

6

**RETROFITTING
POST & PIER HOUSES**

by James E. Russell, P.E.

RETROFITTING POST AND PIER HOUSES

This section describes a prescriptive method for the seismic retrofitting of a specific type of existing housing that is supported along its perimeter walls by a series of wood posts set on top of individual concrete pier pads. This type of construction is commonly referred to as a post and pier foundation. Post and pier houses are very susceptible to damage because they have an inadequate bracing system to resist earthquake forces below the first floor level. An effective bracing system can be provided by installing new L shaped partial perimeter foundations at each corner, properly connected to the existing first floor framing, or with a combination of new partial foundations and new braced cripple walls connecting the existing floor to the new cripple walls.

WHY EARTHQUAKES DAMAGE POST AND PIER HOUSES

In other sections of this manual you have learned about the importance of a complete load path to resist earthquake forces and how wood structural panel sheathing properly nailed to wall framing members with anchor bolts connecting the wall to a continuous foundation are used to provide that resistance. Two major weaknesses occur in the load path of houses supported by a post and pier foundation. One is the absence of sheathed walls below the first story exterior walls. The other is the absence of an adequate foundation under those perimeter walls.

A typical post and pier house uses wood posts spaced at 4 to 8 feet apart along the exterior perimeter walls to support the vertical loads from the floor and walls above. The top ends of these posts are typically toe-nailed to a wood girder that is part of the floor framing. The bottom ends of the posts are usually supported on individual foundation pads, often called pier blocks. These pier blocks are usually concrete, in a pyramid shape, with a square flat top surface where the post is supported. The bottom of the post is typically toe-nailed to a wood block embedded in the top of the pier block. The pier block may or may not have a larger square concrete pad below it embedded in the ground.



Fig. 6. 1 Typical Existing Post & Pier Type House

The weakness in this system is that the posts and their top and bottom connections provide very little resistance to horizontal forces caused by an earthquake. Without a bracing system, the posts will topple over and the house will collapse to the ground.

Sometimes wood bracing installed in an X or V shaped pattern may interconnect the existing posts. These braces are typically nailed or bolted to the top and bottom of each post. This type of bracing may have been used as part of a repair of previous earthquake damage or as an attempt to provide some earthquake bracing. Although this type of bracing does add some resistance when compared to posts without any braces, it has too little strength to prevent damage and possible collapse at this level when subjected to strong earthquake shaking. (Fig. 6.2)



Fig.6. 2 House with Braced Posts along Perimeter

The weakness in this braced system is primarily at the pier pad level. Here the connection between the bottom of the post and top of the pier must resist horizontal loads transmitted by the braces. If a traditional toe-nailed connection is all that is present, it will quickly be overwhelmed and the bottom of the post will slide off the top of the pier pad. This results in a loss of vertical support for the post and leads to a collapse similar to that for an unbraced post system.

Merely adding stronger connections at the bottom of the post such as a metal post base that is embedded in the pier pad and nailed or bolted to the post is also insufficient. The forces generated by the braces will then push on the pier pads and can cause them to slide or possibly overturn. Either one of these two effects will induce damage into the post and brace system causing it to degrade and possibly fail. A more reliable and stable retrofit method is needed for post and pier type foundations than is provided by this type of bracing.

NEW PRESCRIPTIVE RETROFIT METHOD

The prescriptive seismic retrofit standards contained in the Appendix of this manual are applicable to houses that have existing perimeter foundations and cripple walls. However, these standards require that a completely new continuous foundation be installed along all the exterior walls, or that a retrofit using a partial perimeter foundation must be designed by a licensed architect or engineer and be approved by the local building official. The prescriptive methods and details described in this section are consistent with the Uniform Code for Building Conservation (UCBC) and City of Los Angeles standards and use a partial perimeter foundation system to provide equivalent earthquake resistance below the first floor level. Permission to use this partial perimeter system without a specific design prepared by a licensed design professional must always be obtained from the local building official.

PARTIAL PERIMETER VS. CONTINUOUS FOUNDATION

Where a continuous foundation exists or is added, the primary retrofit elements used in the UCBC, are also parts of the partial perimeter system. They include:

- A foundation constructed with a concrete footing and either a poured concrete or grouted masonry stem wall.
- Foundation sill plates and sill bolts with plate washers.
- Sheathed cripple wall with connections between the wall and floor framing.

