]	7½"
24-inch	10"[3]	10"

[1]To be used only when specifically permitted by the building official.

[2]Exposure of the 24-inch by ⅜-inch resawn handsplit tapered shake type shall not exceed 7½ inches on roof slopes less than 8 inches in 12 inches to a minimum of 4 inches in 12 inches.

[3]See Exception 4 of Section 3203 (h) for restrictions.

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TABLE NO. 32-B—ROOF COVERING APPLICATION [1]

BUILT-UP ROOFING [See Section 3203 (d) 2]			
	ROOF SLOPE		
ROOF COVERING MATERIAL	Minimum	Maximum	APPLICATION TO CLEAN SOLID DECK
1. Base Sheet	0:12	1:12 [3]	Non-nailable deck cement per 3203 (d) 2 or nailable deck nail with at least one approved fastener for each 1⅓ square foot, Section 3203 (c) 4
2. Felts	0:12	1:12 [3]	Cement each sheet with 20 lbs. per sq. asphalt or 30 lbs. per sq. pitch, Section 3203 (d) 2
3. Glass Fiber Felts	0:12	1:12 [3]	Cement each sheet with 25 lbs. per sq. asphalt, Section 3202 (d) 2
4. Cap Sheets	½:12	2:12 [3]	Cement with 20 lbs. per sq. asphalt, Section 3203 (d) 2
5. Gravel—400 lbs. per sq. [2]	0:12	3:12	Embed in 60 lbs. per sq. of asphalt or 70 lbs. per sq. of pitch [2]
6. Slag—300 lbs. per sq. [2]	0:12	3:12	Embed in 60 lbs. per sq. of asphalt or 70 lbs. per sq. of pitch [2]

(Continued)

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TABLE NO. 32-B—ROOF COVERING APPLICATION[1]—(Continued)

SHINGLES-SHAKES-TILE (See Section 3203 (d) 3 A for Ice Conditions)						
ROOF MATERIAL	MINIMUM SLOPE	UNDERLAYMENT[3]	NUMBER OF FASTENERS	STAPLES	NAILS	
					Minimum Gauge	Minimum Head
7. Asphalt Shingles	4:12[3]	One Type 15 felt applied per Section 3203 (d) 3 A	4 per 36 inch strip 2 per 18 inch shingle	4	12	⅜
8. Asbestos-Cement Shingles	5:12[3]	One Type 15 asbestos felt applied per Section 3203 (d) 3 A	4 per shingle[4]	NP	11	⅜
9. Metal Shingles	3:12	One Type 30 felt applied per Section 3203 (d) 3 A	4	4	4	4
10. Slate Shingles	4:12	Two Type 15 or One Type 30 felt applied per Section 3203 (d) 3 A	2 per shingle or wire tie	NP	11	4
11. Noninterlocking Tile—Flat or Curved	3:12		2 per tile or wire tie[7]			
12. Interlocking Tile—Flat or Curved			2 per tile or wire tie[5]			7/16
13. Wood Shingles	4:12[6]	NR	2 per shingle Section 3203 (d) 3 G	4	14½	7/32
14. Wood Shakes	4:12[3]	One Type 30 felt interlayment Section 3203 (d) 3H	2 per shake	4	13	7/32

NP—Not Permitted NR—No Requirements

[1]See text of Chapter 32 for specific details and for construction, definitions, materials, re-roofing, drainage and roof insulation.

[2]See Section 3203 (f) 3 for ordinary roof covering.

[3]See Section 3203 (h) for exceptions.

[4]Approval of the building official required.

[5]On slopes 7:12 and less, tiles with installed weight exceeding 7.5 pounds per square foot having a width no greater than 16 inches may have one fastener. Similar tiles with anchor lugs engaged over horizontal battens may have one fastener on slopes exceeding 7:12.

[6]See Table No. 32-A for exposures on lesser slopes.

[7]On slopes 7:12 and less, tiles with installed weight exceeding 7.5 pounds per square foot having a width no greater than 16 inches may have one

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Chapter 33
EXITS

NOTE: This chapter has been revised in its entirety.

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.

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(e) **Exit Obstruction.** Obstructions shall not be placed in the required width of an exit except projections permitted by this chapter.

(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

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assembly use shall not exceed the capacity of exits as determined in accordance with this chapter.

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.

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 10 or more.

EXCEPTIONS: 1. Except as provided in Table No. 33-A, only one exit need be provided from the second story within an individual dwelling unit. Refer to Section 1204 for emergency escape or rescue requirements from sleeping rooms.

2. Two or more dwelling units on the second story may have access to only one common exit when the total occupant load does not exceed 10.

Occupants on floors above the second story and in basements shall have access to not less than two separate exits from the floor or basement.

EXCEPTIONS: 1. 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.

2. Basements within an individual dwelling unit having an occupant load of less than 10 may have one exit.

3. 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 and 3318; Group E, Section 3319; Group H, Section 3320; Group I, Section 3321; Boiler, Furnace and Incinerator Rooms and Cellulose Nitrate Handling

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Rooms, Section 3322; Reviewing Stands, Grandstands and Bleachers, Sections 3323 and 3324; and Open Parking Garages, Section 709 (g). For stage exits, see Section 3907.

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 oeeupant 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 oecupant load of that story plus the percentages of the oecupant 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 adjaeent 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.

When three or more exits are required, they 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

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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.

(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 exceed 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), (h) and (i) 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 (e).

(b) **Swing.** Exit doors shall swing in the direction of exit travel when serving any hazardous area or when serving an area having an occupant load of 50 or more.

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. This requirement shall not apply to exterior exit doors in a Group B Occupancy if there is a readily visible, durable sign on or adjacent to the

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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. The locking device must be a type that will be readily distinguishable as locked. 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.

EXCEPTION: Group R, Division 3 Occupancies.

(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.

(e) **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.

(f) **Door Leaf Width.** A single leaf of an exit door shall not exceed 4 feet in width.

(g) **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 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:

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1. Six inches maximum between rails and leading edge of door at the closest point in its arc 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.

(h) **Floor Level at Doors.** Regardless of the occupant load, there shall be a floor or landing on each side of a door. The floor or landing shall be not more than ½ inch lower than the threshold of the doorway. When doors open over landings, the landing shall have a length of not less than 5 feet.

EXCEPTIONS: 1. When the door opens into a stair of a smokeproof enclosure, the landing need not have a length of 5 feet.

2. In Group R, Division 3 Occupancies and within individual units of Group R, Division 1 Occupancies, a door may open on the top step of a flight of stairs or on an exterior landing, provided the door does not swing over the top step or exterior landing and the landing is not more than 7½ inches below the floor level.

3. In Group R, Division 3 Occupancies, screen doors and storm doors may swing over stairs, steps or landings.

4. In Group R, Division 3 Occupancies and private garages and sheds when a door opens over a landing, the landing shall have a length equal to the width of the door.

(i) **Door Identification.** Glass doors shall conform to the requirements specified in Section 5406.

Exit doors shall be so marked that they are readily distinguishable from the adjacent construction.

(j) **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 as provided in Subsection (b) for Group R, Divisions 1 and 3 Occupancies. 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.

(b) **Width.** Every corridor serving an occupant load of 10 or more shall be not less than 44 inches in width. Regardless of the occupant load, corridors in Group R, Division 3 Occupancies and within dwelling units in Group R, Division 1

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Occupancies shall have a minimum width of 36 inches. 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 1½ 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 (h).

(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 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 Appendix Chapter 7, Part I, 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.

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 Subsection (g) above, 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 without the hose stream test. The door and frame shall

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bear an approved label or other identification showing the rating thereof, the name of the manufaeturer 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 ¼-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.

2. **Openings other than doors.** Interior openings for other than doors or ducts shall be protected by fixed, approved ¼-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 an area 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. Private stairways serving an occupant load of less than 10 shall be not less than 30 inches in width.

Handrails may project into the required width a distance of 3½ inches from each side of a stairway. Other nonstructural projections such as trim and similar decorative features may projeet into the required width 1½ inches on each side.

(e) **Rise and Run.** The rise of every step in a stairway shall be not less than 4 inches nor greater than 7½ inches. Except as permited in Subsections (d) and (f), the run shall be not less than 10 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 ⅜ inch. The greatest riser height within any flight of stairs shall not exceed the smallest by more than ⅜ 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.

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2. Where the bottom riser adjoins a sloping public way, walk or driveway having an established grade and serving as a landing, a variation in height of the bottom riser of not more than 3 inches in every 3 feet of stairway width is permitted.

(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 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 ⅜ 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 7½ 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 9½ inches.

(g) **Landings.** Every landing shall have a dimension measured in the direction of travel equal to the width of the stairway. Such dimension need not exceed 4 feet when the stair has a straight run. A door swinging over a landing shall not reduce the width of the landing to less than one half its required width at any position in its swing nor by more than 7 inches when fully open. See Section 3304 (h).

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 44 inches or less in width and stairways serving one individual dwelling unit in Group R, Division 1 or 3 Occupancies may have one handrail, except that such stairways open on one or both sides shall have handrails provided on the open side or sides.

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

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in Group R, Division 1 or 3, or serving Group M Occupancies need not have handrails.

Handrails shall be placed not less than 30 inches nor more than 34 inches above the nosing of treads. They shall be continuous the full length of the stairs and except for private stairways at least on 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 1¼ 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.

Handrails projecting from a wall shall have a space of not less than 1½ inches between the wall and the handrail.

(k) **Guardrails.** See Section 1711.

(l) **Exterior Stairway Protection.** All openings in the exterior wall below or within 10 feet, measured horizontally, of an exterior exit stairway serving a building over two stories in height shall be protected by a self-closing fire assembly having a three-fourths-hour fire-protection rating.

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 of noncombustible material except that on Types III and IV buildings not exceeding two stories in height, and on Type V buildings, they may be of wood not less than 2 inches in nominal thickness.

Exterior stairways shall not project into yards where 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 6 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.

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(q) **Stairway Numbering System.** An approved sign shall be located at each floor level landing in all enclosed stairways of buildings four or more stories in height. The sign shall indicate the floor level, the terminus of the top and bottom of the stairway and the identification 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.

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, Division 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 3½ inches when fully open.

(e) **Handrails.** Ramps having slopes steeper than 1 vertieal to 15 horizontal shall have handrails as required for stairways, exeept 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.

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 provides a horizontal exit shall be protected by a fire assembly having a fire-protection rating of not less than one and one-half hours. Such fire assembly shall be automatic closing as provided in Section 4306 (b) upon actuation of a smoke detector.

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(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. The capacity shall be determined by allowing 3 square feet of net clear floor area per ambulatory occupant and 30 square feet per nonambulatory occupant.

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 Group I Occupancies, an enclosure will not be required 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 apartments 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 construetion elsewhere.

(c) **Openings into Enclosures.** There shall be no openings into exit enclosures exeept exit doorways and openings in exterior walls. 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. 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.** There shall be no enclosed usable space under stairways 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

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and continuous stairway enclosed from the highest point to the lowest point by walls of two-hour fire-resistive construction. 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.

> **EXCEPTION:** Smokeproof enclosures may be omitted, provided all enclosed exit stairways are equipped with a barometric dampered relief opening at the top and the stairway is 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 0.25-inch water column in the shaft relative to atmopsheric pressure with all doors closed. Activation of the mechanical equipment shall be in accordance with Section 3310 (g) 6.

(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 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 the stairways shall be by way of a vestibule or open exterior exit balcony constructed 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

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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. The doors shall be automatic elosing by actuation 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 justifed 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 cubie feet per minute through the relief opening 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 smoke detector installed outside the vestibule door in an approved location. The activation of the closing device on any door shall activate the closing devices 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 detector or power failure, the mechanical equipment shall operate at the levels specified in Items Nos. 3 and 5.

7. **Standby power.** Standby power for mechanical 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 eurrent. The generator shall be in a separate room having a minimum one-hour fire-resistive occupancy 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 Occupancies.

8. **Acceptance testing.** Before the mechanical 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 mechanical ventilation equipment may be used for such stair shaft and

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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 court 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 Section 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 affected 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 court.

(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.

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 circuits or sources of power where these are required by Subsection (b).

(b) **Power Supply.** 1. **Separate branch circuits.** The power supply for exit illumination shall be provided by two separate branch circuits of the normal premises wiring system, unless an emergency system is installed, where the

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occupant load served by the exiting system exceeds the following:

A. One hundred in both Group H Occupancies and in Group R, Division 1 Occupancies.

B. Fifty in Group I Occupancies.

C. Three hundred in all other occupancies.

One of the required circuits shall supply only fixtures used for exit illumination or exit signs. The other circuit may supply current to other outlets.

2. **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 where the occupant load served by the exiting system exceeds:

A. Nine hundred and ninety-nine in Group A, Division 1 Occupancies.

B. Five hundred in Group A, Division 2 or 2.1 Occupancies except churches with an occupant load of less than 750.

C. One hundred in Group I Occupancies.

D. One hundred in Group R, Division 1 Occupancies having an interior exit corridor system.

E. Five hundred in Group B, Division 2 Occupancies used for retail sales or offices.

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 ¾ 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.

(d) **Power Supply.** 1. **Separate branch circuits.** When separate branch circuits are required for exit illumination by Section 3313 (b) 1, current supply to one of the lamps for exit signs shall be from a circuit having outlets only for other exit signs or exit illumination. Power to the lamp shall be from a separate circuit that may supply other outlets.

2. **Separate sources of power.** When separate sources of power are required for

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exit illumination by Section 3313 (b) 2, power to one of the lamps for exit signs 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 1½ 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 widest aisle leading thereto plus 50 percent of the total required width of the

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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 can be achieved by a slope conforming to Section 3315 (g). 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 rows of seats shall provide a space of not less than 12 inches from the back of one seat to the front of the most forward projection of the seat immediately behind it as measured horizontally between vertical planes.

(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 or the exterior of the building.
4. There should 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 stairway or ramp leading 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 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.

(c) **Balcony Exits.** Every balcony having an occupant load of 11 or more shall

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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 wih 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:** Group A, Divisions 2.1 and 3 Occupancies, such as restaurants, bars, bowling alleys, auditoriums and similar commercial uses, and in churches, panic hardware may be omitted from the main exit when the main exit consists of a single door. 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 must be free to swing without operation of any latching device. 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 Occupaneies having an occupant load of 50 or more, exit doors shall not be provided with a latch or lock unless it is panic hardware.

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.

ROOM is a space or area bounded by any obstructions to exit passage which at any time enclose more than 80 pereent of the perimeter of the area. In computing the unobstrueted 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.

(e) **Distance to Exits.** 1. The distanee from any point in a room shall be not

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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 protected 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 room, 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).

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

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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.

In Divisions 1 and 2, 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 be automatic closing as defined in Section 4306 (b); and shall open in the direction of exit travel.

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.** Every exit opening through which patients are transported in wheelchairs, stretchers or beds shall be of sufficient width to permit the ready passage of such equipment but shall have a clear width of not less than 44 inches. There shall be no projections within the 44-inch 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.

(d) **Basement Exits.** One exit accessible to every room below grade shall lead directly to the exterior at grade level.

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(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 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.

