Earthquake Risks around the U.S.

How to Protect Your Property

Insurance Institute for Business & Home Safety

Prepared by the Institute for Business & Home Safety (IBHS), an initiative of the insurance industry to reduce deaths, injuries, property damage, economic losses and human suffering caused by natural disasters. IBHS is a non-profit association that engages in communication, education, engineering and research.

acknowledgements

The staff of the Institute for Business & Home Safety (IBHS) wishes to acknowledge the valuable input of all those involved in preparing this brochure. In particular, we extend our thanks to:
The IBHS Earthquake Peril Committee Members
The IBHS Public Relations Committee Members
The IBHS Retrofit Committee Members
The National Geophysical Data Center (NGDC)
Earthquake Engineering Research Center, University of California, Berkeley (EERC, UCB)
Earthquake Engineering Research Institute (EERI)

Table of Contents

Introduction 1
Earthquakes and Your Home 2
Earthquakes: What, When, Where and Why? 2
Measuring an Earthquake's Size 3
What You Feel and Why You Feel It 4
What Your Home Experiences 5
Secure Your Space: What You Can Do 5
Nonstructural Retrofits 6
Bookcases 6
Cabinets and Drawers 8
Picture Frames and Bulletin Boards 9
Ceiling Lights, Suspended Ceilings and Hanging Fixtures 10
Windows and Doors 11
Large Appliances 12
Water Heaters 12
Wall-mounted Televisions 14
Structural Retrofits 18
Foundation Systems 19
Slab-on-Grade Foundations 19
Crawl Space and Basement Foundations 20
Post-and-Pier Foundations 22
Floor Systems 24
Wall Systems 24
Wood-Framed Walls 25
Unreinforced Masonry Walls 26
Roof Systems 26
Unreinforced Chimneys 27
Garages 28
Room Additions 28
Suggested Order of Priority 29
Secure Your Space Project List 30
Before, During and After: Be Completely Prepared 31
Checklist 36
References 33
Additional Sources of Information 34

Introduction

Between 2000 and 2009, there more than 32,000 earthquakes in the United States, according to the U.S. Geological Survey. The deadly earthquakes in Chile, Haiti and the California-Mexico Border in 2010 illustrated how damaging a single event can be, and emphasized the importance of taking proactive measures to protect lives and property.[1]

So, what can you do to protect yourself, your home or business and its contents from earthquakes? This guide contains information to help you better understand the areas of your home or business that are more vulnerable to earthquake damage and offers solutions to minimize the risk of property losses.

Key topics covered include:

- The relationship between your home or business and an earthquake;
- Key areas of your home or business that are especially susceptible to damage;
- Ways you reduce damage to your home or business and belongings; and,
- What you can do to protect yourself and your family.

The information and suggestions presented in this brochure range from simple weekend tasks that require basic carpentry skills to involved projects that may require professional assistance. Before starting on any activity, make sure you are comfortable with the required skill level. If you are uncertain, contact a professional engineer, architect or building contractor.

Earthquakes and Your Home or Business

Earthquakes: What, When, Where and Why?

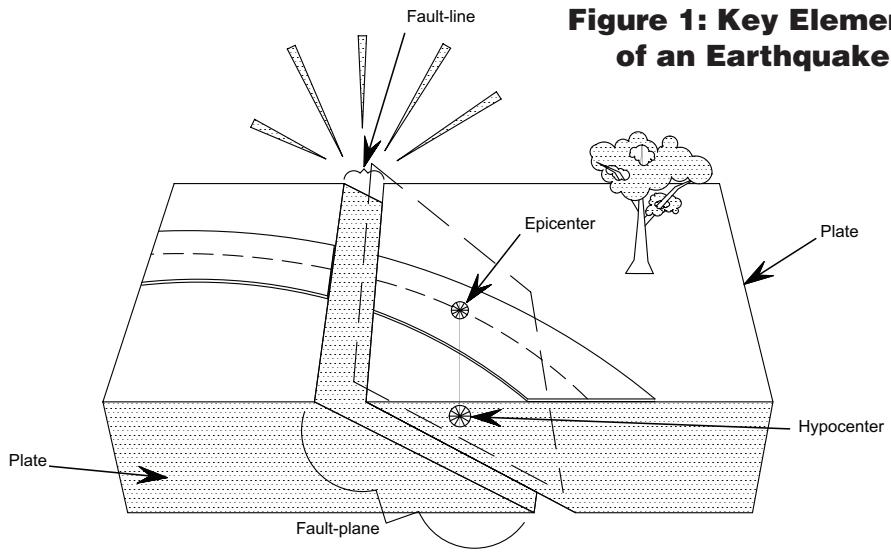
Did you know that the ground beneath you is constantly moving? The earth's surface is broken into many different *plates*, which float on top of the earth's quasi-liquid mantle. Typically, one plate interacts with another by colliding and sliding past each other, or pushing one underneath the other. These areas along which plates interact are known as geological *faults*.

