

Chapter 8

ANCHORAGE OF HOME CONTENTS

8.1 GENERAL

Anchorage of home contents can greatly reduce the risk of injury, property loss, and interruption of home use as a result of an earthquake. Anchorage is particularly recommended for large and heavy items such as water heaters, bookcases, and file cabinets and for items that could cause injury if they fell (e.g., items on shelves above a bed). Other priority items to anchor or otherwise restrain include wood stoves, similar heating appliances, and outside fuel tanks, all of which pose a fire risk.

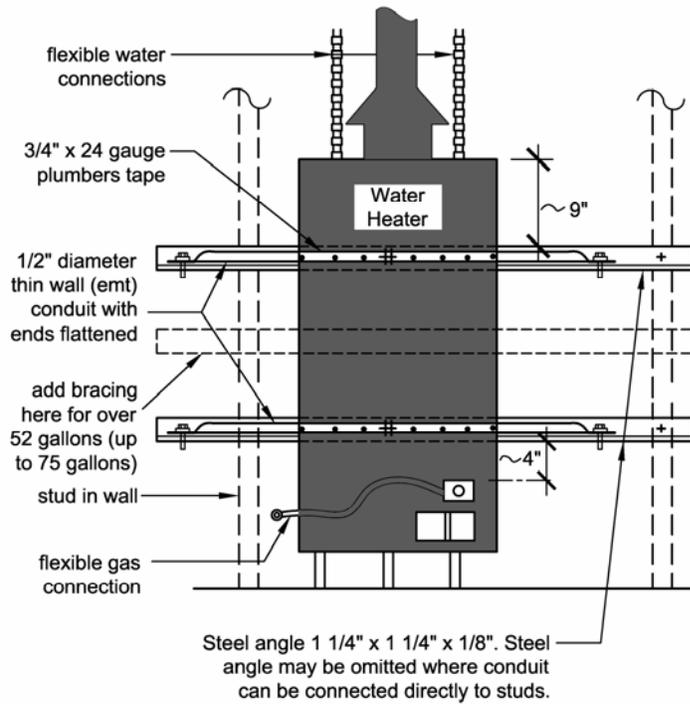
Anchorage of other home contents will further reduce disruption following an earthquake. Measures to anchor computers and televisions range from very simple home fixes to specialized restraint systems available from a number of manufacturers. Locks on kitchen and china cabinets can help reduce the spilling and breakage of contents during an earthquake. Measures are available to secure a wide range of other home contents including pictures, mirrors, fragile objects, and fire extinguishers.

Section 8.2 provides guidance on the anchorage of water heaters. Section 8.3 addresses anchorage of a number of items using excerpts from FEMA 74, *Reducing the Risks of Nonstructural Earthquake Damage* (FEMA, 1994).

8.2 WATER HEATER ANCHORAGE

When not properly anchored, water heaters can fall over, resulting in a fire hazard and water damage. Bracing is required for new water heater installations and is recommended as a top priority for existing installations. *IRC* Chapters 20, 24, and 28 contain some provisions for the installation of water heaters but do not specifically address anchorage. Kits for bracing water heaters are available at many hardware stores. As an alternative to kits, Figures 8-1 and 8-2 provide example details for anchorage using plumber's tape (24-gage by 3/4-inch minimum steel straps) and electrical conduit. These figures are adapted from *Guidelines for Earthquake Bracing of Residential Water Heaters* (California Division of the State Architect, 2002); consult this publication for detailed installation instructions and additional cautions and limitations.

Note that Figures 8-1 and 8-2 are applicable only to water heaters with a maximum capacity of 52 gallons with two strap locations and with a maximum capacity of 75 gallons with three. Some jurisdictions place additional limits on water heater bracing details. Where water heaters are installed on a platform, the water heater base should be attached to the platform and the platform should be anchored to the floor. Placing water heaters in metal pans to retain any spilled water is a possible precaution in addition to bracing. The *IRC* requires that water heaters be placed in pans where loss of water would cause damage. Required clearances to walls and combustible construction need to be maintained; the water heater UL listing and local jurisdiction requirements should be verified prior to moving or installing a water heater.



WATER HEATER WALL BRACING

This detail illustrates earthquake bracing for typical residential water heater systems (30 to 75 gallon capacity) braced to a flat wall. See wall bracing elevation at left. See second page for wall bracing plan and details.

Where the water heater is installed on a raised platform, attach water heater to platform, and platform to floor.

Do not move water heater closer to wall or combustible materials without verifying that minimum required clearances to wall and combustible materials are still met.

See text and referenced documents for additional cautions and limitations, and other available details.

Plumbers tape is also called galvanized steel hanger strap, and must be not thinner than 24 gauge.

The illustrated bracing detail is based on California Division of the State Architect *Guidelines for Earthquake Bracing of Residential Water Heaters*.

WALL BRACING ELEVATION

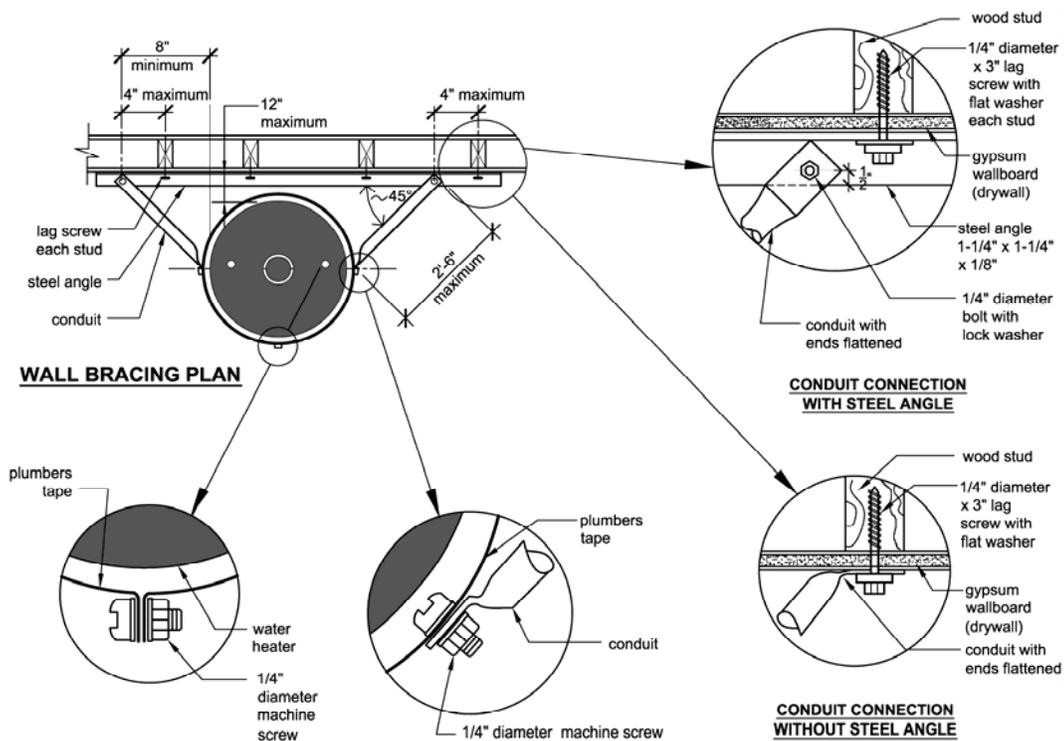
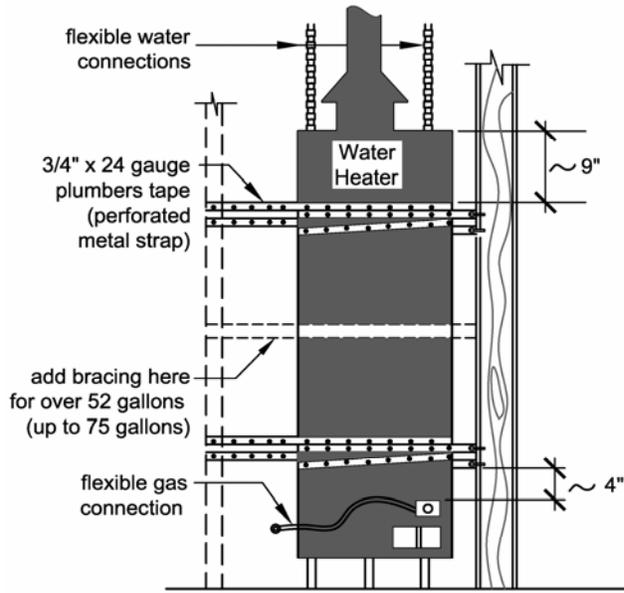


Figure 8-1a and 8-1b Securing a water heater with wall bracing.



CORNER BRACING ELEVATION

WATER HEATER CORNER BRACING

This detail illustrates earthquake bracing for typical residential water heater systems (30 to 75 gallon capacity) installed at a corner. See corner bracing elevation at left. See second page for corner bracing plan and details.