EXCEPTION: 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.

(g) **Locking Devices.** In buildings housing occupancies in which the personal liberties of inmates or patients are restrained within the building and which are constructed in conformance with the special provisions of Section 1002 (b), the exterior doors may be fastened with locks, provided that room doors shall not be fastened by means other than doorknobs or similar devices which can be opened readily from the corridor side without the use of keys or any special knowledge or effort.

Special Hazards

Sec. 3322. (a) **Boiler, Furnace and Incinerator Rooms.** 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. When oil-fired boilers are used, a 6-inch noncombustible sill (dike) shall be provided. 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

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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.

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.** Grandstands or bleachers employing combustible members in the structural frame shall be limited to 11 rows or 9 feet in height. Seat boards, toeboards, bearing or base pads and footboards may be of combustible materials.

(d) **Design Requirements.** See Chapter 23 and Section 2907 (h).

(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.

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.

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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 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 30 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.

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(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.

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 (h).

(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.
E. Seat boards are of other than continuous flat surfaces.

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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 wall or fence with 6 inches of 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[9]	ACCESS BY MEANS OF A RAMP OR AN ELEVATOR MUST BE PROVIDED FOR THE PHYSICALLY HANDICAPPED AS INDICATED[2]
1. Aircraft Hangars (no repair)	10	500	Yes
2. Auction Rooms	30	7	Yes
3. Assembly Areas, Concentrated Use (without fixed seats) Auditoriums Bowling Alleys (Assembly areas) Churches and Chapels Dance Floors Lodge Rooms Reviewing Stands Stadiums	50	7	Yes[3] [4]
4. Assembly Areas, Less-concentrated Use Conference Rooms Dining Rooms Drinking Establishments Exhibit Rooms Gymnasiums Lounges Stages	50	15	Yes[3] [10]
5. Children's Homes and Homes for the Aged	6	80	Yes[5]
6. Classrooms	50	20	Yes[11]
7. Dormitories	10	50	Yes[5]
8. Dwellings	10	300	No
9. Garage, Parking	30	200	Yes[6]
10. Hospitals and Sanitariums—Nursing Homes	6	80	Yes
11. Hotels and Apartments	10	200	Yes[8]
12. Kitchen—Commercial	30	200	No
13. Library Reading Room	50	50	Yes[3]
14. Locker Rooms	30	50	Yes
15. Mechanical Equipment Room	30	300	No
16. Nurseries for Children (Day-care)	7	35	Yes

(Continued)

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TABLE NO. 33-A—MINIMUM EGRESS AND ACCESS REQUIREMENTS—(Continued)

USE[1]	MINIMUM OF TWO EXITS OTHER THAN ELEVATORS ARE REQUIRED WHERE NUMBER OF OCCUPANTS IS AT LEAST	OCCUPANT LOAD FACTOR[9]	ACCESS BY MEANS OF A RAMP OR AN ELEVATOR MUST BE PROVIDED FOR THE PHYSICALLY HANDICAPPED AS INDICATED[3]
17. Offices	30	100	Yes[5]
18. School Shops and Vocational Rooms	50	50	Yes
19. Skating Rinks	50	50 on the skating area; 15 on the deck	Yes[3]
20. Stores—Retails Sales Rooms			
Basement	[7]	20	Yes
Ground Floor	50	30	Yes
Upper Floors	10	50	Yes
21. Swimming Pools	50	50 for the pool area; 15 on the deck	Yes[3]
22. Warehouses	30	300	No
23. Lobby Accessory to Assembly Occupancy	50	7	Yes
24. Malls (see Appendix Chapter 7)			
25. All others	50	100	

[1]Refer to Sections 3320 and 3321 for other specific requirements.

[2]Elevators shall not be construed as providing a required exit.

[3]Access to secondary areas on balconies or mezzanines may be by stairs only, except when such seeondary areas contain the only available toilet facilities.

[4]Reviewing stands, grandstands and bleachers need not comply.

[5]Access to floors other than that closest to grade may be by stairs only, exeept when the only available toilet facilities are on other levels.

[6]Access to floors other than that elosest to grade and to garages used in connection with apartment houses may be by stairs only.

[7]See Section 3303 for basement exit requirements.

[8]See Section 1213 for access to buildings and facilities in hotels and apartments.

[9]This table shall not be used to determine working space requirements per person.

[10]Aecess 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.

[11]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.

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Chapter 34
SKYLIGHTS

Skylights

Sec. 3401. In other than Types III, IV and V buildings, all skylight frames shall be constructed of noncombustible materials. All skylights shall be designed to carry all tributary roof loads as specified in Section 2305. All skylights, the glazing of which is set at an angle of less than 45 degrees from the horizontal, shall be mounted at least 4 inches above the plane of the roof on a curb constructed as required for the frame.

Spacing between supports in one direction for flat wired glass in skylights shall not exceed 25 inches. Corrugated wired glass may have supports 5 feet apart in the direction of the corrugation. All glass in skylights shall be wired glass, laminated glass with an approved interlayer having a minimum thickness of 0.030 inch or tempered glass, minimum thickness 7/32 inch, except that skylights over vertical shafts extending through two or more stories shall be glazed with plain glass as specified in this section, provided that wired glass may be used if ventilation equal to not less than one-eighth the cross-sectional area of the shaft but never less than 4 square feet is provided at the top of such shaft.

Any glass not laminated glass with an approved interlayer having a minimum thickness of 0.030 inch, wired glass or fully tempered glass shall be protected above and below with a screen constructed of wire not smaller than No. 12 U.S. gauge with a mesh not larger than 1 inch. The screen shall be substantially supported below the glass.

Ordinary glass may be used in the roofs and skylights for greenhouses, provided the height of the greenhouse at the ridge does not exceed 20 feet above the grade. The use of wood in the frames of skylights will be permitted in greenhouses if the height of the skylight does not exceed 20 feet above the grade, but in other cases metal frames and metal sash bars shall be used.

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 ½ inch in thickness. Any such glass over 16 square inches in area shall have wire mesh embedded in the same or shall be provided with 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.

For requirements applicable to plastic skylights, see Section 5207.

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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 a 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
MASONRY OR CONCRETE 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 fireplace composed of listed factory-built components assembled in accordanee with the terms of listing to form the completed fireplace.

Masonry Fireplace is a hearth and fire ehamber of solid masonry units such as bricks, stones, masonry units, or reinforced concrete provided with a suitable ehimney.

Chimneys, General

Sec. 3703. (a) **Chimney Support.** Chimneys shall be designed, anehored, 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.** Eaeh chimney shall be so eonstructed as to safely convey flue gases not exceeding the maximum temperatures for the type of construetion 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, firebriek, molded refractory units or other approved lining not less than ⅝ 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 attaehed 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 ½ 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).

(b) **Walls.** Walls of masonry chimneys shall be constructed as set forth in Table No. 37-B.

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(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 ¼-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 ½-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 1½-inch by ⅛-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 ⅛-inch-thick metal or ⅝-inch-thick refractory material.

Factory-built Chimneys

Sec. 3705. Factory-built chimneys shall be installed in strict accordance with the terms of their listings and the manufacturer's instructions as specified in the Mechanical Code.

Metal Chimneys

Sec. 3706. Metal chimneys shall be constructed and installed to meet the requirements of the Mechanical Code.

Fireplaces and Barbecues

Sec. 3707. (a) **General.** Masonry fireplaces, barbecues, smoke chambers

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and fireplace chimneys shall be of masonry or reinforced concrete and shall conform to the requirements of this section. Approved factory-built fireplaces may be used in accordance with their listings.

(b) **Support.** Masonry fireplaces 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 ¼ 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 material shall not be placed within 1 inch 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 ⅛ 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.

(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

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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.

Hearth extensions of approved factory-built fireplaces shall be not less than ⅜ inch thick of asbestos, concrete, hollow metal, stone, tile or other approved noncombustible material. Such hearth extensions may be placed on the subflooring or finish flooring whether the flooring is combustible or not.

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.

TABLE NO. 37-A—MINIMUM PASSAGEWAY AREAS FOR MASONRY CHIMNEYS[1]

TYPE OF MASONRY CHIMNEY	MINIMUM CROSS-SECTIONAL AREA		
	ROUND	SQUARE OR RECTANGLE	LINED WITH FIREBRICK OR UNLINED
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 property.

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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			1	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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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.
3. MEDIUM-HEAT INDUSTRIAL-TYPE APPLIANCES[15] (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[11] (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 combnstion chamber roof	4	5/8 fire-clay tile liner						
Portion more than 10 ft. above combustion chamber roof	8							

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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 5/8 fire-clay tile liner		10			2	2
Portion extending to 40 ft. above combustion chamber roof.	4							
Portion more than 40 ft. above combustion chamber roof	8							
Reinforced Concrete	8	4½ Medium duty fire-brick laid in medium duty refract mortar						
8. COMMERCIAL OR INDUSTRIAL-TYPE INCINERATORS [2]								
Clay or Shale Solid Brick	8	4½ Medium duty fire-brick laid in medium duty refract mortar		10			4	4
Reinforced Concrete	8							

[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.

[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.

(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 2½-inch hose outlets for use by the fire department and also supplies water to fire sprinklers.

FIRE DEPARTMENT HOSE CONNECTION is a connection through which the fire department can pump water.

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 and classified as follows:

Class I is a dry standpipe system without a directly connected water supply and equipped with 2½-inch outlets for use by the fire department or trained personnel.

Class II is a wet standpipe system directly connected to a water supply and equipped with 1½-inch outlets intended for use by the building occupants.

Class III is a combination standpipe system directly connected to a water supply and equipped with both 1½-inch outlets for use by the building occupants and 2½-inch outlets for use by the fire department or trained personnel.

(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 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.

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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. **Nightclubs, discos.** An automatic sprinkler system shall be installed in rooms primarily used for entertaining occupants who are drinking or dining 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 be not 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.

3. **Exhibition and display rooms.** An automatic sprinkler system shall be installed in rooms classified as 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

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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 in specific areas of Group A Occupancies as follows: Under the roof and gridiron, in the tie and fly galleries and in all places behind the proscenium wall of stages; over enclosed platforms in excess of 500 square feet in area; and in dressing rooms, workshops and storerooms accessory to such stages or enclosed platforms.

EXCEPTIONS: 1. Stages or enclosed 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 at points not more than 30 inches below the gridiron nor more than 6 inches below the baffle plate.

4. Under stage or under enclosed 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.

In buildings used for high-piled combustible storage, fire protection shall be in accordance with the Fire Code.

(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. **Division 1.** A fire-extinguishing system shall be installed in Group H, Division 1 Occupancies larger than 1500 square feet in floor area.

2. **Division 2.** A fire-extinguishing system shall be installed in Group H, Division 2 Occupancies exceeding 1500 square feet in area.

A fire-extinguishing system shall be installed in rooms of Group H, Division 2 Occupancies when flammable or combustible liquids are stored or handled in excess of the quantities set forth in Table No. 9-A, or any combination of flammable liquids exceeds 240 gallons.

A fire-extinguishing system shall be installed in paint spray booths or rooms.

3. **Division 3.** A fire-extinguishing system shall be installed in Group H, Division 3 Occupancies larger than 3000 square feet in floor area.

4. **Division 4.** A fire-extinguishing system shall be installed in Group H, Division 4 Occupancies more than one story in height.

(g) **Group I Occupancies.** An automatic sprinkler system shall be installed in Group I Occupancies.

EXCEPTIONS: 1. In hospitals of Types I, II Fire-resistive and II One-hour

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construction, the automatic sprinkler system may be omitted from operating, delivery, cardiac, X-ray and intensive care rooms and patient sleeping rooms not exceeding 450 square feet in area when each such room is provided with smoke detectors connected to a continuously attended station or location within the building. Increases for area and height specified in Sections 506 (c) and 507 shall not apply when this exception is used.

2. 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.

Sprinkler System Alarms

Sec. 3803. When serving more than 100 sprinklers, 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.

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.

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 ageney, 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 sueh 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.

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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 above the first story of every required stairway 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.

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 a three-way 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.

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

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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.

TABLE NO. 38-A—STANDPIPE REQUIREMENTS

OCCUPANCY[1]	NONSPRINKLERED BUILDING[2]		SPRINKLERED BUILDING[3,4]	
	Standpipe Class	Hose Requirement	Standpipe Class	Hose Requirement
1. Occupancies exceeding 150 ft. in height and more than one story	III	Yes	III	No
2. Occupancies 4 stories or more but less than 150 ft. in height, except Group R, Div. 3	[I and II[5]] (or III)	[6] Yes	I (or III)	No
3. Group A Occupancies with occupant load exceeding 1000	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[5]	Yes	No requirement	No

[1]Class II standpipes need not be provided in assembly areas used solely for worship.

[2]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.

[3]Combined systems with their related water supplies may be used in sprinklered buildings.

[4]Portions of otherwise sprinklered buildings which are not protected by automatic sprinklers shall have Class II standpipes installed as required for the unsprinklered portions.

[5]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.

[6]Hose is required for Class II standpipes only.

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Chapter 39
STAGES AND PLATFORMS

Stage Ventilators

Sec. 3901. (a) **General.** There shall be one or more ventilators constructed of metal or other noncombustible material near the center and above the highest part of any working stage raised above the stage roof and having a total ventilation area equal to at least 5 percent of the floor area within the stage walls. The entire equipment shall conform to the requirements in Subsections (b) to (i) of this section or their equivalent.

(b) **Opening Action.** Ventilators 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.

(c) **Glass.** Glass, if used in ventilators, must be protected against falling on the stage. A wire screen, if used under the glass, must be so placed that if clogged it cannot reduce the required ventilating area or interfere with the operating mechanism or obstruct the distribution of water from the automatic sprinkler systems.

(d) **Design.** Ventilators, penthouses and supporting framework shall be designed in accordance with Chapter 23.

(e) **Automatic Openings.** Each ventilator shall be arranged to open automatically after the outbreak of fire by the use of an approved automatic closing device as defined in Chapter 43. The fusible link and operating cable shall hold each door closed against a minimum 30-pound counterforce exerted by springs or counterweights. This minimum counterforce shall be exerted on each door through its entire arc of travel and for a minimum 115 degrees. A manual control shall be provided.

(f) **Spring Actuation.** Springs, when employed to actuate ventilator doors, shall be capable of maintaining full required tension indefinitely. Springs shall not be stressed more than 50 percent of their rated capacity and shall not be located directly in the air stream, nor exposed to the elements.

(g) **Location of Fusible Links.** A fusible link shall be placed in the cable control system on the underside of the ventilator 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 sprinkler systems.

(h) **Control.** Remote, manual or electrical control shall provide for both opening and closing of the ventilator doors for periodic testing and shall be located at a point on the stage designated by the building official. When remote control of ventilator is 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 ventilators.

(i) **Curb Construction.** Curbs shall be constructed as required for the roof.

Gridirons

Sec. 3902. Gridirons, fly galleries and pinrails shall be constructed of noncombustible materials, and fire protection of steel and iron may be omitted.

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The head block well must be provided with an adequate strongback or lateral brace to offset torque.