Note that a new cripple wall is not always necessary. A new foundation stem wall can be extended to the underside of the existing floor framing depending on how high the existing floor is above the surrounding exterior grade. Generally, if the floor is more than 3 feet above grade at any point, a cripple wall will be necessary.

Several additional retrofit elements are needed for a partial perimeter system that do not occur in the UCBC prescriptive standards. They include:

- New holdowns at the ends of new sheathed cripple walls.
- Straps to connect the existing floor framing beams and joists together and to connect them to the new partial foundations and cripple walls. These are load path elements needed to compensate for the use of a partial foundation system compared to a continuous foundation system

Certain elements of a partial perimeter retrofit must be stronger or larger than those prescribed in the UCBC. They include:

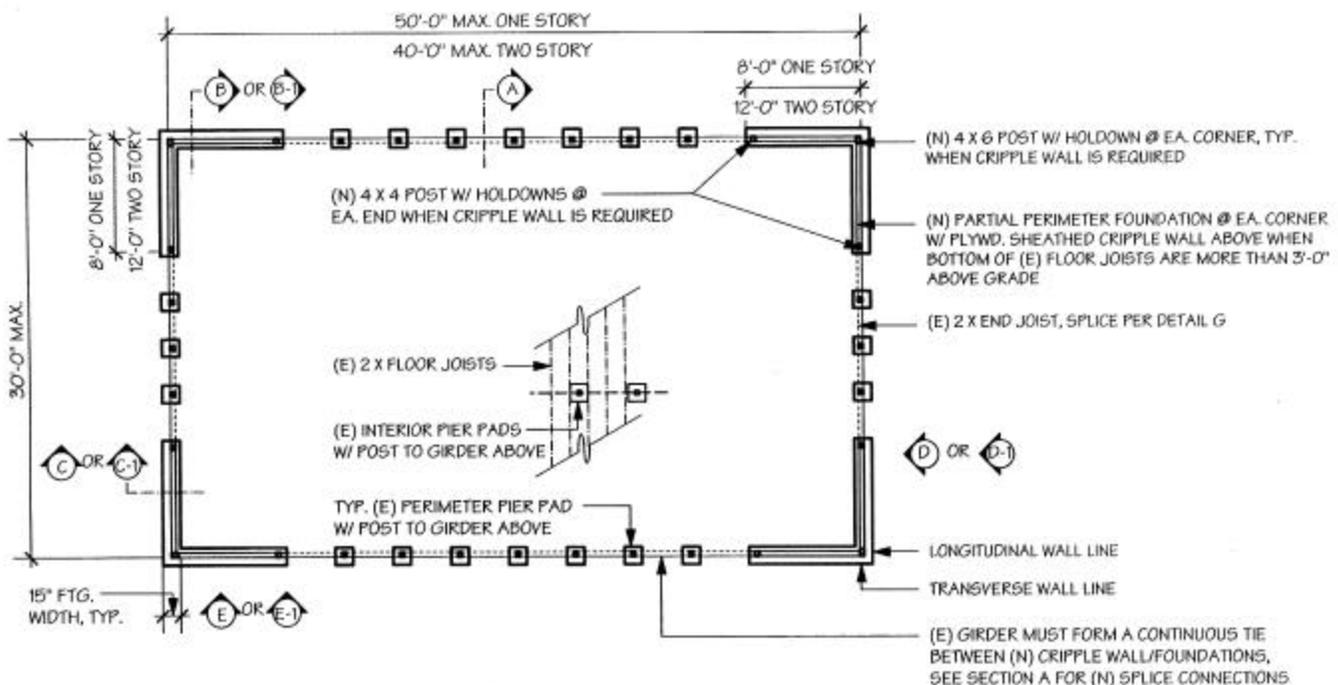
- Nails used to attach plywood to the cripple wall framing must be 10d common instead of 8d common.
- The minimum width of the new footing for a one-story house must be 15 inches rather than 12 inches.
- All foundation sill bolts must be 5/8-inch diameter instead of 1/2-inch, and their spacing is reduced from 6 or 4 feet on center to 2-6 or 2-0 on center.