Where the water heater is installed on a raised platform, attach water heater to platform, and platform to floor.

Do not move water heater closer to wall or combustible materials without verifying that minimum required clearances to wall and combustible materials are still met.

See text and referenced documents for additional cautions and limitations, and other available details.

Plumbers tape is also called galvanized steel hanger strap, and must be not thinner than 24 gauge.

The illustrated bracing detail is based on California Division of the State Architect *Guidelines for Earthquake Bracing of Residential Water Heaters*.

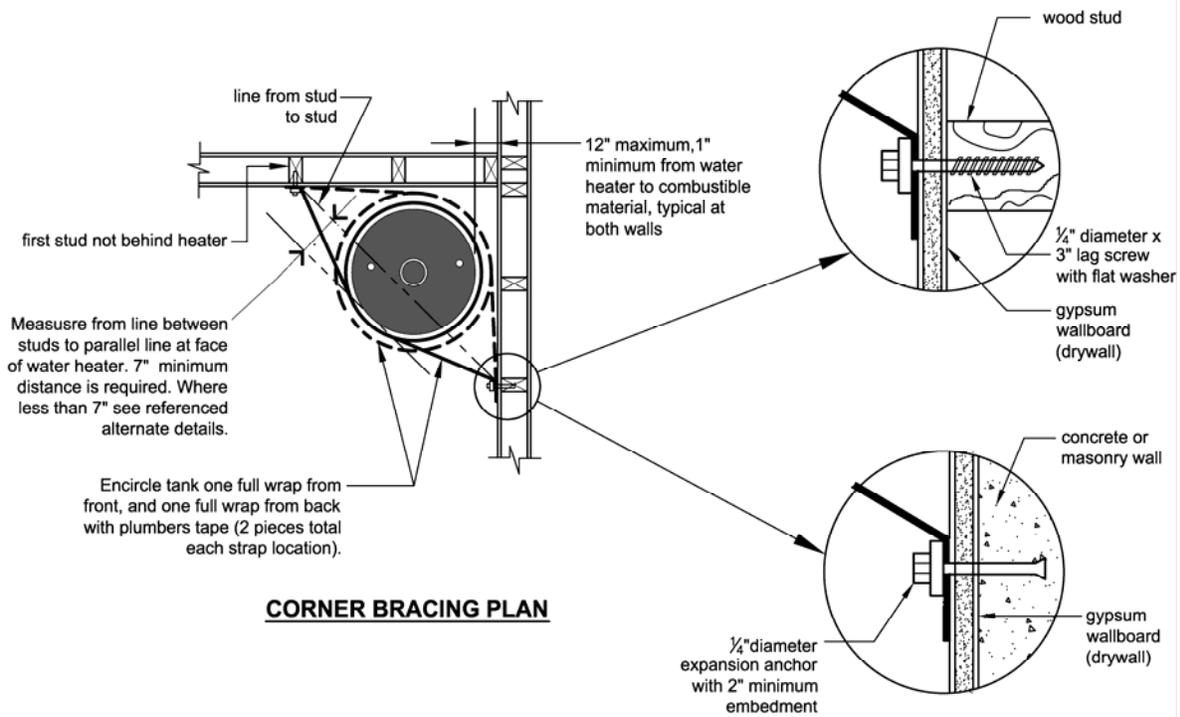


Figure 8-2a and 8-2b Securing a water heater with corner bracing.

8.3 SECURING OTHER ITEMS

The examples included here show representative details for protecting common items from earthquake damage. Two different types of details are discussed:

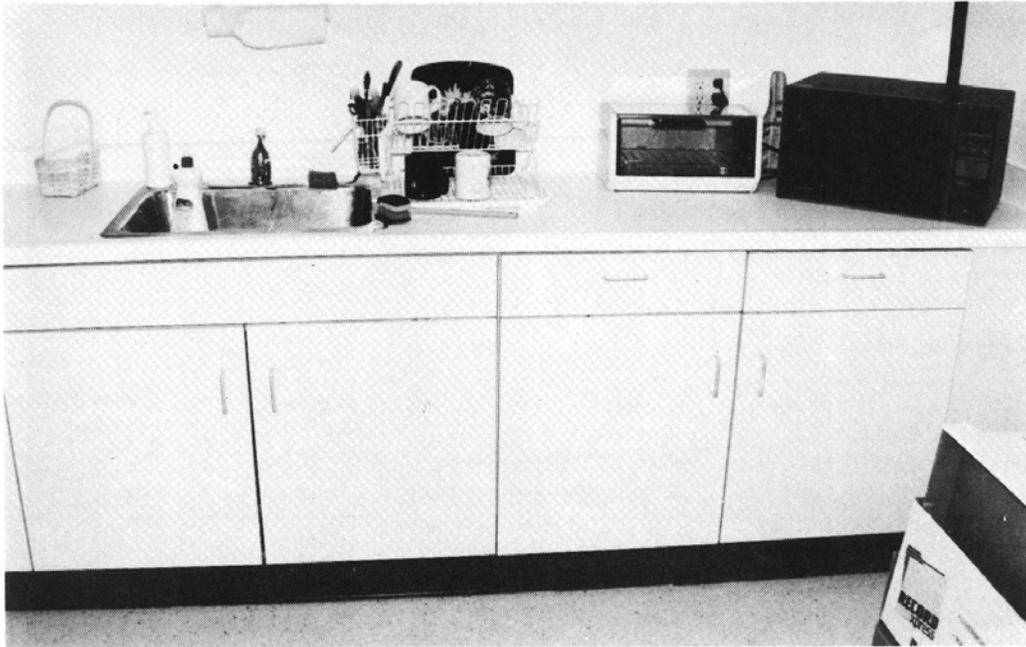
- Do-it-yourself methods, which are simple generic methods for securing typical nonstructural items found in the home. Enough information is provided to permit a handyman with common tools and readily available materials to complete an installation.
- Engineered methods, which are schematic details showing common solutions for the items in question. These sketches do not contain enough information for installation; they are provided here primarily as an illustration of the scope of work required. The designation “Engineering Required” has been used for items where do-it-yourself installation is likely to be ineffective. FEMA 74 recommends that design professionals be retained to evaluate the vulnerability of these items and design appropriate anchorage or restraint solutions, particularly where safety is an issue.

Cost estimates are provided with the details in this section as a rough guide for planning or budgeting purposes. The values are intended to cover the cost of materials and labor. They do not include allowance for architectural or engineering fees, permits, special inspection, etc. These estimates represent a professional opinion based on information available at the time FEMA 74 was published in 1994 so current actual construction costs may vary significantly, depending on the timing of construction, changes in conditions, the availability of materials, regional cost variations, and other factors.

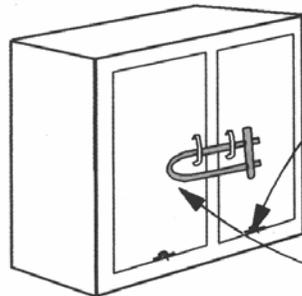
FEMA 74 provides several pages of installation notes that will be of assistance to users interested in selection and installation of fasteners appropriate to construction materials of the house (www.fema.gov/hazards/earthquakes/nehf/fema-74.shtm). Reproductions of FEMA 74 pages are shown in Figures 8-3a through 8-3f.

DRAWER AND CABINET LATCHES

DO-IT-YOURSELF

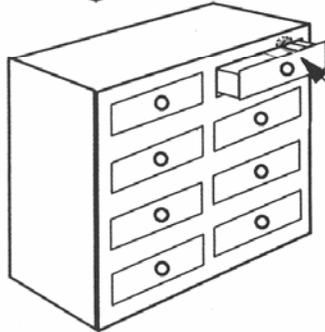


Unrestrained drawers and cabinets
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



INSTALL STRONG MECHANICAL CABINET CATCHES (SAFETY HASP, SLIDE BOLT, TOUCH-DOOR CABINET CATCH, CLIP-ROLLER OR SNAP-ACTION CABINET CATCH, ETC.)