Rooms Accessory to Stage

Sec. 3903. In buildings having a stage, the dressing room sections, workshops and storerooms shall be located on the stage side of the proscenium wall and shall be separated from each other and from the stage by not less than a one-hour fire-resistive occupancy separation, as defined in Chapter 5.

Proscenium Walls

Sec. 3904. A stage as defined in Section 420 shall be completely separated from the auditorium by a proscenium wall of not less than two-hour noncombustible construction. The proscenium wall shall extend not less than 4 feet above the roof over 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 at the stage floor level, each of which shall be not more than 25 square feet in area.

All openings in the proscenium wall of a stage shall be protected by a fire assembly having a one and one-half-hour fire-resistive rating. The proscenium opening, which shall be the main opening for viewing performances, shall be provided with a self-closing fire-resistive curtain as provided in U.B.C. Standard No. 6-1.

Stage Floors

Sec. 3905. All parts of stage floors shall be of Type I construction except the part of the stage extending back from and 6 feet beyond the full width of the proscenium opening on each side, which may be constructed of steel or heavy timbers covered with a wood floor of not less than 2-inch nominal thickness. No part of the combustible construction except the floor finish shall be carried through the proscenium opening. All parts of the stage floor shall be designed to support not less than 125 pounds per square foot.

Openings through stage floors shall be equipped with tight-fitting trap doors of wood of not less than 2-inch nominal thickness.

Platforms

Sec. 3906. (a) **Ventilators.** Enclosed platforms shall be provided with one or more ventilators conforming to the requirements of Section 3901. When more than one ventilator is provided, they shall be so spaced as to provide proper exhaust ventilation.

Ventilators shall not be required for enclosed platforms having a floor area of 500 square feet or less.

(b) **Construction.** Walls and ceiling of an enclosed platform in an assembly room shall be of not less than one-hour fire-resistive construction.

Any usable space having headroom of 4 feet or more under a raised platform of an assembly room shall be of not less than one-hour fire-resistive construction.

(c) **Accessory Rooms.** In buildings having an enclosed platform, the dressing-room section, workshops, and storerooms shall be separated from each other and

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from the rest of the building by not less than a one-hour fire-resistive occupancy separation as defined in Chapter 5, except that a chair-storage area having headroom of not more than 4 feet need not be so separated.

Stage Exits

Sec. 3907. At least one exit not less than 36 inches wide shall be provided from each side of the stage opening directly or by means of a passageway not less than 36 inches in width to a street or exit court. An exit stair not less than 2 feet 6 inches wide shall be provided for egress from each fly gallery. Each tier of dressing rooms shall be provided with at least two means of egress each not less than 2 feet 6 inches wide and all such stairs shall be constructed as specified in Chapter 33. The stairs required in this section need not be enclosed.

Miscellaneous

Sec. 3908. A protecting hood shall be provided over the full length of the stage switchboard.

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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.

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.

(b) **Projection Booth.** 1. **Supply air.** Each projection room shall be provided with two or more separate fresh-air inlet ducts with screened openings terminating within 12 inches of the floor and located at opposite ends of the room. Such air

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inlets shall be of sufficient size to permit an air change every three minutes. Fresh air may be supplied from the general building air-conditioning system, but when this is done it shall be so arranged that the projection booth will continue to receive one change of air every three minutes, regardless of the status of the general air-conditioning system.

2. **Exhaust air.** Each projection room shall be provided with one or more exhaust-air outlets which may be manifolded into a single duct outside the booth. Such outlets shall be so located as to ensure circulation throughout the room. Projection room exhaust-air systems shall be independent of any other air systems in the buildings. Exhaust-air ducts shall terminate at the exterior of the building in such a location that the exhaust air cannot be readily recirculated into the supply-air system. The exhaust system shall be mechanically operated and of such a capacity as to provide a minimum of one change of air every three minutes. The blower motor shall be outside the duct system. The projection room ventilation system may also serve appurtenant rooms, such as the generator room and the rewind room.

(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 each 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 cubic 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 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 flame-spread 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 flame-spread 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. Flame-spread characteristics shall be determined by one of the following methods:

1. The "Tunnel Test" as set forth in U.B.C. Standard No. 42-1.

2. Any other recognized method of test procedure for determining the flame-spread 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 characteristics under the Tunnel Test 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

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as specified in Section 4202 and regulated for purposes of limiting flame spread 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 of any class shall be applied directly against such fire-resistive construction or to furring strips not exceeding 1¾ 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.

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 classification 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 Walls or Ceilings.** When used as interior wall or ceiling finish, carpeting and similar materials having a napped, tufted, looped or similar surface shall have a Class I flame-spread classification.

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TABLE NO. 42-A—FLAME-SPREAD CLASSIFICATION

MATERIAL QUALIFIED BY:	
Class	Tunnel Test
I	0- 25
II	26- 75
III	76-200

TABLE NO. 42-B—MAXIMUM FLAME-SPREAD CLASSIFICATIONS[4]

OCCUPANCY GROUP	ENCLOSED VERTICAL EXITWAYS	OTHER EXITWAYS[5]	ROOMS OR AREAS
A	I	II	III
E	I	II	III
I	I	II	II[1]
H	I	II	III[2]
B	I	II	III
R-1	I	II	III
R-3	III	III	III[3]
M	NO RESTRICTIONS		

[1]In rooms in which personal liberties of inmates are forcibly restrained, Class I material only shall be used.

[2]Over two stories shall be of Class II.

[3]Flame-spread provisions are not applicable to kitchens and bathrooms of Group R, Division 3 Occupancies.

[4]Foam plastics shall comply with the requirements specified in Section 1712.

[5]Finish classification is not applicable to interior walls and ceilings of exterior exit balconies.

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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

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) and shall conform to the following standards. For standards for the specific materials of construction referred to in this chapter, see the appropriate chapter in this code or the Uniform Building Code Standards specifically regulating such materials as listed in 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.

(b) **Tests.** 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. Any 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.

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.

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 Section 43.144 of U.B.C. Standard No. 43-1. Restrained construction shall be identified on the plans.

(c) **Concrete.** Grade A concrete is made with aggregates such as limestone, calcareous gravel, trap rock, slag, expanded clay, shale, slate silicons or any other aggregates possessing equivalent fire-resistive properties and containing 40 percent or less quartz, chert or flint.

Grade B concrete is all concrete other than Grade A concrete and includes concrete made with aggregates containing more than 40 percent quartz, chert or flint.

(d) **Pneumatically Placed Concrete.** Pneumatically placed concrete without coarse aggregate shall be classified as Grade A or B concrete in accordance with aggregate used.

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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 reinforeement.

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 dampers.

> **EXCEPTION:** 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).

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

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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 ½ inch into the protection.

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 ¾ 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 effective.

(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.

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(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 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 No. 2 above, they shall be qualified by tests conducted in accordance with the provisions of Section 4302 (b).

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 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.

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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.** Factory-assembled multiconductor cable which is specifically listed for such use may be used within concealed spaces, such as spaces over suspended ceilings, used for environmental air-handling purposes when the building is protected by an automatic sprinkler system or the plenum space is protected by a smoke-detection system which, upon activation of either system, will cause the air-moving equipment to shut down.

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 dampers shall be fabricated and installed in accordance with U.B.C. Standard No. 43-7.

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.

The closing device shall operate by the activation of an approved detector set to operate when smoke reduces the intensity of a 1-foot-long beam of white light by 4 percent or any other detection device conforming to the requirements specified in U.B.C. Standard No. 43-6.

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.

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(d) **Installation of Fire Door Hardware, Fire Door Frames and Anchorage.** Approved fire door hardware and fire door frames including the anchorage thereof shall be installed in accordance with their listing.

(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 No. 43-2 and No. 43-4.

(f) **Hardware.** Every fire assembly required to have a three-hour fire-protection rating shall be of an automatic-closing type as specified in Section 4306 (b). Every fire assembly required to have a one and one-half hour, one-hour, or three-fourths-hour fire-protection rating shall be of an automatic- or self-closing type as specified in Section 4306 (b).

EXCEPTIONS: 1. Dual fire-exit doors shall have closing devices as specified in Chapter 33.

2. Swinging fire door assemblies shall be automatic closing by a smoke detector when installed in the locations listed below. All hold-open devices shall be an approved type which will release the door in the event of power failure.

A. Cross-corridor doors.

B. Horizontal exit doors.

C. Area separation walls other than doors serving as the entrance into hotel guest rooms or apartment dwelling units.

D. Occupancy separation walls having a minimum two-hour fire-resistive time period.

Heat-actuated devices used in automatic fire assemblies providing three-hour fire protection shall be installed, one 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 opening.

Fire assemblies protecting openings required to have one and one-half, one or three-fourths-hour fire-protection rating, and which are not exit doors, may be activated in a similar manner or by a single fusible link in the opening incorporated in the closing device.

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.

(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.

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(i) **Glazing.** Glazing shall be glass not less than ¼ inch 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 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 clips 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 construction, 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. Duct penetrations of fire-rated shafts unless exhaust or return-air sub-ducts extend 22 inches vertically in a vented shaft.
4. Ducts penetrating the ceiling of fire-resistive floor-ceiling or roof-ceiling assemblies.
5. Ducts penetrating fire-rated corridor walls having openings into the corridor.

(k) **Tin-clad Doors.** If constructed as specified in U.B.C. Standard No. 43-3, tin-clad fire doors installed on each side of openings requiring protection shall be considered as providing a fire assembly having a three-hour fire-protection rating, provided each door bears the label of an approved testing agency showing the classification thereof.

(l) **Installation.** Fire assemblies shall be installed in accordance with their listing.

(m) **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 Sections 3202 (b) and 3203.

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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.
Steel Columns and All Members of Primary Trusses	1	Grade A concrete; members 6"x 6" or greater (not including sandstone, granite and siliceous gravel).[1]	2½	2	1½	1
	2	Grade A concrete, members 8" x 8" or greater (not including sandstone, granite and siliceous gravel).[1]	2	1½	1	1
	3	Grade A concrete, members 12"x 12" or greater (not including sandstone, granite and siliceous gravel).[1]	1½	1	1	1
	4	Grade B concrete and Grade A concrete excluded above, members 6"x 6" or greater.[1]	3	2	1½	1
	5	Grade B concrete and Grade A concrete excluded above, members 8"x 8" or greater.[1]	2½	2	1	1
	6	Grade B concrete and Grade A concrete excluded above, members 12"x 12" or greater.[1]	2	1	1	1
	7	Clay or shale brick with brick and mortar fill.[1]	3¼			2¼
	8	4" Hollow clay tile in two 2" layers; ½" mortar between tile and column; ⅜" metal mesh (wire diameter = .046") in horizontal joints; tile fill.[1]	4			
	9	2" Hollow clay tile; ¼" mortar between tile and column; ⅜" metal mesh (.046" wire diameter) in horizontal joints; Grade A concrete fill[1]; plastered with ¾" gypsum plaster.	3			
	10	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; Grade A concrete fill[1] extending 1" outside column on all sides.			3	

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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.
Steel Columns and All Members of Primary Trusses	11	2" Hollow clay tile with outside wire ties (.08" diameter) at each course of tile with or without Grade A concrete fill; ¼" mortar between tile and column.				2
	12	Portland cement plaster over metal lath wire tied to ¼" cold-rolled vertical channels with No. 18 gauge wire ties spaced 3" to 6" on center. Plaster mixed 1:2½ by volume, cement to sand.			2½[2]	¾
	13	Vermiculite concrete, 1:4 mix by volume over paperbacked wire fabric lath wrapped directly around column with additional 2" x 2" No. 16/16 gauge wire fabric placed ¾" 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			
	14	Perlite or vermiculite gypsum plaster over metal lath wrapped around column and furred 1¼" from column flanges. Sheets lapped at ends and tied at 6" intervals with No. 18 gauge tie wire. Plaster pushed through to flanges.	1½	1		

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Steel Columns and All Members of Primary Trusses	15	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.	1¼	1¼	1	
	16	Perlite or vermiculite gypsum plaster on metal lath applied to ¼" cold-rolled channels spaced 24 inches apart vertically and wrapped flatwise around column.	1½			
	17	Perlite or vermiculite gypsum plaster over 2 layers of ½" 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 2½ cubic feet of aggregate for the three-hour system.	2½	2		
	18	Perlite or vermiculite gypsum plaster over one layer of ½" 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 2½ cubic feet of aggregate.		2		
	19	Perlite or vermiculite gypsum plaster over ⅜" perforated gypsum lath applied tight to column flanges and tied with doubled No. 18 gauge wire ties spaced 15" on center. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2½ cubic feet of aggregate for the two-hour system.		1¼	1⅛	

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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.
Steel Columns and All Members of Primary Trusses	20	Multiple layers of ½" 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
	21	Three layers of ⅝" Type "X" gypsum wallboard.[3] First and second layer held in place by ⅞" diameter by 1⅞" long ring shank nails with 7/16" 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.			1¼	
	22	Three layers of ⅝" Type "X" gypsum wallboard,[3] each layer screw attached to 1⅝" 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 1⅞" spaced 12" on center for middle layer and No. 8 by 2¼" spaced 12" on center for outer layer.		1¼		

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Steel Columns and All Members of Primary Trusses (Cont'd.)	23	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 ½" spacers made of ¾" 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.			1⅛	
Webs or Flanges of Steel Beams and Girders	24	Grade A 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
	25	Grade B concrete and Grade A concrete excluded above 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
	26	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
	27	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.
Webs or Flanges of Steel Beams and Girders	28	Two layers of ⅝" Type "X" gypsum wallboard[3] are attached to U-shaped brackets spaced 24" on center. No. 25 gauge 1⅝" deep by 1" galvanized steel runner channels are first installed parallel to and on each side of the top beam flange to provide a ½" 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 1⅝" 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 ½" long No. 8 self-drilling screws. The vertical legs of the U-shaped bracket are attached to the runners with one ½" long No. 8 self-drilling screw. The completed steel framing provides a 2⅛" and 1½" 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 1¼" long No. 6 self-drilling screws spaced 16" on center. The outer layer of wallboard is applied with 1¾" long No. 6 self-drilling screws spaced 8" on center. The bottom corners are reinforced with metal corner beads.				1¼	

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Webs or Flanges of Steel Beams and Girders	29	Three layers of ⅝" 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 2¼" 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 1⅞" long screws installed in the vertical leg of the bottom corner angles. The outer layer of wallboard is attached with No. 6 2¼" 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.		1⅞		
Bonded Pretensioned Reinforcement in Prestressed Concrete[5]	30	Grade A[6] concrete — Beams or girders	4[7]	3[7]	2½[7]	1½
		Solid slabs[8]		2	1½	1
Bonded or Unbonded Posttensioned Tendons in Prestressed Concrete[5,10]	31	Grade A or B Concrete Unrestrained Members: Solid Slabs[8]		2	1½	
		Beams and Girders[11] 8 in. wide		4½	2½	1¼
		> 12 in. wide	3	2½	2	1½

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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.
Bonded or Unbonded Posttensioned Tendons in Prestressed Concrete[5, 10]	32	Grade A or B Concrete Restrained Members:[12] Solid Slabs[8] Beams and Girders[11] 8 in. Wide >12 in. wide	 1¼ 2½ 2	 1 2 1¾	 ¾ 1¼ 1½	
Reinforcing Steel in Reinforced Concrete Columns, Beams, Girders and Trusses	33	Grade A concrete, members 12" or larger, square or round (Size limit does not apply to beams and girders monolithic with floors.)	1½	1½	1½	1½
	34	Grade B concrete, members 12" or larger, square or round (Size limit does not apply to beams and girders monolithic with floors.)	2	1½	1½	1½
Reinforcing Steel in Reinforced Concrete Joists[9]	35	Grade A concrete	1¼	1¼	1	¾
	36	Grade B concrete	1¼	1½	1	¾
Reinforcing and Tie Rods in Floor and Roof Slabs[9]	37	Grade A concrete	1	1	¾	¾
	38	Grade B concrete	1¼	1	1	¾

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[a]Generic fire resistance ratings (those not designated by company code letter) as listed in the Fire Resistance Design Manual, 1981 Edition, 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 ¾-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 Grade A concrete aggregates producing concrete having an oven-dry weight of 110 pounds per cubic foot or less are used, the tabulated minimum cover may be reduced 25 percent, except that in no case shall the cover be less than ¾ inch in slabs nor 1½ inches in beams or girders.