As plates move over time, the edge of one plate often catches itself on another, forcing that portion of the fault to remain motionless while stress builds. Eventually, the fault reaches a breaking point and slips suddenly, sometimes by yards or sometimes only by inches. This sudden vertical or lateral (sideways) movement releases seismic waves, which we feel as an *earthquake*. The point where the fault first slips is located deep within the earth and is called the *hypocenter*. Directly above that, on the earth's surface, is the *epicenter*. **Figure 1** highlights the key elements of an earthquake.

In the United States, the most active faults are along the West Coast—the most famous being the San Andreas Fault system, which runs through the state of California. This fault system separates the North American Plate from the Pacific Plate. Despite the large number of earthquakes associated with this and other plate boundaries, earthquakes are not restricted to just the plate edges. Approximately five percent of earthquakes occur within the central part of a plate. These earthquakes are known as *intraplate earthquakes*, and have occurred in recent history in Charleston, and the Mississippi Valley near New Madrid, Missouri.

The maps presented in **Figure 2** show areas where the U.S. Geological Survey (USGS) has identified the greatest risks for earthquake ground motion based on known faults. The actual risk of damage depends on many things, including the soil at the building site and the type of building and structural system used. When engineers use ground motion information, such as that available from the USGS, to design residential and short, stiff commercial buildings, they typically begin to specifically incorporate earthquake

Figure 1: Key Elements of an Earthquake

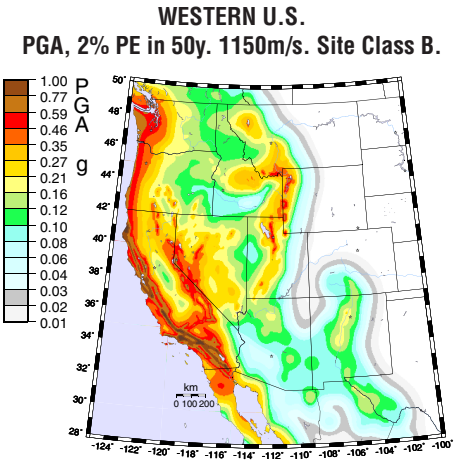


risks into the design in areas where the Peak Ground Acceleration, as shown in Figure 2, is 0.16 or greater.

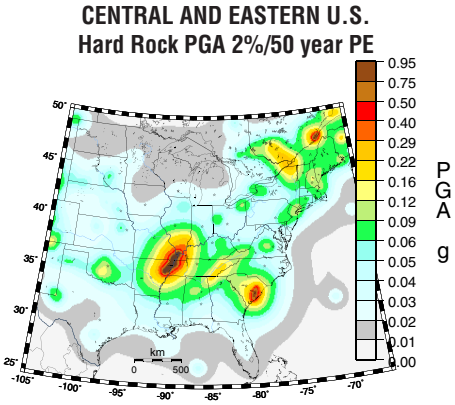
Measuring an Earthquake's Size

Seismologists estimate the size, or *magnitude*, of an earthquake in several different ways. The *Richter* scale measures the size of the earthquake's waves (amplitude); whereas, the *moment magnitude* scale estimates the total energy released during the slip of a fault. Because the moment magnitude scale is more objective than the Richter scale, it is now more commonly used. **Figure 3** shows different levels of earthquakes and their corresponding moment magnitudes (Mw).