ALTERNATIVE: PROVIDE BABY-PROOF CLOSURE



INSTALL MECHANICAL DRAWER CLOSURE (BABY-PROOF LATCHES, DRAWER LOCKS, OR OTHER SPECIALTY LATCHES)

Upgrade Detail C19

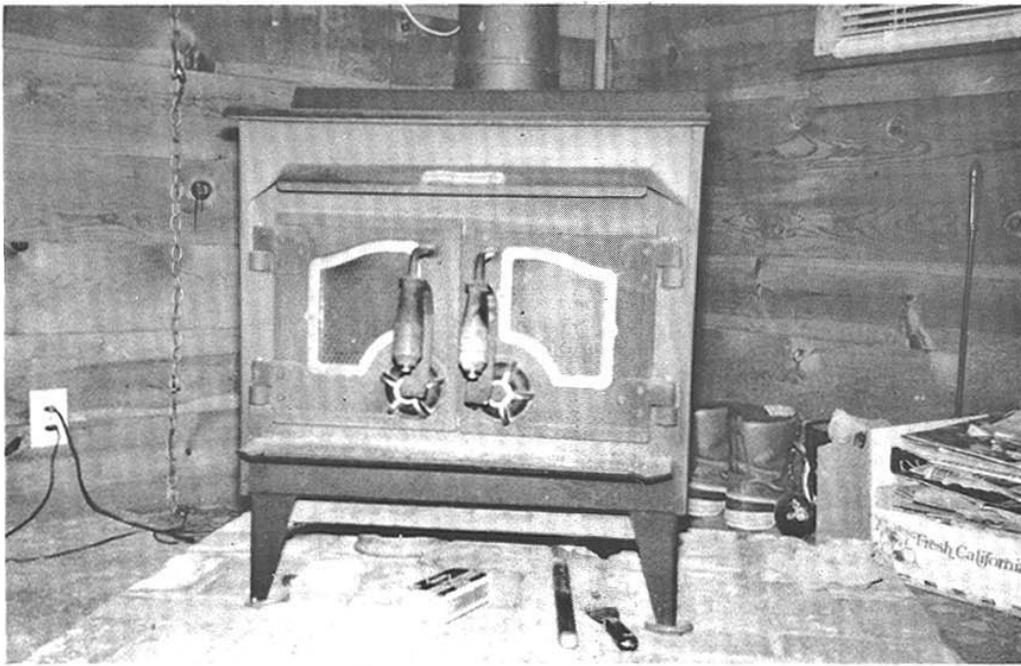
Approximate Cost: \$50 per cabinet

C19

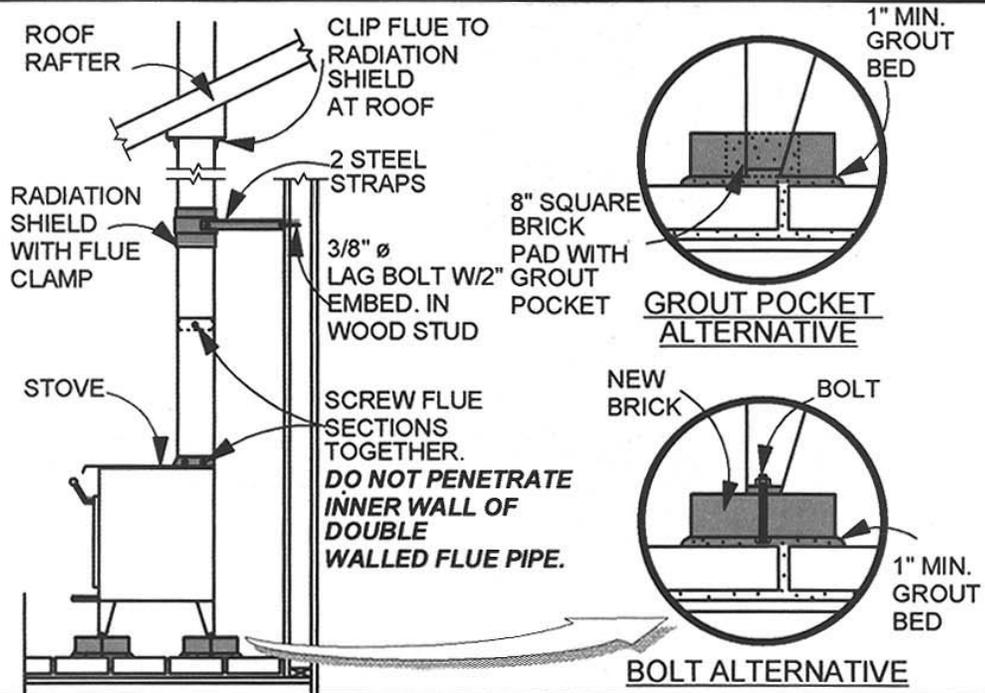
Figure 8-3a Reproduction of FEMA 74 suggestions for securing drawer and cabinet latches.

FREESTANDING WOOD STOVE

DO-IT-YOURSELF



Unrestrained wood burning stove
 Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Upgrade Detail C20
 Approximate Cost: \$500

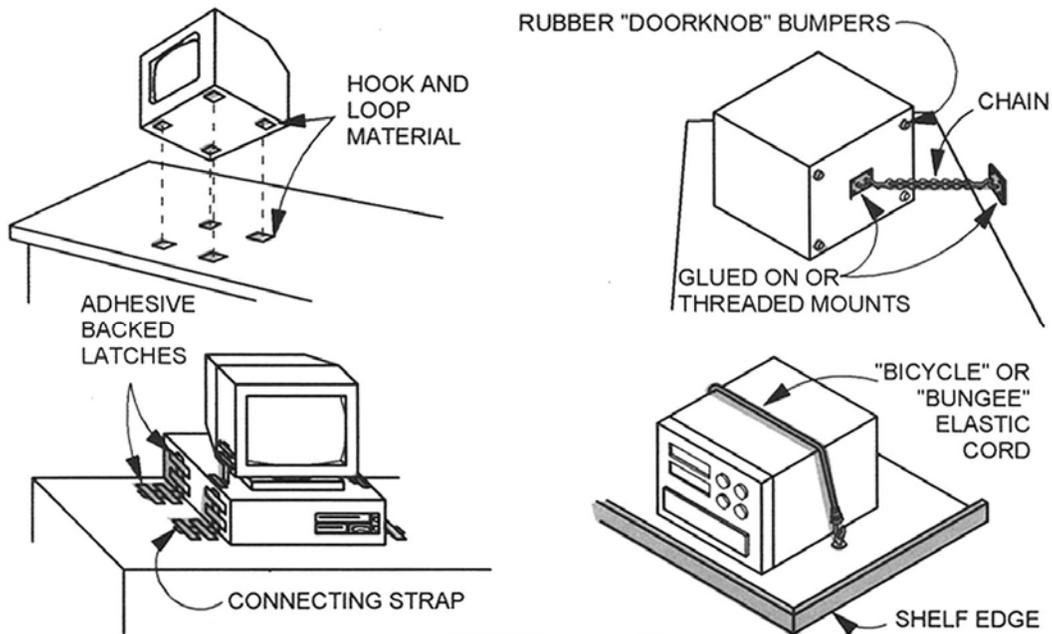
Figure 8-3b Reproduction of FEMA 74 suggestions for securing a freestanding wood stove.

DESKTOP COMPUTERS AND OFFICE EQUIPMENT

DO-IT-YOURSELF



Unsecured computers may fall and suffer damage
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Upgrade Detail C10
Approximate Cost: \$50 per computer

Figure 8-3c Reproduction of FEMA 74 suggestions for securing desktop computers and office equipment.

FREESTANDING WALLS OR FENCES

ENGINEERING REQUIRED



Earthquake Damage: 1994, Northridge, California
Photo Credit: Robert Reitherman

- MANY MILES OF POORLY CONSTRUCTED CONCRETE MASONRY UNIT (CMU) FENCES WERE DAMAGED DURING THE 1994 NORTHRIDGE EARTHQUAKE. COLLAPSE OF WALLS WITH INADEQUATE OR ABSENT REINFORCING AND/OR FOUNDATIONS WAS COMMON IN NORTHRIDGE AND SYLMAR. IN MANY CASES, MOST OF THE SIDEWALK WAS COVERED WITH DEBRIS, AS SHOWN ABOVE.
- FREESTANDING WALLS OR FENCES BUILT OF CMU, BRICK, OR STONE NEED TO BE ENGINEERED AND CONSTRUCTED WITH APPROPRIATE FOUNDATIONS, ADEQUATE REINFORCEMENT, AND GOOD QUALITY MORTAR.
- STANDARD DETAILS FOR LOW FENCES OR SHORT RETAINING WALLS MAY BE AVAILABLE FROM THE LOCAL BUILDING DEPARTMENT.