[6]For Grade B 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 ½ inch greater than that required away from the anchor. Minimum cover to steel bearing plate shall be 1 inch in beams and ¾ 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.
Brick of Clay or Shale	1	Solid units (at least 75 percent solid).	8		6[3]	4
	2	Solid units plastered each side with ⅞" gypsum or portland cement plaster. Portland cement plaster mixed 1:2½ by weight, cement to sand.			4¼[4]	
	3	Hollow brick units[5] at least 71 percent solid.		8		
	4	Hollow brick units[5] at least 71 percent solid, plastered each side with ⅞" gypsum plaster.	8¼			
	5	Hollow (rowlock[6]).	12		8	
	6	Hollow (rowlock[6]) plastered each side with ⅞" gypsum or portland cement plaster. Portland cement plaster mixed 1:2½ by weight, cement to sand.	9			
	7	Hollow cavity wall consisting of two 4" nominal clay brick units with air space between.	10			
	8	Hollow brick units at least 60 percent solid, cells filled with perlite loose fill insulation.	8			
	9	4-in. nominal thick units at least 75 percent solid backed with a hat shaped metal furring channel ¼ 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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Brick of Clay or Shale	10	Cavity wall consisting of two 3-inch nominal thick solid clay units with air space.		8		
Hollow Clay Tile, Non-load-bearing (End or Side Construction)	11	One cell in wall thickness, units at least 50 percent solid, plastered each side with ⅞" gypsum plaster.				4¼
	12	Two cells in wall thickness, units at least 45 percent solid.				6
	13	Two cells in wall thickness, units at least 45 percent solid. Plastered each side with ⅞" gypsum plaster.			7	
	14	Two cells in wall thickness, units at least 60 percent solid. Plastered each side with ⅞" gypsum plaster.			5	
Hollow Clay Tile, Load-bearing (End or Side Construction)	15	Two cells in wall thickness, units at least 40 percent solid.				8
	16	Two cells in wall thickness, units at least 40 percent solid. Plastered one side with ⅞" gypsum plaster.			8½	
	17	Two cells in wall thiekness, units at least 49 percent solid.			8	
	18	Three cells in wall thickness, units at least 40 percent solid.			12	
	19	Two units and three cells in wall thickness, units at least 40 pereent solid.		12		
	20	Two units and four cells in wall thickness, units at least 45 percent solid.	12			
	21	Two units and three cells in wall thickness, units at least 40 percent solid. Plastered one side with ⅞" gypsum plaster.	12½			
	22	Three cells in wall thickness, units at least 43 percent solid. Plastered one side with ⅞" gypsum plaster.		8½		

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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 FACT-TO-FACE[2] (In inches)			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.
Hollow Clay Tile, Load-bearing (End or Side Construction)	23	Two cells in wall thickness, units at least 40 percent solid. Plastered each side with ⅞" gypsum plaster.		9		
	24	Three cells in wall thickness, units at least 43 percent solid. Plastered each side with ⅞" gypsum plaster.	9			
	25	Three cells in wall thickness, units at least 40 percent solid. Plastered each side with ⅞" gypsum plaster.	13			
	26	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 ¾" portland cement plaster and other side with ⅞" gypsum plaster. Portland cement plaster mixed 1:3 by volume, cement to sand.	10			
Combination of Clay Brick and Load-bearing Hollow Clay Tile	27	4" brick and 8" tile.	12			
	28	4" brick and 4" tile.		8		
	29	4" brick and 4" tile plastered on the tile side with ⅞" gypsum plaster.	8½			
Concrete Masonry Units[8]	30	Expanded slag or pumice.	4.7	4.0	3.2	2.1
	31	Expanded clay or shale.	5.7	4.8	3.8	2.6
	32	Limestone, cinders or air cooled slag.	5.9	5.0	4.0	2.7
	33	Calcareous or siliceous gravel.	6.2	5.3	4.2	2.8

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Solid Concrete	34	Horizontal reinforcement not less than 0.25 percent and vertical reinforcement not less than 0.15 percent. (Three-fourths as much for welded wire fabric.)	Grade A Concrete	6½	6	5	3½[4]
			Grade B	7½	6½	5½	4[4]
Glazed or Unglazed Facing Tile, Nonload-bearing	35	One 2" unit cored 15 percent maximum and one 4" unit cored 25 percent maximum with ¼" mortar filled collar joint. Unit positions reversed in alternate courses.			6⅜		
	36	One 2" unit cored 15 percent maximum and one 4" unit cored 40 percent maximum with ⅜" mortar filled collar joint. Plastered one side with ¼" gypsum plaster. Two wythes tied together every fourth course with No. 22 gauge corrugated metal ties.			6¼		
	37	One unit with three cells in wall thickness, cored 29 percent maximum.				6	
	38	One 2" unit cored 22 percent maximum and one 4" unit cored 41 percent maximum with ¼" mortar filled collar joint. Two wythes tied together every third course with No. 22 gauge corrugated metal ties.				6	
	39	One 4" unit cored 25 percent maximum with ¼" gypsum plaster on one side.				4⅛	
	40	One 4" unit with two cells in wall thickness, cored 22 percent maximum.					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 FACT-TO-FACE[2] (In Inches)			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.
Glazed or Unglazed Facing Tile, Nonload-bearing	41	One 4" unit cored 30 percent maximum with ¼" vermiculite gypsum plaster on one side.			4½	
	42	One 4" unit cored 39 percent maximum with ¼" gypsum plaster on one side.				4½
Solid Gypsum Plaster	43	¾" 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]
	44	Studless with ½" 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]
	45	¾" by No. 16 gauge cold-rolled channels 16" on center 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 2½ cubic feet of aggregate for the one-hour system.			2½[4]	2[4]
	46	Studless with ½" full-length plain gypsum lath and perlite or vermiculite gypsum plaster each side.			2½[4]	2[4]
	47	Studless partition with ⅜" 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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Solid Gypsum Plaster	48	¼" by No. 16 gauge vertical cold-rolled channels, 16" on center, with ⅜" 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]
Solid Perlite and Portland Cement	49	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]	
Solid Neat Wood Fibered Gypsum Plaster	50	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]	
Solid Gypsum Wallboard Partition	51	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]	
Hollow (Studless) Gypsum Wallboard Partition	52	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]
	53	1" regular gypsum "V" edge full-length backing board attached to both sides of wood or metal top and bottom runners with nails or 1⅝" drywall screws at 24" on center. Minimum width of runners 1⅝". Face layer of ½" regular full-length gypsum wallboard laminated to outer faces of backing board with approved laminating compound.			4⅛[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.
Noncombustible Studs —Interior Partition with Plaster Each Side	54	3¼" by No. 18 gauge steel studs spaced 24" on center. ⅞" gypsum plaster on metal lath each side mixed 1:2 by weight, gypsum to sand aggregate.				4⅛[4]
	55	3⅞" No. 16 gauge approved nailable[10] studs spaced 24" on center. ⅞" neat gypsum wood fibered plaster each side over ⅜" rib metal lath nailed to studs with 6d common nails, 8" on center. Nails driven 1¼" and bent over.			5⅛	
	56	2½" steel studs 16" on eenter formed with No. 16 gauge angle flanges and No. 7 gauge wire diagonals. ¼" perforated gypsum lath attached to the studs each side with No. 12 gauge wire clips at horizontal and vertical joints. ½" gypsum plaster applied each side mixed 1:2 by weight, gypsum to sand aggregate.				4¼[4]
	57	2½" steel studs 16" on center formed with No. 16 gauge angle flanges and No. 7 gauge wire diagonals. ¼" perforated gypsum lath attached to the studs each side with No. 12 gauge approved steel wire clips. End joints of lath held by approved end joint clips. ¼" perlite or vermiculite gypsum plaster applied each side.			4¼[4]	
	58	4" No. 18 gauge channel-shaped steel studs at 16" on eenter. On each side approved resilient clips pressed onto stud flange at 16" vertical spacing, ¼" 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.		7⅞[4]		

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Noncombustible Studs—Interior Partition with Plaster Each Side	59	2½" 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. ¾" plaster applied over each face, including finish coat.			4½[4]	
Wood Studs Interior Partition with Plaster Each Side	60[11]	2" x 4" wood studs 16" on center with ⅞" gypsum plaster on metal lath. Lath attached by 4d common nails bent over or No. 14 gauge by 1¼" x ¾" crown width staples spaced 6" on center. Plaster mixed 1:1½ for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate.				5⅛
	61[11]	2" x 4" wood studs 16" on center with metal lath and ⅞" neat wood fibered gypsum plaster each side. Lath attached by 6d common nails, 7" on center. Nails driven 1¼" and bent over.			5½[4]	
	62[11]	2" x 4" wood studs 16" on center with ⅜" perforated or plain gypsum lath and ½" gypsum plaster each side. Lath nailed with 1¼" by No. 13 gauge by 19/64" head plasterboard blued nails, 4" on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.				5⅛
	63[11]	2" x 4" wood studs 16" on center with ⅜" Type "X" gypsum lath and ½" gypsum plaster each side. Lath nailed with 1¼" by No. 13 gauge by 19/64" head plasterboard blued nails, 5" on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.				5⅛
	64[11]	2" x 4" wood studs 16" on center with ⅜" perforated gypsum lath and ½" perlite or vermiculite gypsum plaster each side. Lath nailed with 1¼" by No. 13 gauge by 19/64" head plasterboard blued nails, 5" on center. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2½ cubic feet of aggregate.				5⅛

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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.
Wood Studs Interior Partition with Plaster Each Side	65[11]	2"x 4" wood studs 16" on center with ⅞" perforated gypsum lath with 1" hexagonal mesh of No. 20 gauge wire furred out 7/16" and 1" perlite or vermiculite gypsum plaster each side. Lath nailed with 1⅛" by No. 13 gauge by 19/64" head plasterboard blued nails spaced 5" on center. Mesh attached by 1¼" by No. 12 gauge by ⅜" head nails with ⅞" furrings, spaced 8" on center. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds of gypsum to 2½ cubic feet of aggregate.			6¼	
Noncombustible Studs —Interior Partition with Gypsum Wallboard Each Side	66	No. 25 gauge channel-shaped studs 24" on center with one full-length layer of ⅝" 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 3⅝" 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.				2⅞[4]
	67	No. 25 gauge channel-shaped studs 24" on center with two full-length layers of ½" 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 1⅝" 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.			3⅞[4]	

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Noncombustible Studs—Interior Partition with Gypsum Wallboard Each Side	68	No. 16 gauge approved nailable metal studs[10] 24″ on center with full-length ⅞″ Type "X" gypsum wallboard[7] applied vertically and nailed 7″ on center with 6d cooler nails. Approved metal fastener grips used with nails at vertical butt joints along studs.				4⅞
Wood Studs—Interior Partition with Gypsum Wallboard Each Side	69[11]	2″x 4″ wood studs 16″ on center with two layers ⅝″ regular gypsum wallboard[7] each side, 4d cooler nails 8″ on center first layer, 5d cooler nails 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
	70[11]	2″x 4″ wood studs 16″ on center with two layers ½″ regular gypsum wallboard[7] applied vertically or horizontally each side, joints staggered. Nail base layer with 5d cooler nails at 8″ on center, face layer with 8d cooler nails at 8″ on center.				5½
	71[11]	2″ x 4″ wood studs 24″ on center with ⅝″ Type "X" gypsum wallboard[7] applied vertically or horizontally nailed with 6d cooler nails 7″ on center with end joints on nailing members. Stagger joints on each side.				4¾
	72[11]	2″x 4″ fire-retardant treated wood studs spaced 24″ on center with one layer of ⅝″ thick Type "X" gypsum wallboard[7] applied with face paper grain (long dimension) parallel to studs. Wallboard attached with 6d cooler nails spaced 7″ on center.				4¼[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.
Wood Studs—Interior Partition With Gypsum Wallboard Each Side	73[11]	2"x 4" wood studs 16" on center with two layers ⅝" Type "X" gypsum wallboard[7] each side. Base layers applied vertically and nailed with 6d cooler nails 9" on center. Face layer applied vertically or horizontally and nailed with 8d cooler nails 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	
	74[11]	2"x 3" fire-retardant treated wood studs spaced 24" on center with one layer of ¾" 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.				3⅞[4]
Exterior or Interior Walls	75[11]	Exterior surface with ¾" drop siding or ⅜" exterior type plywood over ½" 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 1¼" by No. 11 gauge by 7/16" head galvanized nails at 8" on center. Siding nailed with 7d galvanized smooth box nails. Plywood nailed with 6d galvanized siding or casing nails, 6" on center around the perimeter and 12" on center elsewhere.				Varies
	76[11]	2"x 4" wood studs 16" on center with metal lath and ¾" exterior cement plaster[12] on each side. Lath attached with 6d common nails 7" on center driven to 1" 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.				5⅞

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Exterior or Interior Walls	77[11]	2″ x 4″ wood studs 16″ on center with ⅞″ 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
	78	3⅝″ No. 16 gauge noncombustible studs 16″ on center with ⅞″ 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]
	79	2¼″x 3¾″ clay face brick with cored holes over ½″ gypsum sheathing on exterior surface of 2″ x 4″ wood studs at 16″ on center and two layers ⅜″ Type "X" gypsum wallboard[7] on interior surface. Sheathing placed horizontally or vertically with vertical joints over studs nailed 6″ on center with 1¼″ 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 nails. Outer layer of wallboard placed horizontally or vertically and nailed 8″ on center with 8d cooler 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 ¾″x 6⅞″ attached to each stud with two 8d cooler nails, every sixth course of bricks.			10	

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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.
Exterior or Interior Walls	80[11]	2" x 6" fire-retardant treated wood studs 16" on center. Interior face has two layers of ⅝" 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 ⅝" 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 2½", 12 gauge galvanized roofing nails with a ⅜" diameter head and spaced 6" on center along each stud. Exterior cement plaster consisting of a ½" 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 asbestos fiber 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 asbestos fiber used in the scratch coat.			8¼	
	81[11]	2" x 6" wood studs 16" on center. The exterior face has a layer of ⅝" 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 2½" long galvanized roofing nails spaced 6" on center along each stud. Exterior cement plaster consisting of a ½" scratch coat, a bonding agent and a ½" 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 asbestos fiber 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 asbestos fiber used in the scratch coat. The interior is covered with ⅜" 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 1¼" by No. 13 gauge by 19/64" head plasterboard blued nails spaced 5" on center. Mesh attached by 1¼" by No. 12 gauge by ⅜" head nails with ⅜" furrings, spaced 8" on center. The plaster mix shall not exceed 100 pounds of gypsum to 2½ cubic feet of aggregate.			8⅞	

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Exterior or Interior Walls	82[11]	2"x 6" wood studs at 16" on center. The exterior face has a layer of ⅜" 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 1½" by No. 17 gauge self-furred exterior lath attached with 8d by 2½" long galvanized roofing nails spaced 6" on center along each stud. Exterior cement plaster consisting of a ½" scratch coat, and a ½" 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 ⅜" gypsum lath with 1" hexagonal mesh of No. 20 gauge woven wire lath furred out 5/16" and 1" perlite or vermiculite gypsum plaster each side. Lath nailed with 1⅛" by No. 13 gauge by 19/64" head plasterboard blued nails spaced 5" on center. Mesh attached by 1¼" by No. 12 gauge by ⅜" head nails with ¾" furrings, spaced 8" on center. The plaster mix shall not exceed 100 pounds of gypsum to 2½ cubic feet of aggregate.			8⅞	
	83	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 ¼" 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.			6½[4]	

(Footnotes on following page)

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FOOTNOTES TO TABLE NO. 43-B

[A]Generic fire resistance ratings (those not designated by company code letter) as listed in the Fire Resistance Design Manual, 1981 Edition, 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]Thickness shown for brick and clay tile are nominal thicknesses unless plastered, in which case thicknesses are net. Thicknesses shown for solid or hollow concrete masonry units are "equivalent thicknesses" as defined in U.B.C. Standard No. 24-4. 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 1¼-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 paster 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]Three pounds of asbestos fiber added for each bag of portland cement.