HOW PARTIAL PERIMETER EQUALS CONTINUOUS FOUNDATION

The standard retrofit method for a house with an existing continuous foundation and cripple walls adds wood structural panels in sections along all the perimeter cripple walls and prescribes a minimum number of sill bolts connecting the foundation sill plate to the continuous foundation. Except for houses with existing brick or other unreinforced masonry foundations, the foundation itself should not need to be strengthened. The foundation's primary task is to resist the sliding forces transferred from the foundation sill bolts into the foundation, and to provide sliding resistance against the surrounding soil equal to or greater than the sum of all the sill bolt forces.

The bottom surface of the foundation resists these forces by friction between it and the ground. In addition, the vertical face of the foundation that is below the ground surface also participates in that resistance by pushing against the adjacent soil. Sliding friction and lateral bearing against the soil are the final link in the load path. The amount of surface area a foundation must provide to resist a specific amount of earthquake load is based on the characteristics of the soil that determine its sliding and lateral bearing resistance.

Chapter 18 of the Uniform Building Code provides numerical values for sliding and lateral bearing resistance of various soil types. The minimum depth, width and lengths of foundation used in the partial perimeter system are based on soils having the least resistance. Based on calculations, a continuous foundation is not required to provide the necessary resistance for average sized houses up to two stories in height. The minimum foundation consists of four separate, 15 inch wide L shaped footings, one at each of the building corners.



For a one-story house the length of each leg of the L must be 8'-0" and for a two-story house each leg must be 12'-0". Four sill bolts are required along each leg of the one-story house foundation and five bolts must be provided along each leg of the two-story house foundation to attach the new foundation sill plate.

When a post and pier house has its existing floor framing within 3 feet of the ground surface, constructing a new cripple wall above the new partial foundation should not be necessary. The existing floor joists and girders can be directly connected to the new foundation sill plate. However, for floor framing located higher than this, a new continuously sheathed cripple wall located above the entire length of each of the new L-shaped foundations will be needed. The length of sheathing provided by the partial perimeter system is equivalent to the length provided by the multiple individual sheathed sections prescribed in the UCBC retrofit standards for a house with a continuous foundation and cripple wall.

MOISTURE EFFECTS ON WOOD MATERIALS

The partial perimeter system was specifically developed to address existing post and pier houses. It recognizes that post and pier type foundations are commonly found in coastal geographical locations where moisture content of the air and the ground are very high for much of the year. High moisture levels can have a very undesirable effect on wood framing members and will also decrease the strength of nailed or bolted connections in the wood.

One of the most important considerations when retrofitting any wood framed building is to examine all the existing wood members to be used in the load path and determine if they need to be replaced because of fungus infections, commonly called dry rot, that destroy the wood fibers. Fungus infections flourish in wood when it remains wet and recur where it goes through cycles of wetting and drying. Such conditions are more likely to occur in damp climates, where post and pier construction is quite common, so particular attention must be paid to inspecting all existing wood members used in the retrofit of these houses. Unlike a house with a continuous perimeter foundation and cripple wall, where the underfloor space is fully enclosed and weather protected, the underfloor area of a partial perimeter foundation retrofit is open to the exterior along a substantial length of the perimeter.

Another aspect of wood exposed to damp climates is that the moisture content of wood does not remain stable. Instead, it undergoes cycles where it is very moist and then dries. As moisture content changes, wood fibers alternately swell and shrink and this changes the holding power of nails and the tightness of bolts in the wood. This condition is addressed in the Building Code by the use of a *Wet Service Reduction Factor* to reduce the strength of nailed and bolted connections. All the retrofit connections in the prescriptive partial perimeter system involving nails or bolts in wood have been adjusted to lower their strength to 75 percent of normal to account for this effect. This is the principal reason that 10d nails are needed to attach sheathing to cripple wall framing, and why 5/8-inch sill bolts are typically used.