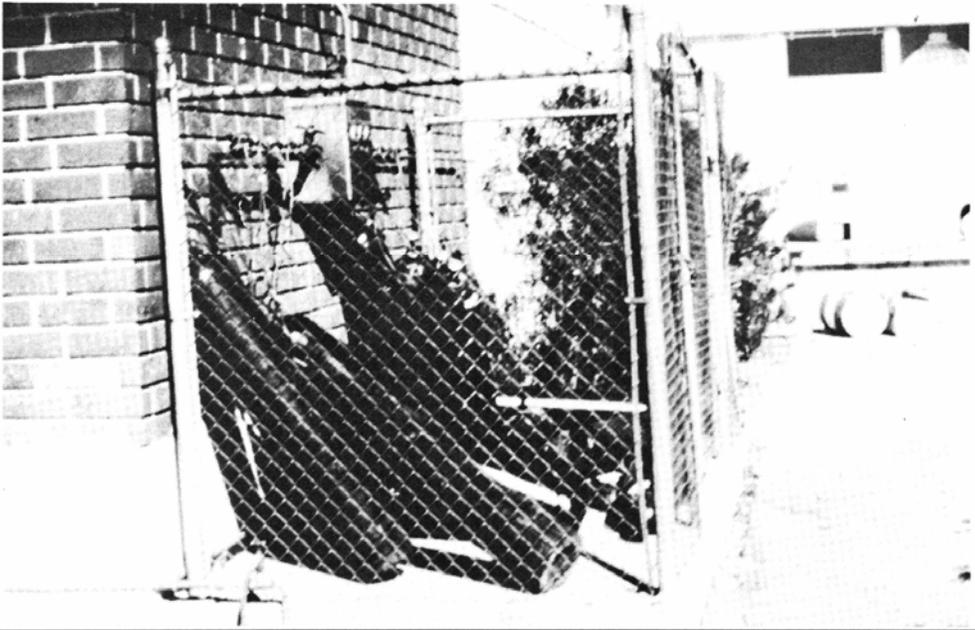
Schematic Upgrade Detail A16

Approximate Cost: Depends on the design

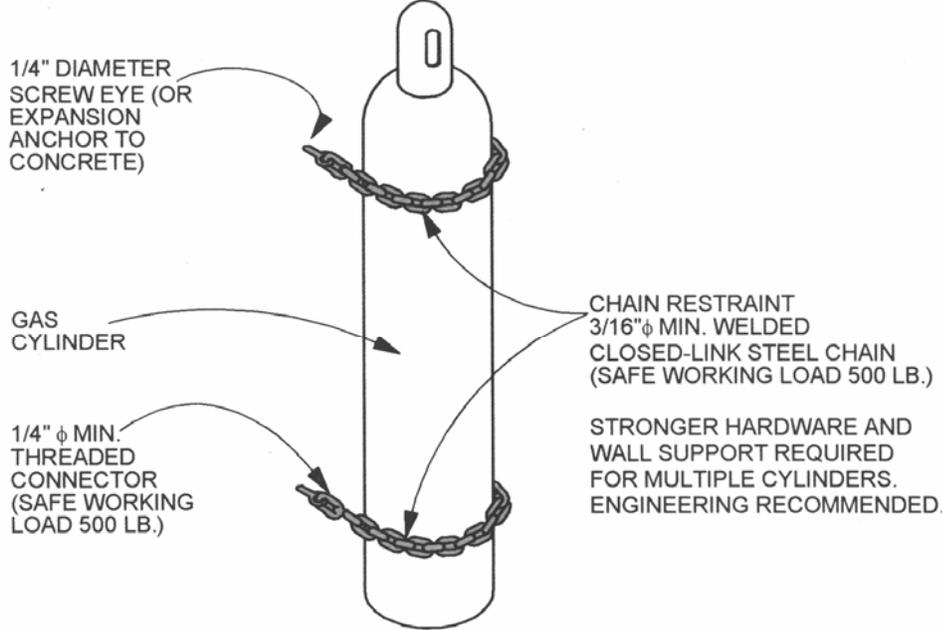
Figure 8-3d Reproduction of FEMA 74 suggestions for securing freestanding walls or fences.

COMPRESSED-GAS CYLINDERS

DO-IT-YOURSELF



Earthquake Damage: 1971, San Fernando, California
Photo Credit: Scientific Service, Inc.



1/4" DIAMETER SCREW EYE (OR EXPANSION ANCHOR TO CONCRETE)

GAS CYLINDER

1/4" ϕ MIN. THREADED CONNECTOR (SAFE WORKING LOAD 500 LB.)

CHAIN RESTRAINT
3/16" ϕ MIN. WELDED CLOSED-LINK STEEL CHAIN (SAFE WORKING LOAD 500 LB.)

STRONGER HARDWARE AND WALL SUPPORT REQUIRED FOR MULTIPLE CYLINDERS. ENGINEERING RECOMMENDED.

Upgrade Detail C21
Approximate Cost: \$30 per lineal foot; \$50 for single units

C21

Figure 8-3e Reproduction of FEMA 74 suggestions for securing compressed-gas cylinders.

MISCELLANEOUS FURNITURE

DO-IT-YOURSELF

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.

Upgrade Detail C28

Approximate Cost: Varies, approximately \$50 per item

C28

Figure 8-3f Reproduction of FEMA 74 suggestions for securing miscellaneous furniture.

Chapter 9

EXISTING HOUSES

Additions or alterations can reduce the earthquake resistance of an existing house. With proper consideration, however, earthquake resistance can be maintained or even increased as part of an addition or alteration. This chapter discusses the earthquake-resistance implications of additions and alterations and provides recommendations and references for earthquake upgrades.

9.1 ADDITIONS AND ALTERATIONS

Additions and alterations modify the load-resisting systems of existing houses. Generally, both the systems supporting gravity loads and those supporting lateral (wind and earthquake) loads are affected. For additions and alterations, *IRC* Section R102.7.1 requires that any new work conform to the *IRC*, but existing construction is allowed to remain unless it is made unsafe or will adversely affect the performance of the house. This wording provides significant opportunity for interpretation by the user and building official. *IBC* Section 3402 provides more specific guidance for acceptable reduction in strength or increase in loading, which may be appropriate to some additions and alterations. The following discussion of additions and alterations highlights issues and concerns that should be considered when interpreting *IRC* requirements.

9.1.1 Alterations

Alterations to existing houses often involve modification or removal of existing bracing walls and portions of floors and roofs. Figure 9-1 shows two alterations that remove exterior bracing walls from a house and disrupt the roof. Interior remodels often remove interior walls that provide bracing for earthquake and wind loads.

Where existing bracing walls are removed or reduced due to alterations, the remaining bracing walls should be checked for conformance with the bracing location, length, and bracing type requirements of the *IRC* provisions. The primary focus should be on bracing in the immediate vicinity of the alteration. If bracing deficiencies occur in other portions of a house, upgrade of those areas is encouraged.

When skylights, dormer windows, or similar openings are added to existing roofs, the openings should be checked for conformance with *IRC* requirements. For earthquake loading, this would include checking the opening size against permitted maximum sizes in the irregularities provisions and checking detailing against *IRC* requirements. The framing around the opening also should be checked for gravity load requirements such as doubled rafters and headers. If a significant rebuilding of the roof is occurring, a broader range of *IRC* provisions require checking as does the completeness of the load path for gravity and lateral loads.

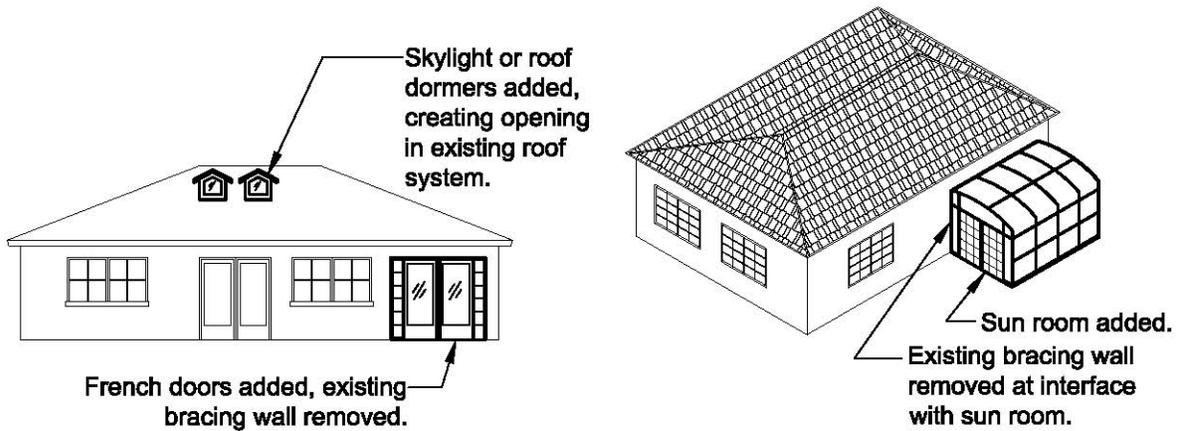


Figure 9-1 Alterations to existing house: bracing wall and roof modifications (left) and modification for the addition of sun room (right).

9.1.2 Additions

An addition to an existing house often results in both the removal of some existing bracing wall, roof, and floor areas and the addition of weight and, therefore, increased earthquake loading. Most additions can be categorized as horizontal additions, vertical additions, or a combination of the two. Horizontal additions generally are built along the side of an existing house and often require reframing of the roof. Vertical additions generally involve the addition of an upper story. Figure 9-2 illustrates horizontal and vertical additions.

Horizontal additions may create irregularities or make existing irregularities worse. Thus, the *IRC* building configuration irregularity provisions should be reviewed to assess the post-addition configuration.

Horizontal additions include the construction of new bracing walls at the new exterior of the house (and sometimes on the interior). A significant reconfiguration of bracing walls at the interface of existing and new construction also often occurs. All bracing walls in the addition and interface should be checked for conformance with the *IRC* as should any portions of the existing house where framing and bracing modifications have been made.