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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.
Concrete—Excluding Expanded Clay Shale or Slate (by Rotary Kiln Process) or Expanded Slag.	1	Slab (no ceiling required).	6½	5½	4½	3½[2]				
Concrete — Expanded Clay Shale or Slate (by Rotary Kiln Process) or Expanded Slag.	2	Slab (no ceiling required).	5	4½	4	3				
Reinforced Concrete Joists	3	Slab with suspended ceiling of vermiculite gypsum plaster over metal lath attached to ¾" cold-rolled channels spaced 12" on center. Ceiling located 6" minimum below joists.	3	2			1	¾		

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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.
Reinforced Concrete Joists	4	⅝" Type "X" gypsum wallboard[3] attached to No. 25 gauge by ⅞" deep by 2⅛" 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 ³⁄₁₂" by 1¼" 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 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.			2½				⅞	

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Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units[4]	5	Gypsum plaster on metal lath attached to the bottom chord 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	⅞	
	6	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				⅞		
	7	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.			2¼	2			⅞[5]	⅞[6]

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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.
Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units [4]	8	Perlite or vermiculite gypsum plaster on ⅜" perforated gypsum lath attached to ¾" cold-rolled channels with approved clips giving continuous support to lath. Channels attached to or suspended below joists and held to bottom chord of joists.	2	2	2	2	1⅛ [7] [9]	⅞ [7] [8] [9]	⅞ [8]	1
	9	Gypsum plaster on ⅛" perforated gypsum lath attached to ¾" cold-rolled channels, with approved clips giving continuous support to lath. Channels attached to or suspended below joists and wire tied to bottom chord of joists.			2				¾ [9]	
	10	Ceiling of ⅝" Type "X" wallboard [3] attached to ¾" deep by 2⅜" 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.			2½				⅝	

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Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units[4]	11	Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath tied 6″ on center to ¾″ channels spaced 13½″ on center. Channels secured to joists at each intersection with two strands of No. 18 gauge galvanized wire.			2½				¼	
Reinforced Concrete Slab and Joists with Hollow Clay Tile Fillers Laid End to End in Rows 2½″ or More Apart; Reinforcement Placed Between Rows and Concrete Cast Around and Over Tile	12	⅞″ gypsum plaster on bottom of floor or roof construction.			8[10]				⅞	
	13	None				5½[11]				
Steel Joists Constructed with a Poured Reinforced Concrete Slab on Metal Lath Forms or Steel Form Units[4]	14	Vermiculite gypsum plaster on metal lath attached to ¼″ cold-rolled channels with No. 18 gauge wire ties spaced 6″ on center.	2½[12]				¾			

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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.
3" Deep Cellular Steel Deck with Concrete Slab on Top. Slab Thickness Measured to Top of Cells	15	Perlite or vermiculite gypsum plaster on ⅞" perforated gypsum lath attached to ¾" cold-rolled channels with approved clips. Channels suspended by No. 8 gauge hanger wire through units between cells.		2½				⅞[8,9]		
	16	Suspended ceiling of vermiculite gypsum plaster base coat and vermiculite acoustical plaster on metal lath attached at 6" intervals to ¾" cold-rolled channels spaced 12" on center and secured to 1½" cold-rolled channels spaced 36" on center with No. 16 gauge wire. 1½" channels supported by No. 8 gauge wire hangers at 36" on center. Beams within envelope and with a 2½" air space between beam soffit and lath have a 4-hour rating.	2½				1⅛[13]			

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1½" 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	17	Ceiling of gypsum plaster on metal lath. Lath attached to ¼" furring channels with No. 18 gauge wire ties spaced 6" on center. ¾" channel 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 by weight, gypsum to sand aggregate.			1⅞	1			¾ [9]	¾ [9]

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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.
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.	18	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.			1½	1			⅞[9]	¾[9]
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	19	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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Double Wood Floor Over Wood Joists Spaced 16" On Center[14, 15]	20	Gypsum plaster over ⅛" perforated gypsum lath attached to joists with 1⅛" by No. 13 gauge by 19/64" head plasterboard blued nails at a spacing of 4" on center. All joints reinforced with 3" wide strips of metal lath nailed through gypsum lath to joists with 1¾" by No. 11 gauge by ½" head nails spaced 5" on center along joists and with two nails per joist in the opposite direction. Plaster mixed 1:2 by weight, gypsum to sand aggregate.									⅞
	21	Perlite or vermiculite plaster over ⅜" perforated gypsum lath nailed with 1⅛" by No. 13 gauge by 19/64" head plasterboard blued nails.									1⅛

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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.
Double Wood Floor Over Wood Joists Spaced 16″ On Center [14] [15]	22	Gypsum plaster over ⅛″ Type "X" gypsum lath. Lath initially applied with not less than four 1⅛″ by No. 13 gauge by ⅞₁₆″ 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 1½″ by No. 11 gauge by ½″ 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 1½″ by ¼″ 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.								⅞

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Double Wood Floor Over Wood Joists Spaced 16" On Center[14 15]	23	Portland cement or gypsum plaster on metal lath. Lath fastened with 1½" by No. 11 gauge by 7/16" head barbed shank roofing nails spaced 5" on center. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, cement to sand aggregate.									⅞
	24	Perlite or vermiculite gypsum plaster on metal lath secured to joists with 1½" by No. 11 gauge by 7/16" head barbed shank roofing nails spaced 5" on center.									⅞
	25	½" Type "X" gypsum wallboard[3] nailed to joists with 5d cooler nails spaced 6" on center. End joints of wallboard centered on joists.									½
Plywood Stressed Skin Panels Consisting of ⅞" Thick Interior C-D (Exterior Glue) Top Stressed Skin on 2" x 6" Nominal (Minimum) Stringers. Adjacent Panel Edges Joined with 8d Common Wire Nails Spaced 12" Maximum on Center.	26	½" thick wood fiberboard weighing 15 to 18 lbs. per cu. ft. installed with long dimension parallel to stringers or ⅞" Standard (exterior glue) plywood glued and/or nailed to stringers. Nailing to be with 5d cooler nails spaced 12" on center. Second layer of ½" Type "X" gypsum wallboard applied with long dimension perpendicular to joists and attached with 8d cooler nails spaced 6" on center at end joints and 8" on center elsewhere. Wallboard joints staggered with respect to fiberboard joints.									1

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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.
Vermiculite Concrete Slab Proportioned 1:4 (Portland Cement to Vermiculite 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 Reinforced with 4"x 8" No. 12/14 Welded Wire Mesh.	27	None				3 [12]				
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"x 8" No. 12/14 Welded Wire Mesh.	28	None				3½ [12]				
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.	29	Perlite gypsum plaster on metal lath wire tied to ¾" furring channels attached with No. 16 gauge wire ties to lower chord of joists.		2 [16]	2 [16]			⅞	¾	

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Perlite Concrete Slab Proportional 1:6 (Portland Cement to Perlite Aggregate) on 1¼" 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.	30	None			$2\frac{13}{16}$					
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.	31	Suspended envelope ceiling of perlite gypsum plaster on metal lath attached to ¾" cold-rolled channels, secured to 1½" 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^{16}				1^{9}			

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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.
Perlite concrete proportioned 1:6 (portland cement to perlite aggregate) poured to ⅛-inch thickness above top of corrugations of 1⅛16-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 2¼″-diameter holes. Boards covered with 2¼″ minimum perlite concrete slab. Slab reinforced with mesh consisting of No. 19 gauge (0.041″ galvanized) steel wire twisted together to form 2-inch hexagons with 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.	32	None			Varies					

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FOOTNOTES TO TABLE NO. 43-C

[a]Generic fire resistance ratings (those not designated by company code letter) as listed in the Fire Resistance Design Manual, 1981 Edition, 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 40 pounds of asbestos fiber per bag of cement.

[6]Portland cement plaster with 15 pounds of hydrated lime and 3 pounds of asbestos fiber per bag of cement.

[7]One-inch by No. 20 gauge hexagonal wire mesh installed below lath and tied to each furring channel at joints between lath.

[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]Furring channels spaced 12 inches on center.

[10]Six-inch hollow clay tile with 2-inch concrete slab above.

[11]Four-inch hollow clay tile with 1½-inch concrete slab above.

[12]Thickness measured to bottom of steel form units.

[13]Five-eighths inch of vermiculite gypsum plaster plus ½ 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 ½-inch interior-type plywood with exterior glue and a layer of 1-inch nominal tongue-and-groove finish flooring or ⅝-inch interior-type plywood finish flooring or a layer of Type I Grade M-1 particleboard not less than ⅝ inch thick.

[15]The ceiling may be omitted over unusable space, and flooring may be omitted where unusable space occurs above.

[16]Thickness measured on top of steel deck unit.

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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 maintained 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 ¾-inch boards or ¼-inch plywood. Plywood fences shall conform to the following requirements:

1. Plywood panels shall be bonded with an adhesive identical to those for exterior plywood.

2. Plywood ¼ inch or 5/16 inch in thickness shall have studs spaced not more than 2 feet on center.

3. Plywood ⅜ inch or ½ 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 ⅝ 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.

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

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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.

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 eonstrued to permit the violation of other laws or ordinances regulating the use and oeeupaney of publie 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 and Appendages

Sec. 4504. Oriel windows, balconies, 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 distanee as determined by the elearance 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.

Clearanee above grade over 8 feet—1 inch of projection is permitted for each

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additional inch of clearance, provided that no such projection shall exceed a distance of 4 feet.

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 projecting 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 curb 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 direction 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 wire glass is used not less than ¼ inch thick with no single pane more than 18 inches wide.

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 Prohibited.** 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 maintenance of electroliers.

Awnings

Sec. 4506. (a) **Definitions.** 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.

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(c) **Projection.** Awnings may extend over public 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 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. 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 speeified in this chapter and, when required for fire-resistive construction, also shall eonform with the provisions of Chapter 43.

Other approved wall or ceiling coverings may be installed in accordance with the reeommendations 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 eompliance 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 ⅜-inch and ¾-inch rib metal lath or ½-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 ⅜-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 ⅜ 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 comform 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.

(c) **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 ½ 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 ⅛ inch shall be lapped at sides by nesting outside ribs. When edge ribs are ⅛ inch or less, rib metal lath may be lapped ½ 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 ¼ 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 weep screed 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.

Approved acoustical finish plaster may be applied over any base coat plaster, over lean masonry or concrete, or other approved surfaces.

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(e) **Interior Masonry or Concrete.** Condition of surfaces shall be as specified in Section 4708 (g). 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.

For machine-placed plasters, asbestos fiber may be added to portland cement plaster in approved amounts. Approved portland cement plaster containing asbestos fiber, blended at the time of manufacture, and so labeled, may be used.

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 ¼ inch in any direction under a 5-foot straightedge.

(d) **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.

(e) **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.

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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.

(f) **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.

(g) **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 (g).

(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

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damp for 24 hours by light water spraying.

Pneumatically Placed Plaster (Gunite)

Sec. 4710. Pneumatieally plaeed portland eement plaster shall be a mixture of portland eement and sand, mixed dry, conveyed by air through a pipe or flexible tube, hydrated at the nozzle at the end of the eonveyor 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 pereent 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 ⅞ 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.

Shower and public toilet walls shall conform to Section 510 (b).

Water-resistant gypsum backing board shall conform to U.B.C. Standard No. 47-14.

(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.

(e) **Single-ply Application.** All edges and ends of gypsum wallboard shall oeeur on the framing members, exeept 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 eoneealed 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 ⅜ 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.

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

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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 except 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 the joint treatment.

EXCEPTION: Assemblies tested without joint treatment.

Gypsum wallboard tape and joint compound shall conform with the provisions of U.B.C. Standard No. 47-6.

Softwood Plywood Paneling

Sec. 4712. 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.