The type of sheathing prescribed for use on the cripple walls of a partial perimeter system was chosen to address the moisture exposure issue. Exterior grade plywood is specified because it has a very high durability for exposure to moisture. Plywood rather than Oriented Strand Board, known as OSB, was selected because OSB has different moisture expansion characteristics that make it less desirable for use where its moisture content is expected to vary. For a more detailed discussion of sheathing materials see the *Shear Walls* section titled *How to Install Sheathing*.

HOLDOWN ANCHORS ARE NEEDED

The purpose of holddown anchors and their proper installation are discussed in the part of the manual titled *Connections Resisting Uplift Forces* and in the section on *Shear Walls*. Holddowns are generally needed either when a shear wall is very tall with respect to its length or when vertical loads from the weight of the building above, carried by the wall, are insufficient to offset the overturning force generated by the horizontal earthquake load the wall is resisting.

In the partial perimeter system, holddowns are used at each end of the new cripple walls. The reason holddowns are not required by the other prescriptive standards when retrofitting a house with a continuous foundation, is that the entire wall length can be engaged as part of the resistance to uplift. Using a partial perimeter system results in shorter wall lengths and less resistance.

The holddowns shown in Elevations D and E in the Appendix must provide at least 2,500 pounds resistance to earthquake loading. A variety of products can provide this capacity. The drawings depict one type of holddown that uses bolts through the cripple wall end posts and a bolt embedded in the new foundation. Similar holddowns using special screws instead of bolts may be used if the local building official approves them and they provide an equivalent minimum capacity. Other types of holddowns that use nails to connect to the post may also be used, but typically they require a post height of at least 24 inches. In addition, all nailed type holddowns have limitations on how close they can be placed to the corner of a concrete foundation and some may not be able to provide the minimum required capacity.