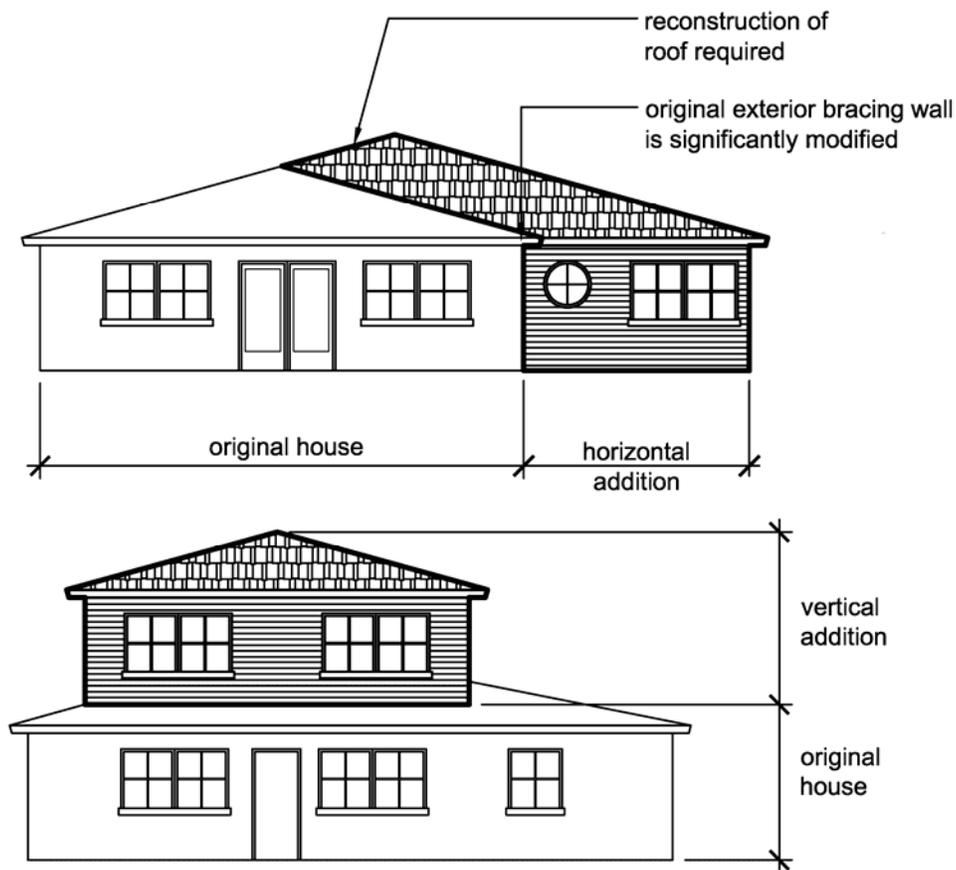


Figure 9-2 Horizontal addition (above) and vertical addition (below).

Finally, it is very important that the addition and the existing house be tied together very well. Ideally the level of interconnection should be the same as would occur if they had been built at the same time, but this generally cannot be practically achieved. Top plates and sill plates should be strapped between the new and existing construction to provide continuity.

Sheathing should be continuous and fastened to the same or interconnected framing members where possible. Where not possible, strapping of framing members should occur at a regular interval. Figure 9-3 shows the earthquake behavior of a house with failed cripple walls and adjoining (very small) slab-on-grade addition; a combination of cripple wall upgrade and strapping between the house and the addition would have greatly improved the performance of this house.

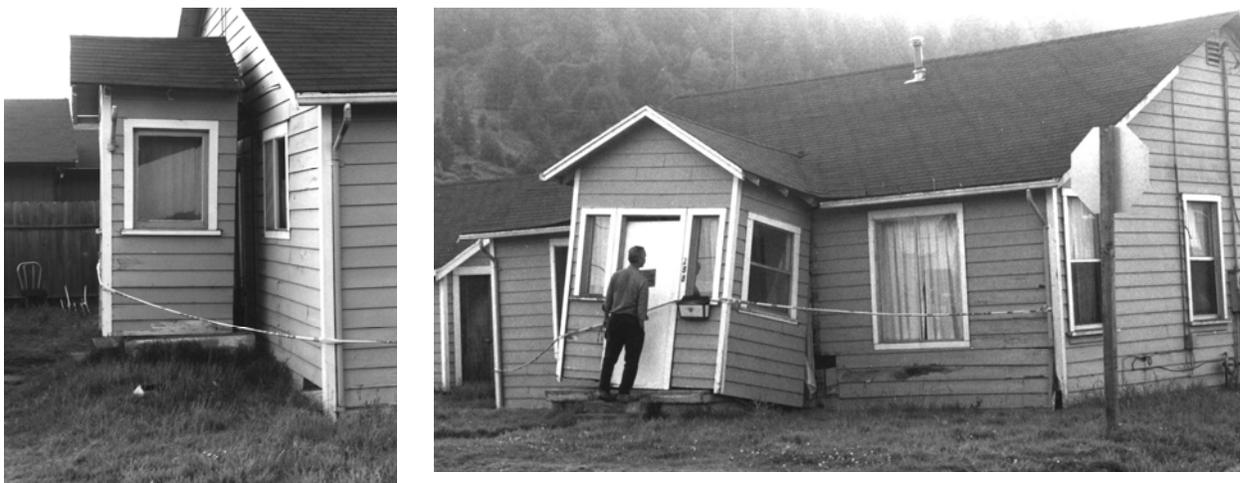


Figure 9-3 Cape Mendocino earthquake damage to cripple wall house with slab-on-grade additions.

A vertical addition demands significantly greater consideration of both gravity and lateral (earthquake and wind) loads. This is because the story that is added often will more than double both the gravity and lateral loads on the existing lower story. Thus, when adding an upper story, the entire house, including the lower story, should be brought into conformance with current code requirements. Although it should be possible to meet *IRC* requirements, use of the engineered design requirements of the *IBC* or *NFPA 5000* may result in a more practical design.

With any addition or alteration, it is important that the gravity and lateral load paths be checked in detail to ensure that they are complete and meet the requirements of the *IRC*, *IBC*, or *NFPA 5000*. Additions and alterations often create nontypical load path details, and it is important that these details result in a complete load path with load-carrying capacity that is not less than would have resulted had typical details been used. In some cases, the new detailing deviates enough from that which is typical that engineered design should be employed.

Adding to or altering an existing house offers a clear opportunity to voluntarily upgrade existing portions of the house to better resist earthquake forces. The following section describes where such upgrades might be employed.

9.2 EARTHQUAKE UPGRADE MEASURES

As noted elsewhere in this guide, the life-safety performance of houses in past earthquakes has been good with only a few exceptions. There are, however, certain conditions or portions of houses that have repeatedly resulted in earthquake damage, loss, and, in some cases, life loss or injury. Among these are:

- Missing or inadequate bolting to the foundation,
- Inadequate cripple wall bracing,

- Damage to bracing and finish materials,
- Excessive drift at garage fronts,
- Partial or complete collapse of hillside houses,
- Separation and loss of vertical support at “split-level” floor offsets, and
- Damage and collapse of masonry chimneys.

Because existing houses vary widely in configuration and construction based on age, region, siting, etc., it is necessary to identify upgrade measures appropriate to the particular house. In deciding on voluntary upgrade measures, take into account the configuration of the house and the potential benefit of the upgrade. Based on the principles discussed in this guide, some simple upgrade measures for existing houses are described below. This discussion addresses when the various upgrade measures are appropriate and suggests approximate levels of priority. Note, however, that the primary objective of most published upgrade measures for houses is reduction of hazard to life.

If an upgrade is being undertaken on a voluntary basis, the house generally will not be required to conform to all of the code requirements for new construction. The building official or authority having jurisdiction should be consulted regarding minimum requirements. It is recommended that a basis for the upgrade work (i.e., published prescriptive method or earthquake load level) be established and clearly documented. When a house is being remodeled or extensively renovated, a systematic upgrade to meet the *IRC* requirements for new construction may be reasonable and may be required by the authority having jurisdiction.

The remainder of this section provides an overview of common upgrade measures. Those interested in implementing specific measures are referred to the list of references and resources in Appendix E for further information on implementation.

9.2.1 Foundation Bolting

Many houses constructed in California before the 1950s and even later in other parts of the United States do not have anchor bolts that attach the wall bottom plate or foundation sill plate to the concrete or masonry foundation. During an earthquake, this can allow the wood framing to slide off the foundation, causing loss of vertical support and sometimes cripple wall or partial basement story collapse. Where the headroom and foundation configuration permit, this situation can be remedied by adding new anchor bolts. Common anchorage configurations are illustrated in Figure 9-4. Expansion-type anchors can be used in strong concrete and masonry foundations. Adhesive anchors are recommended for use with unreinforced masonry or weaker concrete foundations but can be used with all foundation types. When anchor bolts are added, use of steel plate washers in accordance with the *IRC* is recommended.