Shear-resisting Construction with Wood Frame

Sec. 4713. (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 doubled 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 Sec-

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tion 2517 (g) for bearing walls, and studs shall be spaced not farther apart than 16 inches center to center. Marginal studs and plates shall be anchored 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 1½ 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 ⅜ 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 16 18 20 22.5 25.0	No. 9 gauge wire No. 8 gauge wire $\frac{3}{16}$" diameter, mild steel rod[2] $\frac{1}{12}$" diameter, mild steel rod[2] ¼" diameter, mild steel rod[2] 1" x $\frac{1}{8}$" mild steel flats[3]
Hangers for Attaching Runners and Furring Directly to Beams and Joists	For Supporting Runners	Single Hangers Between Beams[4]	8 12 16	No. 12 gauge wire No. 10 gauge wire No. 8 gauge wire
		Double Wire Loops at Beams or Joists[3]	8 12 16	No. 14 gauge wire No. 12 gauge wire No. 11 gauge wire
	For Supporting Furring without Runners[4] (Wire Loops at Supports)	Type of Support: Concrete Steel Wood	8	No. 14 gauge wire No. 16 gauge wire (2 loops)[5] 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]Other sections of hot- or cold-rolled 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)	
				Metal			
			Wood	Solid Plaster Partitions	Other	Wood or Concrete	Metal
1. Expanded Metal Lath (Diamond Mesh)		2.5 3.4	16[3] 16[3]	16[3] 16[3]	12 16	12 16	12 16
2. Flat Rib Expanded Metal Lath		2.75 3.4	16 19	16 24	16 19	16 19	16 19
3. Stucco Mesh Expanded Metal Lath		1.8 and 3.6	16[4]	—	—	—	—
4. ⅜" Rib Expanded Metal Lath		3.4 4.0	24 24	24[5] 24[5]	24 24	24 24	24 24
5. Sheet Lath		4.5	24	[5]	24	24	24
6. Wire Fabric Lath	Welded	1.95 pounds, No. 11 gauge, 2" x 2" 1.16 pounds, No. 16 gauge, 2" x 2" 1.4 pounds, No. 18 gauge, 1" x 1"[6]	24 16 16[4]	24 16 —	24 16 —	24 16 —	24 16 —
	Woven[4]	1.1 pounds, No. 18 gauge, 1½" Hexagonal[6] 1.4 pounds, No. 17 gauge, 1½" Hexagonal[6] 1.4 pounds, No. 18 gauge, 1" Hexagonal[6]	24 24 24	16 16 16	16 16 16	16 24 24	24 16 16
7. ⅜" Gypsum Lath (perforated)			16	—	16[7]	16	16
8. ⅜" Gypsum Lath (plain)			16	—	16[7]	16	16
9. ½" Gypsum Lath (perforated)			16	—	16[7]	16	16
10. 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. 47-1. 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 ¼ inch. Self-furring lath meets furring requirements. Exception: Furring of expanded metal lath is not required on supports having a bearing surface width of 1⅝ 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] Type and Size	MAXIMUM SPACING[5] (In Inches) Vertical	MAXIMUM SPACING[5] (In Inches) Horizontal	SCREWS[3 6] MAX. SPACING[5] (In Inches) Vertical	SCREWS[3 6] MAX. SPACING[5] (In Inches) Horizontal	STAPLES[3 4] Round or Flattened Wire Wire Gauge No.	Crown (In Inches)	Leg[7] (In Inches)	MAX. SPACING[5 6] (In Inches) Vertical	MAX. SPACING[5 6] (In Inches) Horizontal
1. Diamond Mesh Expanded Metal Lath and Flat Rib Metal Lath	4d blued smooth box 1½"[11] No. 14 gauge 7/32" head (clinched)[7] 1" No. 11 gauge 7/16" head, barbed 1½" No. 11 gauge 7/16" head, barbed	6 6 6	— — 6	6	6	16	¾	⅞	6	6
2. ⅜" Rib Metal Lath and Sheet Lath	1½" No. 11 gauge 7/16" head, barbed	6	6	6	6	16	¾	1¼	At Ribs	At Ribs
3. ¾" Rib Metal Lath	4d common 1½" No. 12½ gauge ¼" head 2" No. 11 gauge 7/16" head, barbed	At Ribs	— At Ribs	At Ribs	At Ribs	16	¾	1⅝	At Ribs	At Ribs

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4. Wire Fabric Lath[9]	4d blued smooth box (clinched)[8] 1" No. 11 gauge 7/16" head, barbed	6 6	— —	6	6	16	3/4	7/8	6	6
	1½" No. 11 gauge 7/16" head, barbed 1¼" No. 12 gauge 3/8" head, furring 1" No. 12 gauge 3/8" head	6 6 6	6 6			16	1/16[9]	7/8	6	6
5. 3/8" Gypsum Lath	1⅜" 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. ½" 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 5/8 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 1/8 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] 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	7/8" maximum
6. Monolithic Concrete Ceilings[4 5]	3/8" maximum[6 7 8]	1/2" maximum[7 8]

[1]For fire-resistive construction, see Tables No. 43-A, No. 43-B and No. 43-C.

[2]When measured from back plane of expanded metal lath, exclusive of ribs, or self-furring lath, plaster thickness shall be ¼-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 (Center to Center) (In Inches)		NAILS[2]—TO WOOD
				Nails[3]	Screws[4]	
½	Horizontal	Either Direction	16	7	12	No. 13 gauge, 1⅜" long, 19/64" head; 0.98" diameter; 1¼" long, Annular ringed; 5d, cooler nail (0.86" dia., 1⅜" long, 15/64" head)
	Horizontal	Perpendicular	24	7	12	
	Vertical	Either Direction	24	8	12	
⅝	Horizontal	Either Direction	16	7	12	No. 13 gauge, 1⅜" long, 19/64" head; 0.98" diameter; 1¼" long, Annular ringed; 5d, cooler nail (0.86" dia., 1⅜" long, 15/64" head)
	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
½ or ⅝	Horizontal	Either Direction	16	16	16	24	As required for ½" and ⅝" gypsum wallboard, see above
		Perpendicular	24	16	24	24	
	Vertical	Either Direction	24	16	24	[5]	

[1]For fire-resistive construction, see Tables No. 43-B and No. 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 ⅝ 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. 13½ gauge, 1⅜ inch long, 15/64-inch head for ½-inch gypsum wallboard; 6d, No. 13 gauge, 1⅞ inch long, 15/64-inch head for ⅝-inch gypsum wallboard.

[3]Two nails spaced 2 inches to 2½ 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 ⅝ inch and through metal framing not less than ¼ inch.

[5]Not required.

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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	Perpendicular 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 No. 43-B and No. 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 ¾ 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 nail as set forth in Table No. 25-17-I 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 ¾-inch crown width with leg length of ⅞ inch, 1⅛ inch and 1⅜ inch for gypsum wallboard thicknesses of ⅜ inch, ½ inch and ⅝ 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
1. Expanded metal, or woven wire lath and portland cement plaster	⅞"	Unblocked	6	180	No. 11 gauge, 1½" long, 7/16" head No. 16 gauge staple, ¾" legs
2. Gypsum lath, plain or perforated	⅜" Lath and ½" Plaster	Unblocked	5	100	No. 13 gauge, 1⅛" long, 19/64" head, plasterboard blued nail
3. Gypsum sheathing board	½" x 2' x 8'	Unblocked	4	75	No. 11 gauge, 1¾" long, 7/16" head, diamond-point, galvanized
	½" x 4' ½" x 4'	Blocked Unblocked	4 7	175 100	
4. Gypsum wallboard or veneer base	½"	Unblocked	7	100	5d cooler nails
			4	125	
		Blocked	7	125	
			4	150	
	⅝"	Blocked	4	175	6d cooler nails
		Blocked Two-ply	Base ply 9 Face ply 7	250	Base ply—6d cooler nails Face ply—8d cooler nails

[1]These vertical diaphragms shall not be used to resist loads imposed by masonry or concrete construction. See Section 4713 (b). Values are for short-time loading due to wind or earthquake and must be reduced 25 percent for normal loading.

[2]Applies to nailing at all studs, top and bottom plates and blocking.

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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 722—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.

(c) **Certifying Agency.** To be acceptable under this code, every certificate of approval shall be made by an approved agency.

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(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 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.

Emergency Operation and Special Provisions

Sec. 5103. (a) **Automatic Elevators.** Automatic passenger elevators shall conform to the following:

1. **Commandeering switch.** In other than dwelling units, elevators shall be provided with a two-position switch for emergency operation. Such switch shall be located near the entrance to the elevator at each main floor of the building.

When the switch is in the "on" position, all elevators which are in normal service shall return nonstop to the floor where the switch is in the "on" position and the doors shall open, except that an elevator traveling away from the main floor may reverse at the next available floor without opening its doors. When the switch is in the "on" position, door-reopening devices for power-operated doors which may be affected by smoke or heat so as to prevent door closure shall be rendered inoperative; and elevators equipped with power-operated doors and standing at a floor other than the main floor, with doors open, shall close their doors without delay. Except for elevators in emergency service, the switch shall be connected so that elevators may be returned to normal service by moving the switch to the "off" position.

2. **Heat- and smoke-sensing devices.** The return to a main floor may be initiated by heat- or smoke-sensing devices, or both, in the building independently of the switch required by provision 1 above, except that such devices at the main floor shall not initiate the return of the elevators. If so, the switch required at a main floor shall have three positions. The third position shall restore normal service independent of the heat- or smoke-sensing device, or both.

3. **Elevator car emergency switch.** A switch shall be provided in or adjacent to an operating panel of each elevator car. This switch, when operated, shall put the elevator on emergency service and shall be operable only after the switch required by provision 1 above has been activated. When the emergency service switch in the elevator is actuated:

(i) An elevator shall be operable only by a person in the elevator.

(ii) Elevators on emergency service shall not respond to elevator landing calls.

(iii) The opening of power-operated doors shall be controlled only by continuous-pressure "open" buttons or switches. If the open button or switch is

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released during the "open" motion, the doors shall automatieally reclose.

(iv) Door-reopening devices for power-operated doors which may be affected by smoke or heat so as to prevent door closure shall be rendered inoperative.

4. **Keys for elevator switches.** Keys, where permitted for the switches required by provisions 1 and 3 above, shall be kept on the premises by the person responsible for the maintenance and operation of the elevators in a location readily accessible to authorized persons in an emergency but not where they are available to the public.

(b) **Attendant-operated Elevators.** Elevators operated only by a designated operator in the car shall be provided with a signal system to permit signaling the operator from the main floor to return nonstop to a designated main floor. Attendant-operated elevators having power-operated doors and door-reopening devices affected by smoke or heat shall be rendered inoperative, and such doors and devices shall conform to Subsection (a) 3, (iii) and (iv) above.

(c) **Dual-operated Elevators.** Elevators arranged for dual operation shall, when on automatic operation, conform to Subsection 5103 (a) and when attendant operated shall conform to Subsection 5103 (b).

(d) **Door Operation.** Each elevator lobby or entrance area shall be provided with an approved smoke detector which will operate before the optical density reaches 0.03 per foot and conforming to U.B.C. Standard No. 43-6, and which will not permit the elevator doors to open when the detector is activated.

(e) **Access.** Each elevator car shall have a height, recessed area or movable ceiling which will make possible the carrying of a 9-foot-high ladder.

(f) **Standby Power.** Standby power shall be provided to at least one elevator in each bank where the highest floor level of human occupancy is more than 75 feet above the lowest level of fire department vehicle access. Standby power shall be transferable to all other elevators in the bank and shall be capable of operating the elevator with a full load at contract speed. Standby power 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 at least a one-hour fire-resistive occupancy separation from the remainder of the building and shall have a fuel supply adequate to operate the equipment for two hours.

(g) **Restricted- or Limited-use Elevators.** The building official may waive the requirements of this section for any elevator designed for limited or restricted use serving only specific floors or a special function.

(h) **Size of Cab.** In buildings three or more stories in height served by an elevator, or a building served by an elevator required by Table No. 33-A, at least one elevator serving all floors shall be of a size that will accommodate a wheelchair. Such elevators shall have horizontal dimensions not less than the following:

Distance between side walls, 68 inches, except that elevators with capacities of less than 2000 pounds may be reduced to 54 inches minimum.

Distance between wall and door, 54 inches.

Distance between wall and return panel adjacent to the door, 51 inches.

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Clear door opening width, 32 inches.

In buildings regulated by Section 1807, at least one elevator serving all floors shall be of a size that will accommodate a 22-inch by 78-inch ambulance stretcher in the horizontal position, unless otherwise designed to provide equivalent utility. Such elevators shall have horizontal dimensions not less than the following:

Distance between side walls, 80 inches.

Distance between wall and door, 54 inches.

Distance between wall and return panel adjacent to the door, 51 inches.

Clear door opening width, 42 inches.

This elevator shall be identified.

(i) **Call and Car Operation Buttons.** Automatic passenger elevators shall have call and car operation buttons within 54 inches of the floor. Emergency telephones also shall be within 54 inches of the floor.

Emergency Communications

Sec. 5104. Every elevator car shall be provided with a two-way communication system connected to an approved emergency service which operates 24 hours every day.

Emergency Signs

Sec. 5105. Except at the ground floor level, an approved pictorial sign of a standardized design shall be posted adjacent to each elevator call station which specifies "IN CASE OF FIRE, DO NOT USE ELEVATORS—USE EXIT STAIRS."

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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 plasties, 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 teehnical 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:

APPROVED PLASTIC MATERIALS shall be 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.

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.

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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.

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 neeessary 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 whieh it is employed.

Glazing of Unprotected Openings

Sec. 5204. In Type V-N construetion, 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:

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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.

3. The area and size shall be limited to that set forth in Table No. 52-A.

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 8 feet of an exterior wall located where openings in such exterior wall are either prohibited or required to be protected.

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 33⅓ 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

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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.

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, Division 1 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 33⅓ 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, Division 1 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 8 feet of an exterior wall located where openings in such exterior wall are either prohibited or required to be protected.

(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

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in Chapter 33 shall not exceed 30 percent of the aggregate area of the ceiling in which they are installed.

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 Section 5208 (a).

Partitions

Sec. 5210. Light-transmitting plastics 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 constructed in accordance with provisions specified in Section 4506 for projections and appendages. For patio covers, see Appendix Chapter 49.

Greenhouses

Sec. 5212. Approved plastics 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 least 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 tops 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 33⅓ 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 33⅓ 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	MINIMUM SEPARATION OF PANELS	
				VERTICAL	HORIZONTAL
CC1	25	100	16	6	4
CC2	15	75	8	8	4

[1]The maximum pereent 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 accordanee with approved plans and specifications. Identification of glazing in hazardous locations shall be in accordance with Section 5406.

Area Limitations

Sec. 5403. Exterior glass and glazing shall be capable of safely withstanding the loads set forth in Table No. 23-F, acting inward or outward. The area of individual lights shall be not more than set forth in Table No. 54-A or as adjusted by Table No. 54-B.

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-C. 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.

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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 I 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 and sliding panels of sliding-type doors other than wardrobe doors.
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.

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7. Glazing in fixed panels other than those covered by Item No. 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 1½ 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 indoors or in locations described in Section 5406 (d), Item No. 6 or 7, above.
3. Glazing materials used as curved glazed panels in revolving doors.
4. Commercial refrigerated cabinet glazed doors.

(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.

Hinged Shower Doors

Sec. 5407. Hinged shower doors shall open outward.