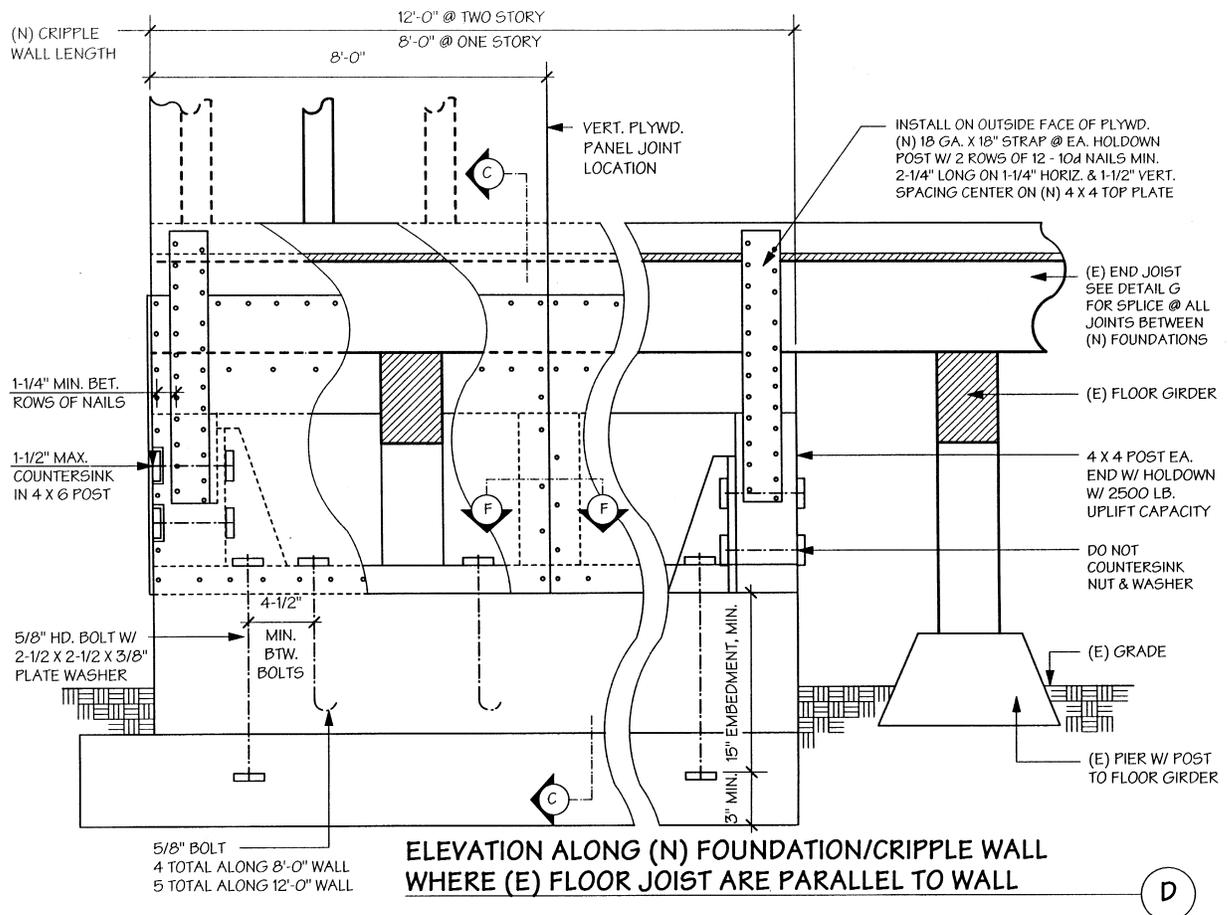


Fig. 6.4

In addition to the holdown anchor which connects the new posts at each end of the cripple wall to the foundation, a strap shown in Elevation D must be added at each end on the transverse wall sides to tie the new posts to the existing floor framing above. This is needed because the transverse walls are parallel to the floor joists and, therefore, do not carry enough dead load to adequately resist the uplift forces. The strap completes the load path between the holdown post and the floor framing so that the floor will not lift off the new cripple wall.

TRANSFERRING FORCES TO THE PARTIAL FOUNDATIONS

Another unique aspect of a partial perimeter system is that connections are required to transfer earthquake forces into the new foundations and cripple walls that are located only at each corner of the building. Essentially, each of the four new L shaped foundations are isolated from each other and therefore must be connected to the entire length of floor that lies between them to collect all of the forces in the existing floor system. With a continuous foundation, this kind of discontinuity does not exist, so none of the special ties and straps shown in the foundation/cripple wall elevations of the partial perimeter system are prescribed in other prescriptive standards.

Along the exterior perimeter of the floor, between the new corner foundations, where the ends of two pieces of an existing floor girder are spliced over a post, that splice must be reinforced with a new metal strap nailed or bolted to both pieces (Fig. 6.5). The details in the Appendix show both the bolted and nailed connection. The girder is used to drag forces along the edge of the floor into the new cripple wall or foundation at each end of the wall line and the strap provides this load path connection. Similarly, where existing floor joists are parallel to the exterior wall, a strap is needed at any joist splice occurring between the two corner foundations.