If there is insufficient overhead room or the foundation configuration does not permit the use of anchor bolts, a wide variety of proprietary anchors are available from manufacturers. The primary purpose of this anchorage is to transmit horizontal earthquake loads acting parallel to the foundation from the foundation sill plate to the foundation. Where used, proprietary anchors should be designed for this use and loading direction by the manufacturer.

A high priority is suggested for addition of foundation bolting to houses that are not bolted based on the relatively low upgrade cost and generally high benefit. Applicable references include the *International Residential Code* (ICC, 2003a), the *International Existing Building Code Appendix Chapter A3* (ICC, 2003c), *Training Materials for Seismic Retrofit of Wood-Frame Homes* (ABAG), *Homeowner's Handbook* (City of San Leandro, California), and *Project Impact* (City of Seattle).

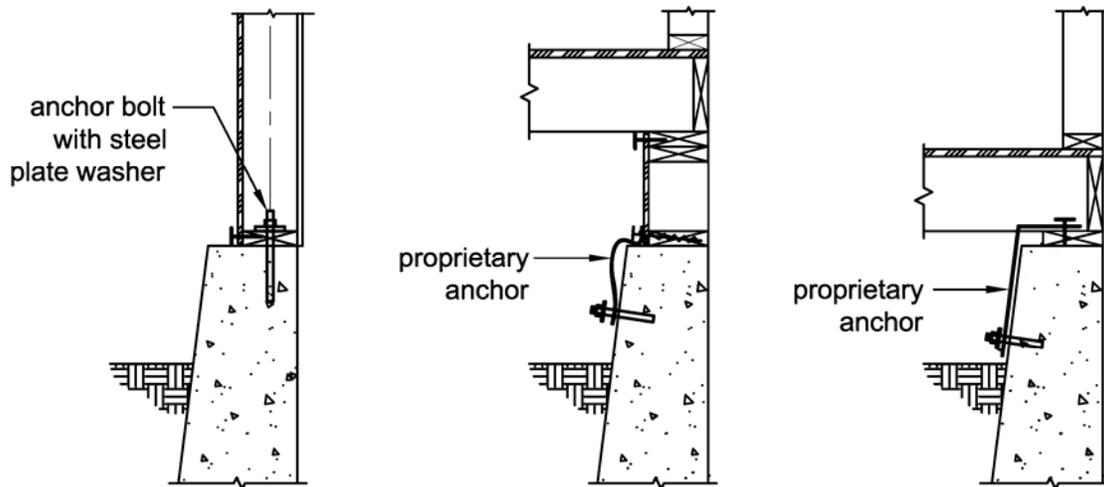


Figure 9-4 Common anchorage configurations.

9.2.2 Cripple Wall Bracing

Cripple walls are partial-height wood light-frame walls that extend from the top of the foundation to the first framed floor. Cripple walls are very susceptible to damage during an earthquake but are also one of the easiest portions of a house to upgrade for improved earthquake performance. Many of the cripple walls of existing houses (especially those constructed prior to 1960) have inadequate bracing capacity due to the type of sheathing used, inadequate attachment of the sheathing, inadequate attachment of the framing to the foundation and first floor, or decay of the system. Figure 9-5a shows a house with collapsed cripple walls (note that the porch floor is still at the original house floor elevation). As a minimum, this house will have to be jacked up to be repositioned on the foundation and have utilities reconnected. The house in Figure 9-5b suffered more severe damage due to cripple wall collapse.



Figure 9-5a House with collapsed cripple walls. Photo Courtesy of National Information Service for Earthquake Engineering, University of California, Berkeley

Figure 9-5b A house with severe damage due to cripple wall collapse. Photo Courtesy of FEMA.



Prior to an upgrade, the existing cripple wall system should be inspected and any sections of the framing that show signs of decay should be replaced. Framing materials in areas where moisture is present or in contact with the foundation should be replaced with preservative treated or decay-resistant materials. The upgrade should include anchorage of the foundation sill plate to the foundation, framing anchorage to the first-floor framing, and sheathing of the cripple walls with wood structural panel sheathing applied to either the exterior or interior face of the crawl space walls. Sheathing and connections may be installed to meet the requirements of the *IRC* or in accordance with other provisions developed specifically for upgrades. The basic elements of cripple wall bracing are illustrated in Figure 9-6.

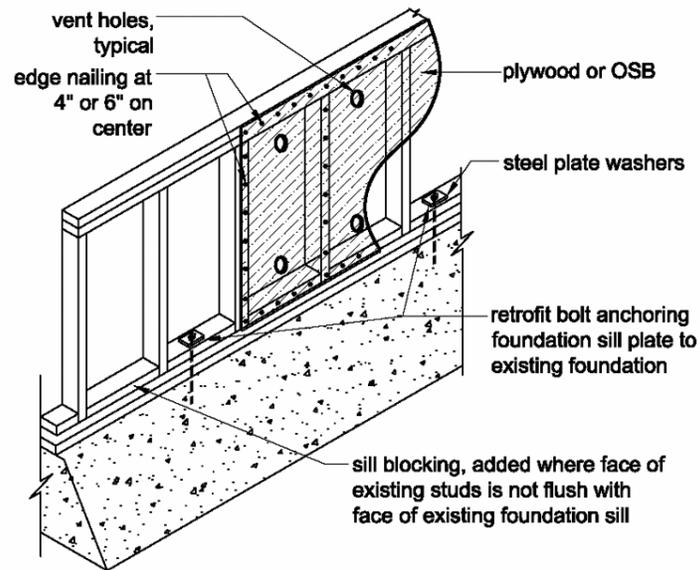


Figure 9-6 Cripple wall bracing.

Upgrade of interior cripple walls also is recommended where a crawl space is large. Where bracing is to be installed only at the perimeter of a large crawl space, performance can be improved by providing additional bracing length, reducing nail spacing from 6 inches to 4 inches, or providing sheathing on both faces of the cripple wall. A high priority is suggested for upgrading inadequately braced cripple walls based on the relatively low cost and generally high benefit. Applicable references include the *International Residential Code* (ICC, 2003a), the *International Existing Building Code* Appendix Chapter A3 (ICC, 2003c), *Training Materials For Seismic Retrofit of Wood-Frame Homes* (ABAG), *Homeowner's Handbook* (City of San Leandro), and *Project Impact* (City of Seattle).

9.2.3 Weak- and Soft-Story Bracing

Earthquake damage often is concentrated in the first story of multistory houses because the first story experiences higher loads while usually having the least amount of bracing. To reduce this damage, the first-story walls can be upgraded to increase their strength and stiffness. One method of accomplishing this is to remove the interior finish material (usually gypsum wall board or interior plaster) at the bottom of the wall in the corners of the house and to add hold-down anchors for overturning resistance. The anchors should be attached to the end studs (or other studs that have sheathing edge nailing) and the vertical rod or bolt should be attached to the foundation below (see Figure 9-7). This upgrade does not require that the entire interior finish be removed but only a section in each corner that is one stud spacing in width and several feet in height. This is an effective upgrade measure where continuous reinforced foundations exist.

Hold-down anchorage to isolated footings or unreinforced masonry footings is likely to be much less effective and engineering review is recommended.

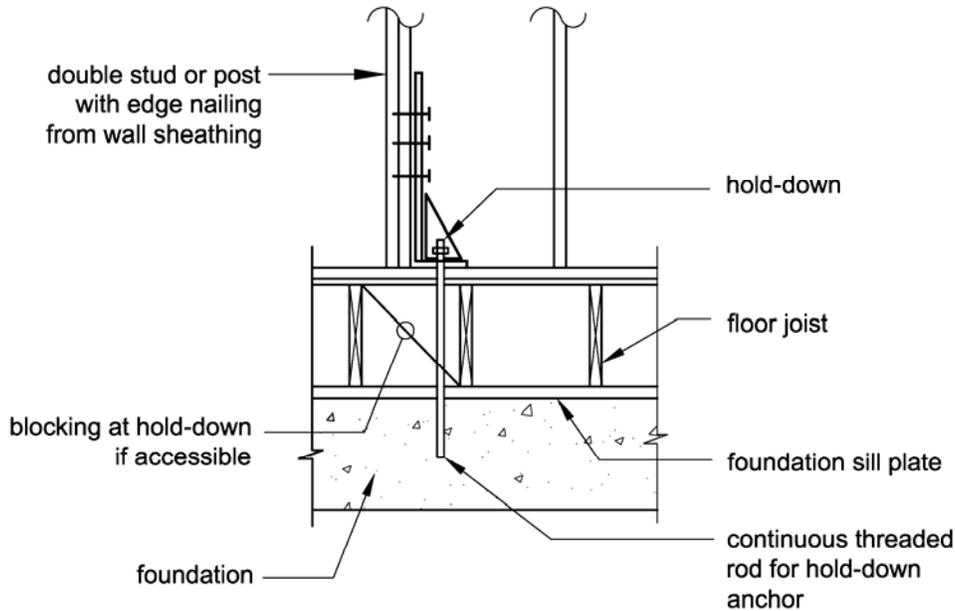


Figure 9-7 Weak- and soft-story bracing.