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TABLE NO. 54-A—MAXIMUM ALLOWABLE AREA OF GLASS [1]
(In Square Feet)

WIND LOAD (In Pounds per Square Foot)	PLATE OR FLOAT GLASS THICKNESS (In Inches)													SHEET GLASS THICKNESS (In Inches)								
	1/8	3/16	7/32	1/4	5/16	3/8	7/16	1/2	5/8	3/4	1	1 1/4		SS	DS	3/16	7/32	1/4	5/16	3/8	7/16	1/2
10	41	72	81	89	107	144	185	275	351	465	525	656	956	41	56	95	109	128	180	213	243	311
15	27	48	54	60	71	96	123	183	234	310	350	438	637	27	38	63	73	86	124	142	162	207
20	21	36	40	45	53	72	92	137	176	232	262	328	478	20	28	47	55	64	93	107	122	155
25	16	29	32	36	43	58	74	110	140	186	210	262	382	16	23	38	44	51	74	85	97	124
30	14	24	27	30	36	48	62	92	117	155	175	219	319	14	19	32	36	43	62	71	81	104
35	12	21	23	26	31	41	53	79	100	133	150	188	273	12	16	27	31	37	53	61	69	89
40	10	18	20	22	27	36	46	69	88	116	131	164	239	10	14	24	27	32	46	53	61	78
45	9	16	18	20	24	32	41	61	78	103	117	146	212	9	13	21	24	29	41	47	54	69
50	8	14	16	18	21	29	37	55	70	93	105	131	191	8	11	19	22	26	37	43	49	62
60	7	12	13	15	18	24	31	46	59	77	88	109	159	7	9	16	18	21	31	36	41	52
70	6	10	12	13	15	21	26	39	50	66	75	94	137	6	8	14	16	18	27	30	35	44
80	5	9	10	11	13	18	23	34	44	58	66	82	120	5	7	12	14	16	23	27	30	39
90	4.5	8	9	10	12	16	21	31	39	52	58	73	106	4.5	6	11	12	14	21	24	27	35
100	4	7	8	9	11	14	18	27	35	46	52	66	96	4	5.5	9	11	13	19	21	24	31

[1]Maximum areas apply for rectangular lights of plate, float or sheet glass firmly supported on all four sides in a vertical position. Glass mounted at a slope not to exceed one horizontal to five verticals may be considered vertical. Maximum areas based on minimum thicknesses set forth in Table No. 54-1-C, Uniform Building Code Standard No. 54-1.

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TABLE NO. 54-B—ADJUSTMENT FACTORS—RELATIVE RESISTANCE TO WIND LOAD[1]

GLASS TYPE	APPROXIMATE RELATIONSHIP
1. Laminated	0.6
2. Wired	0.5
3. Heat-strengthened	2.0
4. Fully tempered	4.0
5. Factory-fabricated Double Glazing[2]	1.5
6. Rough Rolled Plate	1.0
7. Sandblasted	Varies[3]
8. Regular Plate, Float or Sheet	1.0

[1]To determine the maximum allowable area for glass types listed in Table No. 54-B multiply the allowable area established in Table No. 54-A by the appropriate adjustment factor. Example: For ¼-inch heat-strengthened glass determine the maximum allowable area for a 30-pound-per-square-foot wind load requirement. Solution procedure: Use Table No. 54-A to determine the established allowable area for ¼-inch plate or float glass. Answer: 36 square feet, then multiply 36 by 2—the heat-strengthened glass adjustment factor. Answer: 72.

[2]Use thickness of the thinner of the two lights, not thickness of the unit.

[3]To be approved by the building official since adjustment factor varies with amount of depreciation and type of glass.

TABLE NO. 54-C—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	¼"	¼"	5/16"	⅜"	½"
2. Minimum Glass Edge Clearance	⅛" [1,2]	⅛" [1,2]	3/16" [1]	¼"	¼" [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	¼"	3/16"	⅜"	½"
6. Minimum Glass Edge Clearance	⅛" [2]	3/16"	¼"	¼"
7. Continuous Glazing Rabbet and Glass Retainer[3]	Required above third story	Required		
8. Resilient Setting Material[4]	Not Required	Required		

(Footnotes on following page.)

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FOOTNOTES TO TABLE NO. 54-C

[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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CHAPTERS 55-59
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, 1982 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, 3904	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 Subject 1256 (March, 1974) 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.
CHAPTER 18	
18-1; 1807 (i), 1807 (l) 6, App. 721	Fire Alarm and Standby Power-generating Systems for High-rise Buildings. Installation Standard of the International Conference of Building Officials.

*ASTM refers to American Society for Testing and Materials.

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CHAPTER 23

23-1; 2312 (d)

Determination of the Characteristic Site Period, T_s. Engineering Standard of the International Conference of Building Officials.

CHAPTER 24

24-1; 2403 (b), 2404 (c) 2 A, 2418 (c) 2 A

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; 2403 (c)

Sand-lime Building Brick. Standard Specification C73-67 of the ASTM.

24-3; 2403 (d)

Concrete Building Brick. Standard Specification C55-55 of the ASTM.

24-4; 2403 (e), Table No. 43-B

Hollow Load-bearing Concrete Masonry Units. Standard Specification C90-70 of the ASTM.

24-5; 2403 (e)

Solid Load-bearing Concrete Masonry Units. Standard Specification C145-59 of the ASTM.

24-6; 2403 (e)

Hollow Nonload-bearing Concrete Masonry Units. Standard Specification C129-59 of the ASTM.

24-7; 2403 (e)

Method of Test for Concrete Masonry Units. Standard Methods C140-70 of the ASTM.

24-8; 2403 (f)

Structural Clay Load-bearing Wall Tile and Standard Methods of Sampling and Testing Structural Clay Tile. Standard Specificiation C34-70 and Standard Method C112-70 of the ASTM.

24-9; 2403 (f)

Structural Clay Nonload-bearing Tile. Standard Specification C56-70 of the ASTM.

24-10; 2403 (f)

Structural Clay Floor Tile. Standard Specification C57-65 of the ASTM.

24-12; 2406 (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.

24-13; 2403 (g)

Cast Stone. Specification ACI 704-44 of the American Concrete Institute.

24-14; 2403 (h), 2405 (b)

Unburned Clay Masonry Units and Standard Methods of Sampling and Testing Unburned Clay Masonry Units. Test Standard of the International Conference of Building Officials.

24-15; 2403 (m), 2603 (f) 3

Cold-drawn Steel Wire for Concrete Reinforcement. Standard Specification A82-79 of the ASTM.

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24-16; 2403 (o)

Cement, Masonry. Standard Specification C91-67 of the ASTM.

24-17; 2403 (p)

Quicklime for Structural Purposes. Standard Specification C5-59 (1974) of the ASTM.

24-18; 2403 (p)

Hydrated Lime for Masonry Purposes. Standard Specification C207-74 of the ASTM.

24-19; 2403 (p)

Processed Pulverized Quicklime. Standard Definitions of Terms C51-71 of the ASTM.

24-20; 2403 (q) 1 and 3, 2418 (c) 2 C

Mortar for Unit Masonry and Reinforced Masonry Other Than Gypsum. Standard Specifications C161-44T and C270-59T of the ASTM.

24-21; 2403 (q) 1, 2403 (t), 2618 (q) 2 C

Aggregate for Masonry Mortar. Standard Specification C144-76 of the ASTM.

24-22; 2403 (q) 3, 2403 (r) 3

Field Tests Specimens for Mortar and Grout. Test Standard of the International Conference of Building Officials.

24-23; 2403 (r) 1

Aggregates for Grout. Standard Specification C404-61 of the ASTM.

24-24; 2404 (c) 3, 2418 (c) 3 B

Sampling and Testing Brick. Standard Methods C67-60 of the ASTM.

24-25; 2403 (k)

Glazed Structural Clay Facing Tile. Standard Specification C126-71 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 of the Western Wood Products Association (July 1, 1974).

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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. Specifications for Grades of California Redwood Lumber of the Redwood Inspection Service (November, 1970).

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. 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, 25-K, 25-S-2, 25-T and 47-J

Construction and Industrial Plywood. Product Standard PS 1-74 of the U.S. Department of Commerce, and National Bureau of Standards and Calculation of Diaphragm Action, an engineering standard of the International Conference of Building Officials.

25-10; 2502 (a), 2511 (b), 2511 (f), Tables Nos. 25-C-1 and 25-C-2

Structural Glued-laminated Timber. Voluntary Product Standard PS 56-73. U.S. Department of Commerce, and Standard Specification D3737-78 of the ASTM.

25-11; 2502 (a), 2511 (d) 5, Tables Nos. 25-C-1, 25-C-2 and 25-D

Structural Glued-laminated Timbers: Softwood and Hardwood Species. Standard Specifications for Structural Glued-laminated Timber of Softwood Species (1979), American Institute of Timber Construction, and Standard Specification for Hardwood Glued-laminated Timber (1976), American Institute of Timber Construction.

25-12; 2502 (a), 2505, 2516 (c), 2909 (a) 1

Preservative Treatment by Pressure Processes and Quality Control Standards. Standard Specifications C1-74, C2-74, C3-74, C4-74, C9-72, C23-74 and C28-73 of the American Wood Preservers Association and 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, ANSI 05.1-1972 of the American National Standards Institute, Inc.

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 Construction (1977), including the 1980 Supplement, National Forest Products Association.

25-17; 2510 (a), 2510 (b), 2510 (c), 2510 (d), 2510 (e), 2510 (h), 2514 (b) 1, 2514 (b) 2, 2516 (j) 1, 3203 (c) 4, Tables Nos. 25-F, 25-G, 25-H and 47-H

Timber Connector Joints, Bolted Joints, Drift Bolts and Wood Screws, and Lag Screws. National Design Specification for Wood Construction (1977), including the 1980 Supplement, National Forest Products Association. Light Metal Plate Connected Wood Truss Design, Design Specification for Light Metal Plate Connected

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Wood Trusses TPI-68, Truss Plate Institute. Nails and Staples, Federal Specification No. FF-N-105B (March 17, 1971).

25-18; 2512

Structural Glued Built-up Members—Plywood Components. Design and Fabrication Specifications of American Plywood Association.

25-19; 2517 (e) 2

Adhesives. Standard Specification D2559-72, Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet-use) Exposure Conditions and Standard Specification D3024-72, Protein Base Adhesive for Structural Laminated Wood Products for Use Under Interior (Dry-use) Exposure Conditions of the ASTM, and American Plywood Association Specification AFG-01, September, 1974.

25-20

Test For Glue Joints in Laminated Wood Product. Standard Test Method D1101-59 of the ASTM, and AITC 200-73 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 Lumber. Inspection Manual, AITC 200-73 of American Institute of Timber Construction, referenced in Voluntary Product Standard PS 56-73, the basis for U.B.C. Standard No. 25-10 and Standard Methods of Testing D805-63 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 208.1-1979.

25-26; 2502 (a), 2516 (g) 6

Hardboard Siding. Voluntary Product Standard PS 60-73 of the United States Department of Commerce.

25-27; 2504 (c) 9

Temperature Effects. National Design Specification for Wood Construction (1977), including the 1980 Supplement, National Forest Products Association.

CHAPTER 26

26-1; 2403 (o), 2603 (c), 2604 (f) 2

Portland Cement and Blended Hydraulic Cements. Standard Specifications C150-81 and C595-81a of the ASTM.

26-2; 2603 (d), 2708 (d)

Concrete Aggregates. Standard Specification C33-81 of the ASTM.

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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; 2403 (l), 2603 (f) 2, 2603 (f) 3, 2625 (d) 2
Reinforcing Bars for Concrete. Standard Specifications A615-80, A616-79, A617-79 and A706-80 of the ASTM.

26-5; 2603 (f) 2
Fabricated Deformed Steel Bar Mats. Standard Specification A184-79 of the ASTM.

26-6; 2603 (f) 2
Welded Steel Wire Fabric and Deformed Steel Wire. Standard Specifications A185-79, A496-78 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
Welding Reinforeing Steel, Metal Inserts and Connections in Reinforced Concrete Construction. AWS D1.4-79 of the American Welding Society.

26-9; 2603 (g)
Admixtures for Concrete. Standard Specifications C494-80, C260-77 and C618-80 of the ASTM.

26-10; 2604 (e), 2604 (i) 2, 2604 (j), 2604 (i) 3
Concrete Tests. Part I—Making and Curing Concrete Test Specimens in the Laboratory. Part II—Making and Curing Concrete Compression and Flexure 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 Method C31-69 (1980), Standard Method of Test C39-80, Standard Method C42-77, Standard Method of Test C78-75 (1978), Standard Method C192-81, Standard Method C617-76 (1978) and Standard Method C172-71 (1977) of the ASTM.

26-11; 2604 (h)
Evaluation of Compression Test Results in Field Concrete. American Concrete Institute Standard 214-65.

26-12; 2602, 2604 (c) 2 H
Splitting Tensile Strength. Standard Test Method C496-71 (1979) of the ASTM.

26-13; 2605 (b)
Ready-mixed Concrete. Standard Specification C94-81 of the ASTM.

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, A441, A446, A490, A500, A501, A514, A529, A570, A572, A588, A606, A607, A611, A618, A633, A666 and A715 of the ASTM.

27-2; 2701 (b), 2719, 2720, 2721 (k)
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32-7; 407, 1712 (b) 5, 3203 (b), 5207 (a) 2

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Wood Shingles. Standards of the Red Cedar Shingle & Handsplit Shake Bureau and Material Standard of the International Conference of Building Officials.

32-12; 3203 (d) 3 F

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32-13; 3203 (c) 5

Wire. Standard Specifications B134-62, B211-63 and B250-62 of the the ASTM.

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Power-operated Exit Doors. Test Standard of the International Conference of Building Officials.

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33-4; 3304 (d)

Panic Hardware. Standard 305, May 7, 1973, of the Underwriters Laboratories Inc.

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38-2; 3801 (d), 3805 (a)

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43-2; 802 (b) 2, 3305 (h), 3309 (c), 4306 (e), 4306 (i), 4306 (j) 1

Fire Tests of Door Assemblies. Standard 10B-1970 of the Underwriters Laboratories Inc., and International Conference of Building Officials Test Standard for Smoke and Draft Control Door Assemblies.

43-3; 4306 (k)

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43-8; 306 (a) 9, 4303 (e)

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47-3; Table No. 47-E.

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47-8; Table No. 47-B

Gypsum Lath. Standard Specification C37-69 of the ASTM.

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APPENDIX

Chapter 1

LIFE SAFETY REQUIREMENTS FOR EXISTING BUILDINGS

Note: This is a new Appendix chapter

General

Sec. 108. (a) **Purpose.** The purpose of this chapter is to provide a reasonable degree of safety to persons occupying existing buildings that do not conform with the minimum requirements of this code by providing for alterations to such existing buildings.

EXCEPTION: Group R, Division 3 or Group M Occupancies.

(b) **Effective Date.** Within 18 months after the effective date of this appendix, 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.

(c) **Alternate Materials and Methods.** Alternate materials and methods may be used, provided such materials or methods comply with the spirit and intent of this appendix.

The building official may modify any of the provisions of this appendix in conformance with Section 106 of this code.

Exits

Sec. 109. (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 deviee for the ladder is aecessible only from the opening or balcony served.
6. So installed that it will not eause a person using it to be within 6 feet of exposed electrical wiring.

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(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 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 ½-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 1¾ inches thick. Where the existing frame will not accommodate the 1¾-inch-thick door, a 1⅜-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 ¾-inch plywood or ½-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 protected 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 ⅝ 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 rooms 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 ¾ 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. 110. 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 head above the openings on the tenant side. The sprinkler system may be supplied

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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. 111. 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. 112. Any buildings over four stories in height shall be provided with an approved Class I or Class III standpipe system.

Smoke Detectors

Sec. 113. Every dwelling unit and every guest room in a hotel or lodging house used for sleeping purposes shall be provided with smoke detectors installed in accordance with this code.