Fig.6. 5 New Metal Strap Reinforcement

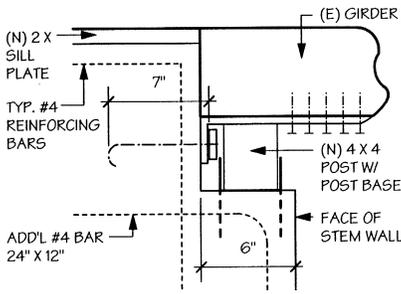
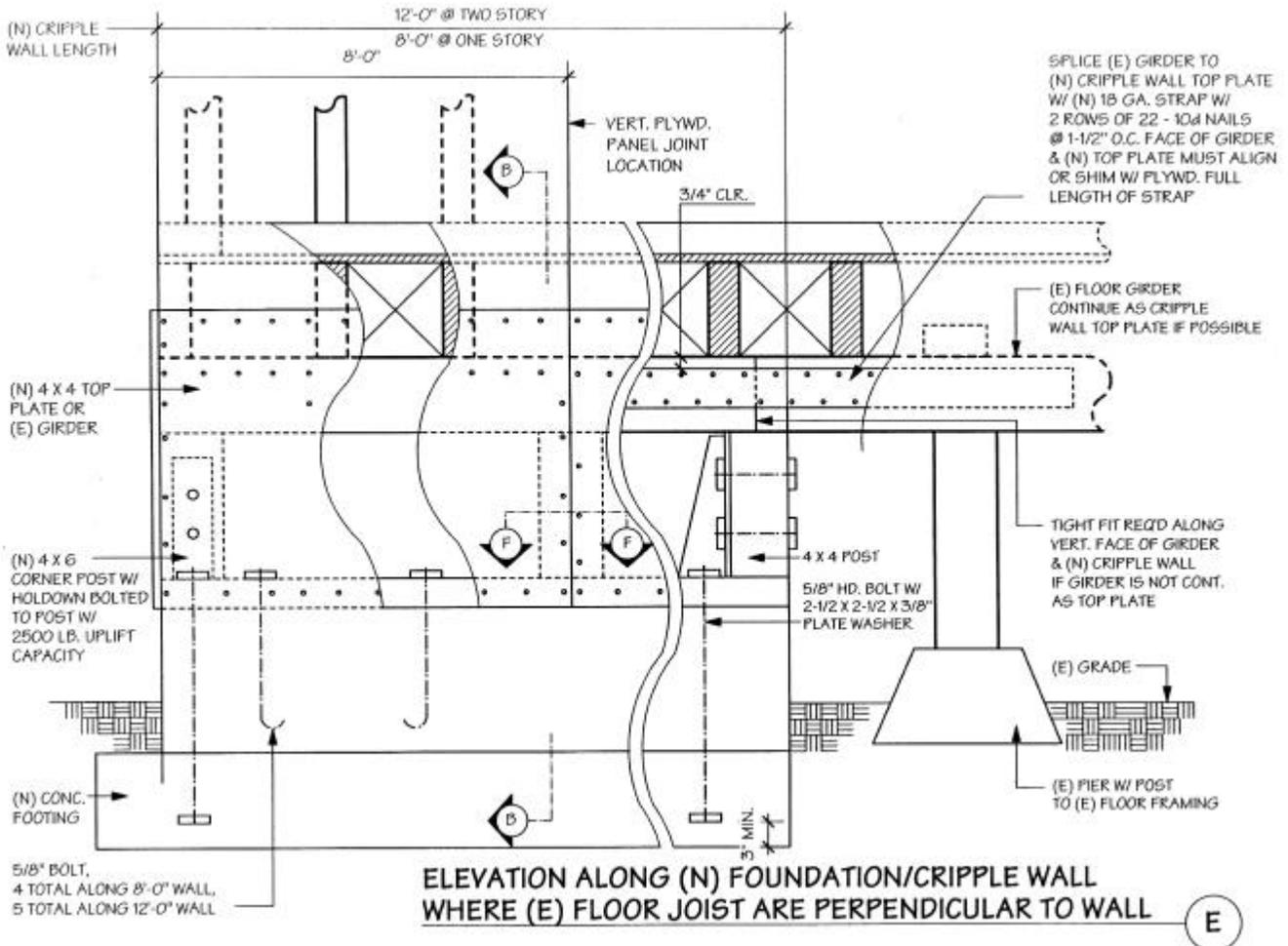


Fig 6.6 Girder Connection to New Foundation Stem Wall

A very important load path connection also must be provided at the end of each new partial cripple wall/foundation segment. The existing girder must be very securely connected to the new foundation or cripple wall to fully transfer the entire load along the edge of the floor that lies beyond the new partial foundation. When a new cripple wall is not needed, the Elevation E-1 view shows an anchor bolt embedded in the foundation stem wall secured to an L shaped 12 gage connector. The long leg of the connector is nailed to the girder (Fig. 6.6).

Where a new cripple wall is provided there are two options. The best solution is to use the existing girder as the top plate of the new cripple wall. If the girder extends as a single piece the full length of the new cripple wall, no connection is necessary. However, if the girder has an existing splice location within the length of the cripple wall, the typical girder splice shown in the Appendix details must be provided at that location.

If using the existing girder as the cripple wall top plate is not feasible, and it is cut flush with the end of the new cripple wall, a metal strap connecting the girder to the top plate of the new cripple wall must be provided as shown in Elevation E (Fig. 6.7). Because this connection will be subject to both tension and compression forces, it is very important that the girder end be carefully cut so that it will tightly fit against the new cripple wall or foundation. Also, to provide enough surface area to make this nailed splice connection and not interfere with the row of nailing along the top edge of the plywood, the new cripple wall top plate must be a minimum 4x4 member instead of using a typical double 2x4 top plate.