If the interior finish material is being removed for other reasons, then additional upgrade opportunities present themselves. These include additional anchorage of the top of the wall to the floor framing above, attachment of the bottom plate of the wall to the floor framing below, and the addition of blocking at the floor framing for the story above if not present at all locations that bear on walls. In addition, before gypsum wallboard or another finish material is attached to the walls, wood structural panel sheathing can be applied to the interior of the walls using 4-inch nail spacing around the perimeter of each sheet of sheathing and to the stud or post with the hold-down attached. A moderate priority is suggested for soft- and weak-story bracing upgrades in one- and two-family detached houses based on their moderate costs. The benefit can vary widely depending on the configuration of the existing house.

9.2.4 Open-Front Bracing

An open-front configuration occurs when bracing walls are omitted (or of grossly inadequate length) along one edge of a floor or roof. This is applicable to stories braced by light-framed walls. A number of apartment buildings with open front first stories were severely damaged or collapsed in the Loma Prieta and Northridge earthquakes. In this apartment building type, called “tuck-under parking,” significant lengths of first-story bracing wall were omitted in order to provide access to under-building parking. One- and two-family houses with open-front configurations also are vulnerable to earthquake damage. Two common occurrences of open-

front configurations in one- and two-family houses are the fronts of attached garages with inadequate bracing length and window walls with no bracing. These conditions are illustrated in Figure 9-8.

The open-front garage condition is of most concern when there is living space over the garage. In newer houses, narrow wall segments at the side of garage door openings may contain pre-fabricated bracing wall systems or engineered bracing walls that can be identified by the use of steel hold-down connectors or straps. Where there is no indication of such bracing systems, the installation of bracing is recommended. In detached one- and two-family houses, wood structural panel sheathing and anchorage connectors can be added in accordance with *IRC* provisions using adhesive anchors to existing foundations (Figure 9-9). The performance of narrow bracing walls with hold-down devices relies on the continuity of the existing foundation. If the existing foundation is not continuous, shows signs of damage or is constructed of unreinforced masonry or post-tensioned concrete, an engineering evaluation should be undertaken. Steel moment frames or collectors transferring loads to other portions of the house are alternative upgrade measures where use of bracing walls is not possible.

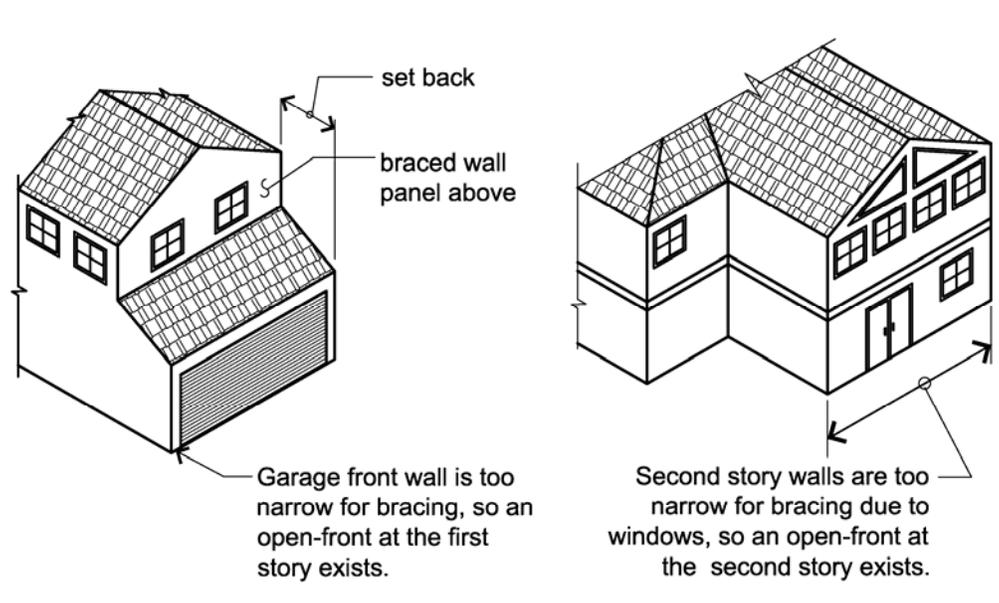


Figure 9-8 Common open-front occurrences in one- and two-family detached houses.

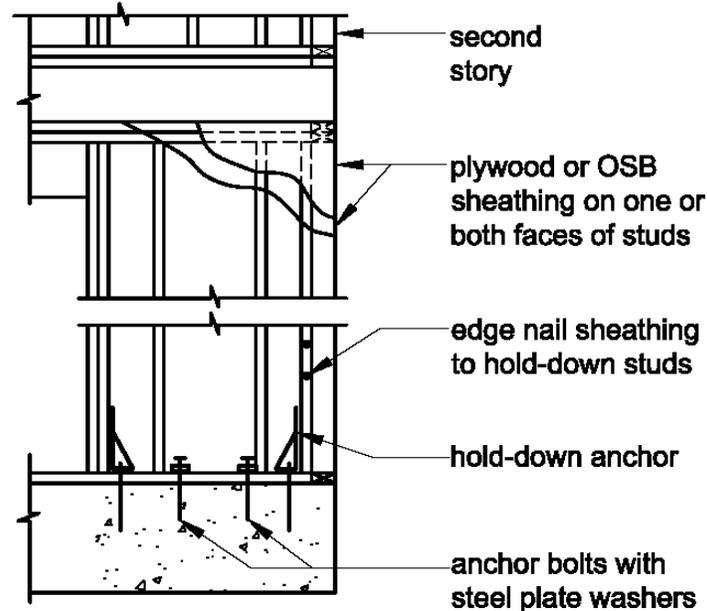


Figure 9-9 Detailing of narrow bracing wall piers at open fronts.

A high priority is suggested for upgrade of open fronts in the first stories of multistory houses. A moderate priority is suggested in single-story houses or the top story of multistory houses.

9.2.5 Hillside House Bracing

A number of houses on steep hillsides collapsed or were severely damaged in the Northridge earthquake. Where damage occurred, the lot sloped downward from the street level, and the main floor of the house was located at or near street level with either a stilt system or tall wood light-frame walls between the house and grade. Many of the failures began with floor framing pulling away from the uphill foundation or foundation wall. Typical damage to these types of houses is shown in Figure 9-10. As a result of Northridge earthquake damage, the City of Los Angeles has developed provisions for anchoring such houses to their uphill foundations to reduce the risk of failure.

There are no prescriptive upgrade measures currently available for these hillside houses so upgrade requires an engineered design. Upgrade measures to improve the response of the structure and reduce the amount of damage that occurs during an earthquake include:

- Securely anchoring the floor framing to the uphill foundation. This will require that anchors (i.e., hold-down connectors) be used to attach the floor joists to the foundation

using adhesive anchors (see Figure 9-11). This detail should be repeated at each framed floor level that attaches directly to an uphill foundation.

- Attaching the bottom plates of the framing of the stepped (or sloped) and downhill cripple walls to the foundations. Supplemental anchorage is particularly important where the top of the side foundations are sloped rather than stepped.
- Attaching the stepped or sloped side cripple wall top plates together at all splice joints using strap connectors. These straps should be heavy and connected securely to both sides of the splice, making the top plate of the stepped cripple wall act as though it were one piece along the entire length of the wall.
- Continuously sheathing the stepped wall and the down-hill wall with wood structural panel sheathing. Adequate shear transfer into and out of the cripple walls should be provided.

These upgrade measures should reduce but will not necessarily eliminate earthquake damage. A high priority is suggested for evaluation of hillside house vulnerability. The need for upgrade should be determined based on an engineering evaluation. Applicable references are *Voluntary Earthquake Hazard Reduction in Existing Hillside Buildings* (City of Los Angeles, 2002) and *Framing Earthquake Retrofitting Decisions: The Case of Hillside Homes in Los Angeles* (von Winterfeldt, Roselund and Kitsuse, 2000).



Figure 9-10 House located on a hillside site damaged during the Northridge, California, earthquake.