Separation of Occupancies

Sec. 114. Occupancy separations shall be provided as specified in Section 503 of this code. When approved by the building official, existing wood lath and plaster in good condition or ½-inch gypsum wallboard may be acceptable where one-hour occupancy separations are required.

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Chapter 7

Note: This is a new Appendix chapter.

Part I

COVERED MALL BUILDINGS

General

Sec. 711. (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 mall 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 aecess 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. 712. (a) **Type of Construction.** One- and two-level malls may be of any type of construction permitted by this code. Three-level malls 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 space, streets or yards not less than 60 feet in width along all exterior walls.

Special Provisions

Sec. 713. (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. **Purpose.** The purpose of smoke control is to restrict movement of smoke to the general area of fire origin and to maintain means of egress in a usable condition.

2. **General.** Activation of the sprinkler system or smoke detectors shall activate the smoke-control system. The smoke-control system shall also be capable of manual operation. A smoke detector shall be provided within the

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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.

(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

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mall except for occupancy separations required by Section 715 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;
4. All edges and the back shall be fully encased in metal.

(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. 714. (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 3301 (d) of this code. Exit requirements for individual tenant spaces shall be based on the occupant load thus determined.

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

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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.** Whenever the distance of travel to the mall from any location within a tenant space used by persons other than employees exceeds 75 feet or the tenant space exceeds 1500 square feet, not less than two exits shall be provided.

(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.

(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.

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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 speeial 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. 715. (a) **General.** Covered mall buildings shall be classified as Group B, Division 2 Occupaneies and may contain accessory uses consisting of Groups A, E or R, Division 1 Oecupancies. 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 main entrance which opens onto a mall need have no separation.

Part II
AVIATION CONTROL TOWERS

General

Sec. 716. The provisions of this part 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 eontrol cab.
2. Electrical and mechanical equipment rooms.

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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. 717. 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 or Type III One-hour construction. The height of the building or parts thereof shall not exceed the limitations specified in Table No. 7-A and the area of such buildings shall not exceed 1,500 square feet on any floor.

Exit Facilities

Sec. 718. 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. 719. Smoke detectors conforming to U.B.C. Standard No. 43-6 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. 720. Aviation control towers need not be accessible to the handicapped as specified in the provisions of Chapters 17 and 33.

Standby Power and Emergency Generation Systems

Sec. 721. 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. 7-A—MAXIMUM HEIGHT (IN FEET) OF AVIATION CONTROL TOWERS

TYPES OF CONSTRUCTION			
I-F.R.	II-F.R.	II One-hour	III One-hour
Unlimited	240	100	65

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Chapter 11
AGRICULTURAL BUILDINGS

Scope

Sec. 1107. The provisions of this chapter 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. 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 space, street 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 space, streets 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 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. 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. 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 & IV		V	
	F-R	1-Hour	N	1-Hour or Type IV	N	1-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. 11-B— REQUIRED SEPARATIONS BETWEEN GROUP M, DIVISION 3 AND OTHER OCCUPANCIES (In Hours)

Occupancy	A	E	I	H	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

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Chapter 12
REQUIREMENTS FOR GROUP R, DIVISION 3 OCCUPANCIES

General

Sec. 1201. (a) **Purpose.** The purpose of this chapter 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 chapter apply to the construction, prefabrication, alteration, repair, use, occupancy and maintenance of detached one- or two-family dwellings not more than three stories in height and their accessory structures.

One and Two Family Dwelling Code Adopted

Sec. 1202. Buildings regulated by this chapter shall be designed and constructed to comply with the requirements of the One and Two Family Dwelling Code, 1979 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.

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Chapter 23
EARTHQUAKE INSTRUMENTATION

Earthquake Recording Instrumentation

Sec. 2312. 1. **General.** 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.

2. **Location.** 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.

3. **Maintenance.** 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.

4. **Instrumentation of existing buildings.** 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	1
Tinian	3
Marcus Island	1
Okinawa	3
Philippine Islands	3
Samoa Islands	3
Wake Island	0

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Chapter 32
RE-ROOFING

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 Uniform Building Code Standards or shall follow the 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 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.

Built-up Roofs

Sec. 3211. (a) **General.** Built-up roof covering shall be completely removed before applying the new roof covering.

EXCEPTION: The building official may allow existing roof coverings to remain when inspection reveals that:

1. The structural design is sufficient to sustain the weight of an additional roof.
2. There is not more than one existing roof on the structure.
3. The existing roof is securely attached to the deck.
4. The roof deck is not rotted and is structurally sound.
5. Existing insulation is not water soaked.

(b) **Preparation of Roof and Application of New Covering.** When the conditions specified in Subsection (a) above have been met, the re-roofing shall be accomplished as follows:

1. **Gravel surfaced.** The roof shall be cleaned of all loose gravel and debris. All blisters shall be cut and made smooth. One-half-inch insulation board shall be nailed or cemented to the existing roofing with hot bitumen applied at the rate of 40 pounds per square, over which a new roof complying with Section 3203 shall be installed, or all existing gravel shall be removed to provide a smooth surface. All blisters shall be cut and cemented or nailed smooth. A base sheet as defined in the code shall be nailed in place. The base sheet shall not be mopped to the old roofing. New roofing conforming to Section 3203 shall be applied.

2. **Smooth or cap-sheet surfaced.** All blisters and curled edges shall be cut and cemented or nailed smooth. A base sheet shall be nailed or, in the case of nonnailable decks, mopped to the existing roofing. New roofing conforming to Section 3203 shall be applied.

3. **Flashing 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.

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4. **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 to receive new roofing and flashing. All rotted wood shall be replaced with new materials. Surface finish material shall be replaced to match original construction.

5. **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 asbestos felt or mineral surfaced cap sheet.

Shingles and Shakes

Sec. 3212. Based upon inspection of the existing roofing, the building official may permit a re-cover in accordance with the following provisions:

1. **Asphalt shingle application.** Not more than two overlays of asphalt shingles shall be applied over an existing asphalt shingle roof.

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 of not less than Type 30 nonperforated felt.

2. **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, 30-pound felt interlaced between each layer of shakes).

3. **Wood shingle application.** Not more than one overlay of wood shingles shall be applied over existing wood shingles.

4. **Application over shakes.** New roof covering shall not be applied over an existing shake roof.

5. **Flashing and edgings.** Rusted or damaged flashing, vent caps and metal edgings shall be replaced with new materials as necessary.

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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, 1981 Edition, as published by the Gypsum Association may be accepted where a laboratory test indicates 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.*

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 except 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,* 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. 4 in Chapter 23 for Basic Wind Speeds.

*The plastic referenced in Sections 4901 and 4902 is readily removable translucent or transparent plastic not more than 0.125 inch in thickness.

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Chapter 51
ELEVATORS, DUMBWAITERS, ESCALATORS AND MOVING WALKS

NO REQUIREMENTS

Chapter 53
ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION

General

Sec. 5301. (a) **Purpose.** The purpose of this chapter 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) **Code for Energy Conservation in New Building Construction Adopted.** In order to comply with the purpose of this chapter, buildings shall be designed to comply with the requirements of the *Code for Energy Conservation in New Building Construction* 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 December, 1977.

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Chapter 55
MEMBRANE STRUCTURES

General

Sec. 5501. (a) **Purpose.** The purpose of this chapter 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 chapter 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 chapter, 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.

NONCOMBUSTIBLE MEMBRANE STRUCTURE is a membrane structure in which the membrane and all component parts of the structure are noncom-

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bustible 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.

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.

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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 chapter 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 chapter 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 occupaney 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 emergeney 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 remaindcr 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 average effective temperature of not more than 82°F. for at least 90 percent of the days of the year.

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(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 Rating of Interior Surfaces

Sec. 5706. Interior surfaces of single-purpose fallout shelters shall have a flame-spread rating 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 chapter is to safeguard life, limb, property and the public welfare by regulating grading on private property.

Scope

Sec. 7002. This chapter 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 chapter the definitions listed hereunder shall be construed as specified in this section.

APPROVAL shall mean a written engineering or geological opinion concerning the progress and completion of the work.

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 be placed.

BORROW is earth material acquired from an off-site location for use in grading on a site.

CIVIL ENGINEER shall mean a professional engineer registered in the state to practice in the field of civil works.

CIVIL ENGINEERING shall mean 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 shall mean a geologist experienced and knowledgeable in engineering geology.

ENGINEERING GEOLOGY shall mean 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.

GRADE shall mean the vertical location 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.

SITE is any lot or parcel of land or contiguous combination thereof, under the

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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 shall mean a civil engineer experienced and knowledgeable in the practice of soils engineering.

SOILS ENGINEERING shall mean the application of the principles of soil mechanics in the investigation, evaluation and design of civil works involving the use of earth materials and the inspection and 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.

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.

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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 when necessary, and opinions and recommendations covering adequaey of sites to be developed by the proposed grading.

Recommendations ineluded 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, eonclusions 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 ineluded 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) **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.

(b) **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. 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.

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TABLE NO. 70-A—GRADING PLAN REVIEW FEES

50 cubic yards or less	No Fee
51 to 100 cubic yards	$10.00
101 to 1000 cubic yards	15.00
1001 to 10,000 cubic yards	20.00

10,001 to 100,000 cubic yards—$20.00 for the first 10,000 cubic yards, plus $10.00 for each additional 10,000 cubic yards or fraction thereof.

100,001 to 200,000 cubic yards—$110.00 for the first 100,000 cubic yards, plus $6.00 for each additional 10,000 cubic yards or fraction thereof.

200,001 cubic yards or more—$170.00 for the first 200,000 cubic yards, plus $3.00 for each additional 10,000 cubic yards or fraction thereof.

Other Fees:

Additional plan review required by changes, additions or revisions to approved plans (minimum charge—one-half hour)	$15.00 per hour

TABLE NO. 70-B—GRADING PERMIT FEES

50 cubic yards or less	$10.00
51 to 100 cubic yards	15.00

101 to 1000 cubic yards—$15.00 for the first 100 cubic yards plus $7.00 for each additional 100 cubic yards or fraction thereof.

1001 to 10,000 cubic yards—$78.00 for the first 1000 cubic yards, plus $6.00 for each additional 1000 cubic yards or fraction thereof.

10,001 to 100,000 cubic yards—$132.00 for the first 10,000 cubic yards, plus $27.00 for each additional 10,000 cubic yards or fraction thereof.

100,001 cubic yards or more—$375.00 for the first 100,000 cubic yards, plus $15.00 for each additional 10,000 cubic yards or fraction thereof.

Other Inspections and Fees:

1.	Inspections outside of normal business hours (minimum charge—two hours)	$15.00 per hour
2.	Reinspection fee assessed under provisions of Section 305 (g)	$15.00 each
3.	Inspections for which no fee is specifically indicated (minimum charge—one-half hour)	$15.00 per hour

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.

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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.

(b) **Slope.** The slope of cut surfaces shall be no steeper than is safe for the intended use. Cut slopes shall be no steeper than two horizontal to one vertical.

(c) **Drainage and Terracing.** Drainage and terraeing shall be provided as required by Seetion 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 bc 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 benehing into sound bedrock or other competent material as determined by the soils engineer. The beneh 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. Where fill is to be placed over a cut, the bench under the toe of fill shall be at least 10 feet wide but the eut must be made before plaeing fill and approved by the soils engineer and engincering gcologist as a suitable foundation for fill. Unsuitable soil is soil which, in the opinion of the building official or the civil engineer or the soils engineer or the geologist, is not competent to support other soil or fill, to support structures or to satisfactorily perform the other functions for which the soil is intended.

(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 irreducible material with a maximum dimension greater than 12 inehes 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:

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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. Field density shall be determined in accordance with U.B.C. Standard No. 70-2 or equivalent as approved by the building official.

(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.

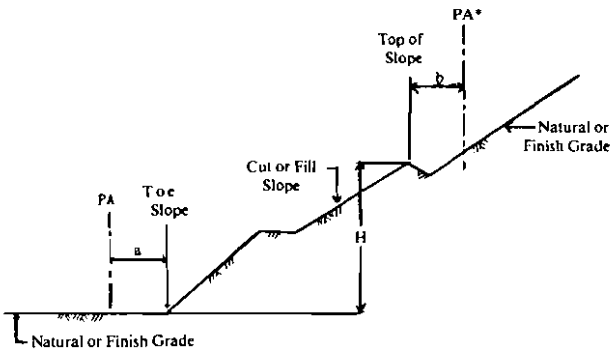
(g) **Drainage and Terracing.** Drainage and terracing shall be provided and the area above fill slopes and the surfaces of terraces shall be graded and paved as required by Section 7012.

Setbacks

Sec. 7011. (a) **General.** The setbacks and other restrictions specified by this section are minimum and may be increased by the building official or by the recommendation of a civil engineer, soils engineer or engineering geologist, if necessary for safety and stability or to prevent damage of adjacent properties from deposition or erosion or to provide access for slope maintenance and drainage. Retaining walls may be used to reduce the required setbacks when approved by the building official.

(b) **Setbacks from Property Lines.** The tops of cuts and toes of fill slopes shall be set back from the outer boundaries of the permit area, including slope-right areas and easements, in accordance with Figure No. 1 and Table No. 70-C.

(c) **Design Standards for Setbacks.** Setbacks between graded slopes (cut or fill) and structures shall be provided in accordance with Figure No. 2.



*Permit Area Boundary

FIGURE NO. 1

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TABLE NO. 70-C
REQUIRED SETBACKS FROM PERMIT AREA BOUNDARY
(IN FEET)

	SETBACKS	
H	a	b[1]
Under 5	0	1
5 - 30	H/2	H/5
Over 30	15	6

[1]Additional width may be required for interceptor drain.

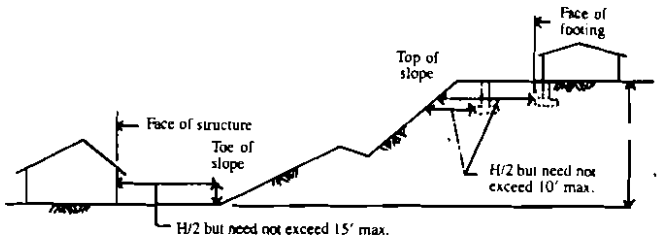

FIGURE NO. 2

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.

(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.

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(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 down-drains 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 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

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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.

The building official shall inspect the project at the various stages of the work requiring approval and at any more frequent intervals necessary 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

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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 provide approval that the work was done in accordance with the final approved grading plan.

2. A soil grading report prepared by the soils engineer including loeations and elevations of field density tests, summaries of field and laboratory tests and other substantiating data and comments on any ehanges made during grading and their effeet on the recommendations made in the soils engineering investigation report. He shall provide approval as to the adequacy of the site for the intended use.

3. A geologic grading report prepared by the engineering geologist ineluding a final description of the geology of the site including any new information disclosed during the grading and the effect of same on recommendations incorporated in the approved grading plan. He shall provide approval as to the adequaey 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 ineluding installation of all drainage facilities and their proteetive devices and all erosion-control measures have been completed in aeeordance with the final approved grading plan and the required reports have been submitted.

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