ELEVATION (E) ALONG (N) FOUNDATION/CRIPPLE WALL WHERE (E) FLOOR JOIST ARE PERPENDICULAR TO WALL

E

One further consideration at this connection is that the vertical face of the girder and the new top plate must align because the strap should not be kinked or bent. A misalignment of 3/4 inch or less can be accommodated by installing plywood of the appropriate thickness on the face of the existing girder to make it flush with the new top plate. If this plywood shim is installed, the length of the 10d nails used in the strap must be increased to provide a minimum of 1-1/2 inches of penetration into the girder. Given the complexity of this connection, the use of the existing girder for the top plate of the new cripple wall is the preferred method.

Along the walls where the existing floor joists are parallel to the new foundation and cripple wall, the same concept of a continuous member applies. As shown in Elevation D, the end joist must be a single piece that extends the full length of the new foundation. This end joist must continue at least to the next perpendicular girder line beyond the end of the new foundation, where it may be spliced as shown in the Detail G (Fig.6.8).

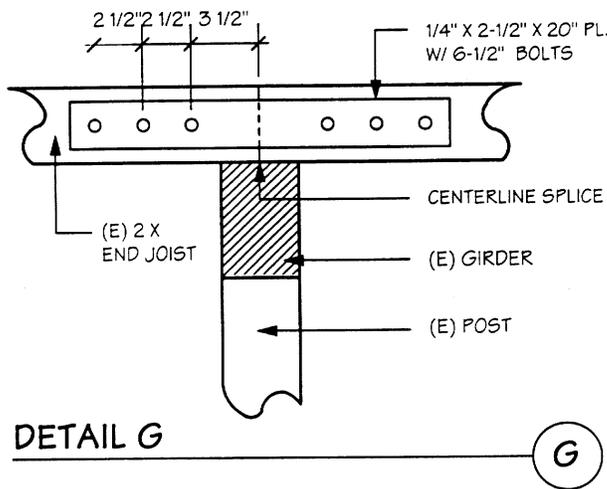


Fig. 6.8 Strap for Joist Splice

Also along this wall, another strap must be provided to tie together the new double 2x top plates of the cripple wall where they are interrupted by the existing girders framed over new support posts. This connection is shown in Section C (Fig. 6.9).

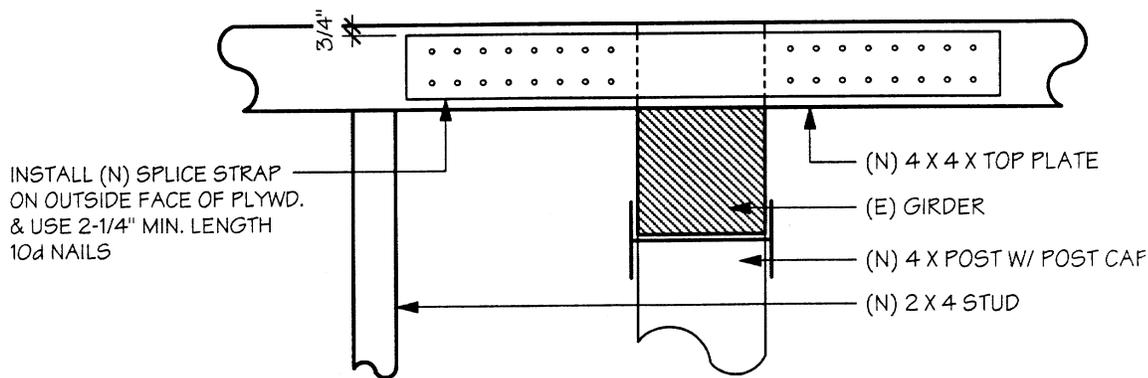


Fig. 6.9 Strap for Plate Splice

EVALUATING EXISTING CONDITIONS

The first step in any retrofit project is to carefully examine the existing building and its site to determine the extent of any unique conditions that exist for that building on its specific site. Some situations will preclude the use of a prescriptive method and instead will need the services of an experienced design professional. The condition of the existing wood framing, particularly along the perimeter walls must be checked for fungus or insect damage and all damaged wood must be replaced.