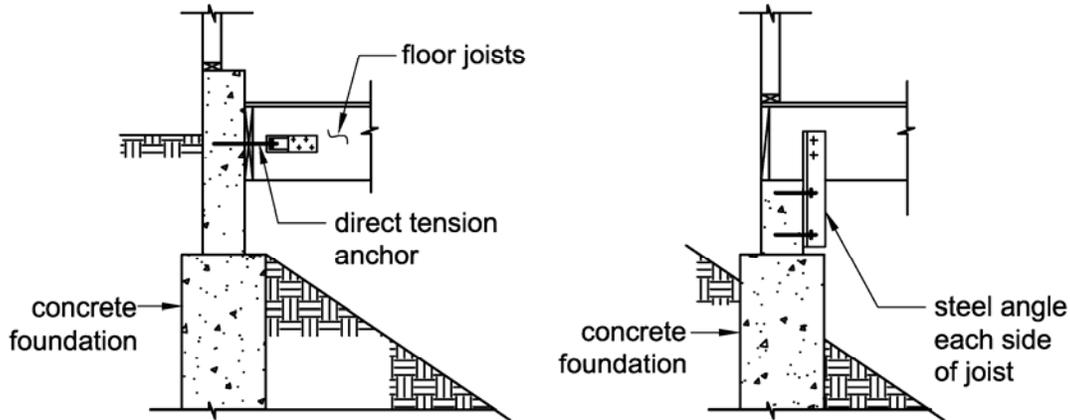


Figure 9-11 Anchorage of floor framing to the uphill foundation.

9.2.6 Split-Level Floor Interconnection

Split-level houses experienced partial collapse and significant damage in the 1971 San Fernando earthquake. These houses had vertical offsets in the floor framing elevation on either side of a common wall or other support as shown in Figure 9-12. Earthquake damage occurred when sections of floor and roof framing pulled away from the common wall. (See Section 2.3 of this guide for additional discussion of irregularities.) The behavior of split-level configurations can be improved by adequately anchoring floor framing on either side to the common wall. Where offset floors are close enough in elevation that a direct tension tie can be provided between levels, an upgrade can be accomplished with installation of steel straps; a strap spacing of not more than 8 feet on center is recommended (Figure 9-12). Where direct tension ties are not practical, ATC (1976) provides a variety of details for anchorage of framing to the supporting wall. Finish removal will often be required in order to install connections, making this upgrade most practical when remodel work is occurring. It is difficult to establish a priority for this upgrade because significant damage was observed only in the San Fernando earthquake and photos suggest that the houses damaged had little or no positive connection provided between offset floor levels. An applicable reference is *A Methodology for Seismic Design and Construction of Single-Family Dwellings* (ATC, 1976).

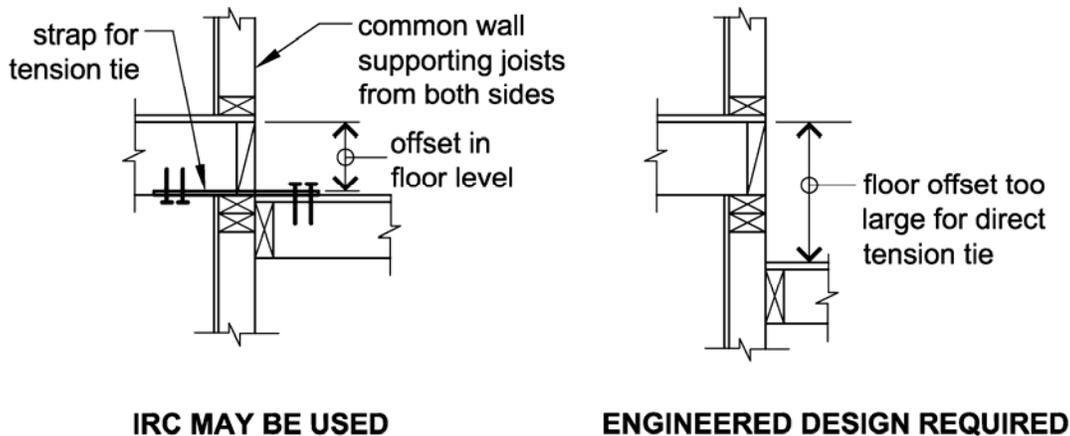


Figure 9-12 Split-level ties for floor framing.

9.2.7 Anchorage of Masonry Chimneys

Fireplaces and chimneys in new construction were discussed in Chapter 7 where it was noted that masonry and concrete fireplaces are heavy, rigid, brittle, and very susceptible to earthquake damage. *IRC* requirements for new construction in SDCs D₁ and D₂ dictate use of horizontal and vertical reinforcing and anchorage of the chimney to the framing at floors, ceilings, and roof.

Chimneys on existing houses generally are even more vulnerable than new chimneys because they seldom have reinforcing or are anchored to the house. Common chimney failures range from hairline fractures of masonry and flue liners to complete fracture (i.e., the top of the firebox and at the roof line) permitting large sections of the chimney to fall away from or into the house, shattering into a pile of rubble (see Chapter 7 for discussion and illustrations). Chimneys are reported to have caused one fatality in the 1992 Landers earthquake and critically injured one person in the 2000 Napa earthquake (Association of Bay Area Governments).

The upgrading of chimneys is very controversial within the earthquake engineering community. Upgrading of existing masonry chimneys most often includes strapping the chimney to the house at the roof, ceiling, and floor levels. Where the chimney extends a significant distance above the roof line, braces from the top of the chimney down to the roof also may be added. Advocates of chimney bracing believe that anchoring the chimney will reduce the hazard posed by falling portions of the chimney. Opponents note that even with strapping, a chimney seeing significant earthquake loading is likely to be damaged to the point that removal and reconstruction are required. Opponents further point out that upgrading does not always improve chimney performance. Both arguments deserve consideration and the reader is referred to the reference list for additional discussion. Easy and practical approaches to reducing risk to life are provided on the Association of Bay Area Governments (ABAG) website and include the suggestion that occupants should not sleep in the area immediately surrounding a fireplace with an unreinforced or unanchored chimney.

Where chimneys occur at the house exterior, steel straps similar to those discussed in Chapter 7 can be wrapped around the outside of the chimney and anchored to floor, ceiling, and roof framing in much the same way as was illustrated for new construction. Because this strap will have exterior exposure, heavy steel should be used and corrosion protection will need to be maintained. It also is important that the *IRC* Section R1001.15 gap be maintained between the chimney face and combustible framing. Although the addition of straps is not likely to keep a chimney from being damaged, it may reduce the falling hazard if it is damaged. A recommended alternative is removal of the chimney or fireplace and chimney and replacement with a factory-built fireplace and flue surrounded by light-frame walls.

Applicable references include *Info on Chimney Safety and Earthquakes* (ABAG) and *Reconstruction and Replacement of Earthquake Damaged Masonry Chimneys* (City of Los Angeles, 2001).

9.2.8 Anchorage of Concrete and Masonry Walls

Under earthquake loading, concrete and masonry walls can pull away from roof and floor framing. This is primarily a concern where bolted ledgers support framing and no direct anchorage of the wall to the framing exists. This condition can be effectively upgraded by providing a tension connection between the wall and the floor and roof framing as shown in Figure 9-13. The connection should be made to the joists when the joists run perpendicular to the wall and should be made to blocking and extend at least 4 or 5 feet into the interior of the floor system when the joists run perpendicular. An engineering evaluation of the existing condition and engineered design of upgrade measures are recommended.

Applicable references include *International Existing Building Code Appendix Chapter A2* (ICC, 2003c) and *Guidelines for Seismic Evaluation and Rehabilitation of Tilt-up Buildings and Other Rigid Wall / Flexible Diaphragm Structures* (SEAONC, 2001).

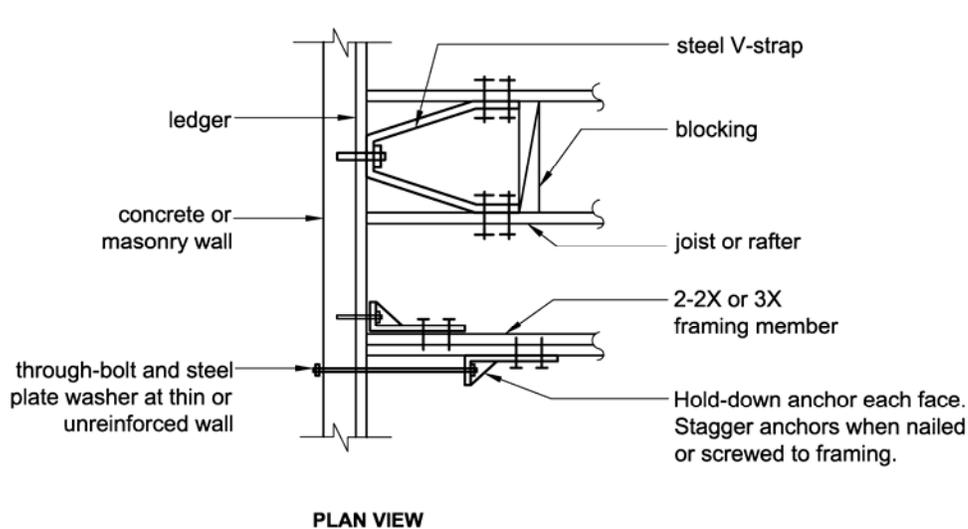


Figure 9-13 Anchorage of concrete or masonry walls to floor, roof, or ceiling framing.