WHEN YOU NEED AN ARCHITECT AND ENGINEER

There are several important limitations on the use of the prescriptive partial perimeter system. Houses that are on a sloping site, where one side or end of the building is substantially higher above grade than other portions of the building, should not use this system. If the ground surface along the perimeter walls has a slope that exceeds 1 foot vertical in every 10 feet of horizontal distance, special structural considerations are necessary to accomplish an effective retrofit. Some sloping sites may need to be evaluated by a geotechnical engineer to establish the potential risk of landsliding or other forms of ground failure.

Houses that are over two stories in height or that exceed the maximum width and length dimensions shown on the prescriptive plan are too large to rely on prescriptive methods to provide adequate earthquake protection. The maximum height of new foundations are limited to 4 feet 6 inches measured from the bottom of the footing, and new cripple walls are also limited to a maximum of 4 feet in height. Retrofitting buildings where these limits are exceeded requires the professional services of a licensed architect or engineer.

The prescriptive method also assumes that the building is not located on soils that are subject to liquefaction during earthquake shaking or where highly plastic clay soil exceeds 25 feet in depth. Maps indicating locations of liquefiable soils are available in some cities and counties, and the local building departments will usually be aware of or have special foundation requirements in areas of highly plastic clay soils.

The prescriptive method should not be used for buildings located within 5 kilometers (approximately 3 miles) of a known active earthquake fault. Maps have been published by the International Conference of Building Officials for the entire State of California identifying these locations called Near Source areas. The 1997 Uniform Building Code requires that all buildings inside these areas be designed to resist larger forces than were used to develop the details used in the partial perimeter foundation system.

PARTIAL PERIMETER RETROFITS REQUIRE MORE ATTENTION TO DETAIL

Constructing a partial perimeter foundation system for a post and pier type house, involves much more work than installing new sheathing, foundation sill plate anchors, and miscellaneous framing anchors, which is typically all that is needed for houses with an existing continuous foundation and cripple walls. Prior to beginning to excavate for the new concrete footings, a system of shoring must be installed to adequately support the house where some of the existing posts and piers must be removed. Proper shoring is not only a major safety concern but it also serves to prevent damage to existing interior and exterior finishes like plaster that are intolerant of even small changes in the level of the supporting floor.

Preparing to pour the new concrete foundations involves accurately placing new anchor bolts and holdowns as well as installing the needed reinforcing steel. The formwork for the vertical stem wall must be strong enough to contain the concrete as it is poured and vibrated to form a solid mass without voids. If the optional masonry stem wall is used, proper knowledge of mixing and placing mortar are essential to its proper construction.

If the existing floor level is close enough to the ground, a cripple wall may not be needed on top of the new foundation wall, but in this case the top of the new foundation must be very carefully leveled before it is poured. All of the remaining work, including installing a new cripple wall if required, requires good carpentry skills to provide all of the additional nailed and bolted connections this system requires.

BUILDING INSPECTION REQUIREMENTS

The local building inspection authority will determine the exact number and types of inspections needed during the construction. Some jurisdictions may require a preconstruction inspection to determine if a prescriptive method is appropriate or if conditions exist that need the services of an architect or engineer. Typically inspections are performed prior to pouring any concrete or grouting of any masonry. In addition, a framing inspection will be needed during which the nailing of any cripple wall sheathing, the proper installation of plate washers on sill bolts and the installation of holdowns and other connections will be verified. A final inspection may also be necessary to determine that exterior weather protective surfaces have been properly installed over the new cripple walls.

SEISMIC RETROFITTING FLOOD-PRONE STRUCTURES

Some elevated residential structures will be located in both earthquake and flood hazard zones. For these buildings, seismic retrofit work must also be compatible with the latest standards for flood construction as contained in Part 59 of Title 44 of the Code of Federal Regulations.

FEMA's National Flood Insurance Program produces community maps that designate special flood hazard areas inundated by 100-year floods. The local community map repository should be consulted for complete information on base flood elevations before starting any new construction of partial or full perimeter foundation walls.