Figure 2: Peak Ground Acceleration

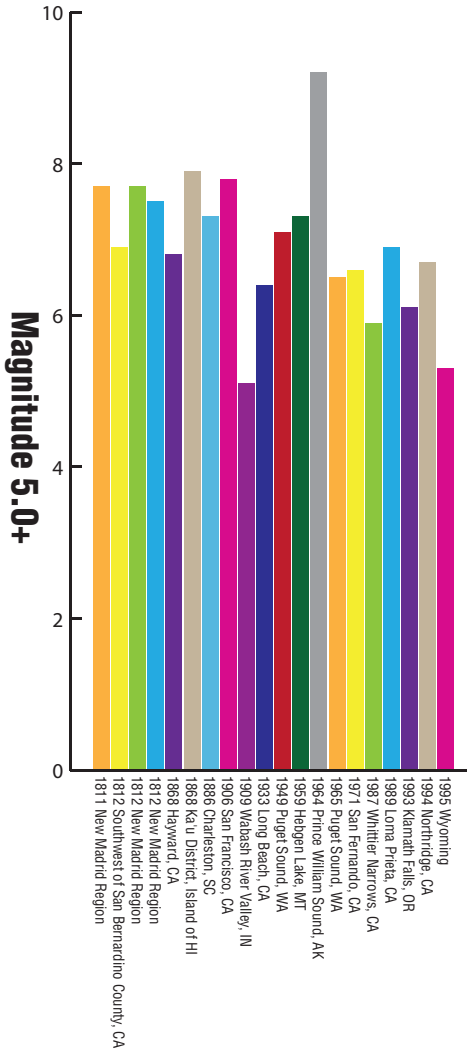


Source: U.S. Geological Survey, May 2010



Source: U.S. Geological Survey, April 2009

Figure 3: 20 Memorable U.S. Earthquakes



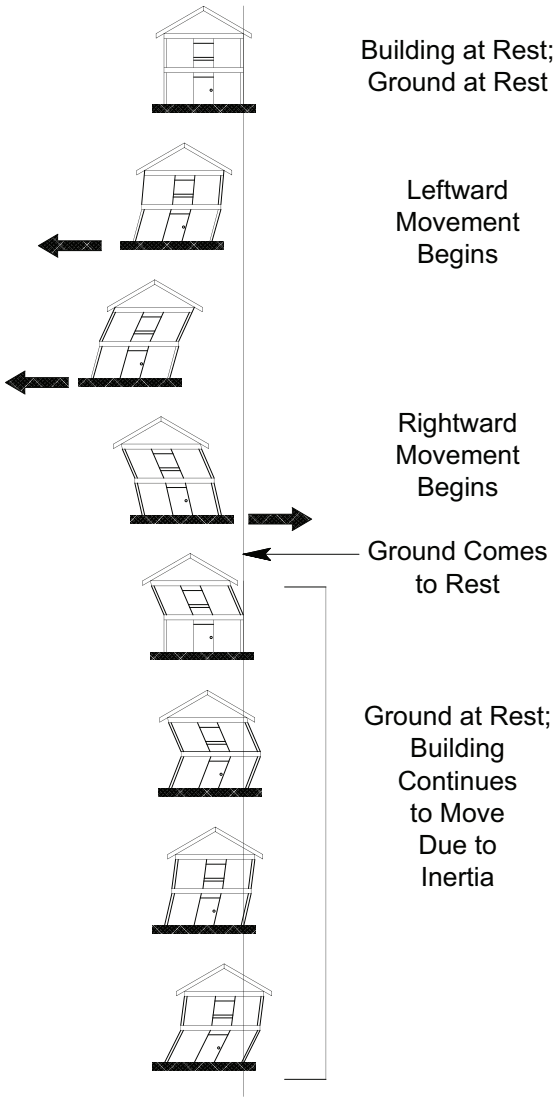
What You Feel and Why You Feel It

The amount of movement you experience during an earthquake doesn't depend just upon its magnitude. Where you're located in relation to the earthquake's epicenter also has an effect. The farther away you are, the less shaking you feel, since the seismic waves lose energy as they travel through the earth. Earthquake waves are similar to waves generated by a drop of water hitting the surface of a pond. As the circular waves travel away from the impact, they lose energy and reduce in size and frequency. In time, they disappear altogether.

Also, the kind of soil underneath and around your home or business plays a large role in how much of the earthquake you experience. Unlike water, soil is not uniform throughout. The soil type can have a dramatic effect on the way seismic waves travel through the earth. For instance softer, less compact soil can actually increase the forces. More stable soils, such as bedrock or compacted fill, dissipate an earthquake's energy more quickly.

Three major factors – an earthquake's magnitude, your proximity to the epicenter and the condition of the soil around you – determine the amount of shaking you feel. The *Modified Mercalli Intensity* scale measures this intensity by evaluating the earthquake's effect on you and your home or business.

Figure 4: Your Structure in an Earthquake



What Your Home or Business Experiences

Imagine that a strong earthquake strikes where you live. Loose items fall and break. Cabinets and bookcases tip over, blocking exits. Dust billows everywhere. Gas and water lines rupture, and phone and electrical service are interrupted for days. Your home or business may collapse, slide off its foundation or simply come apart at the seams. How well your property performs may be partly determined by the building codes in place at the time of construction. Research by the Institute for Business & Home Safety found that building codes in many Midwestern states are inadequate for seismic protection or do not exist. The earthquakes in Chile and Haiti in 2010 showed the importance of strong building codes. The death toll and level of destruction were minimized in Chile due to the adoption and enforcement of modern codes, whereas Haiti did not have building codes in place.

Figure 4 Illustrates how your home or business reacts in an earthquake. Because it is not able to move in sync with the surrounding ground, your home or business and its contents can experience substantial damage. One important trait of typical home configurations in North America is that we like to have more and larger windows and doors on the first floor than on the other floors. This results in what is called a soft story, where damage to the house is concentrated on the first floor. This may not be as common in modern commercial construction.

What You Can Do

You can protect your property by modifying it, or retrofitting it, in two different ways:

Nonstructural retrofits protect the contents against damage with little cost and effort.

Examples of retrofits include:

- Securing water heaters, large appliances, bookcases, pictures and bulletin boards;
- Latching cabinet doors; and
- Using safety film on windows.

To complete these improvements simply follow the instructions included in this guide. In most cases, you won't need a building permit. It's a good idea, however, to contact your local building department to make sure.

Structural retrofits strengthen the structure or skeleton so it can better withstand the force of an earthquake. The skeleton is made up of many different parts, or *components*, which must work together in order to resist an earthquake.

Modifications to the structure tend to be more involved and often require the expertise of a registered design professional (engineer, architect or building contractor) and your local building department's approval. Use this brochure to identify potential problem areas. If you have any questions or concerns about what you see, contact a professional engineer or architect.

Nonstructural Retrofits

In this section, you will learn inexpensive and easy ways to protect yourself against some of the interior damage earthquakes can cause.

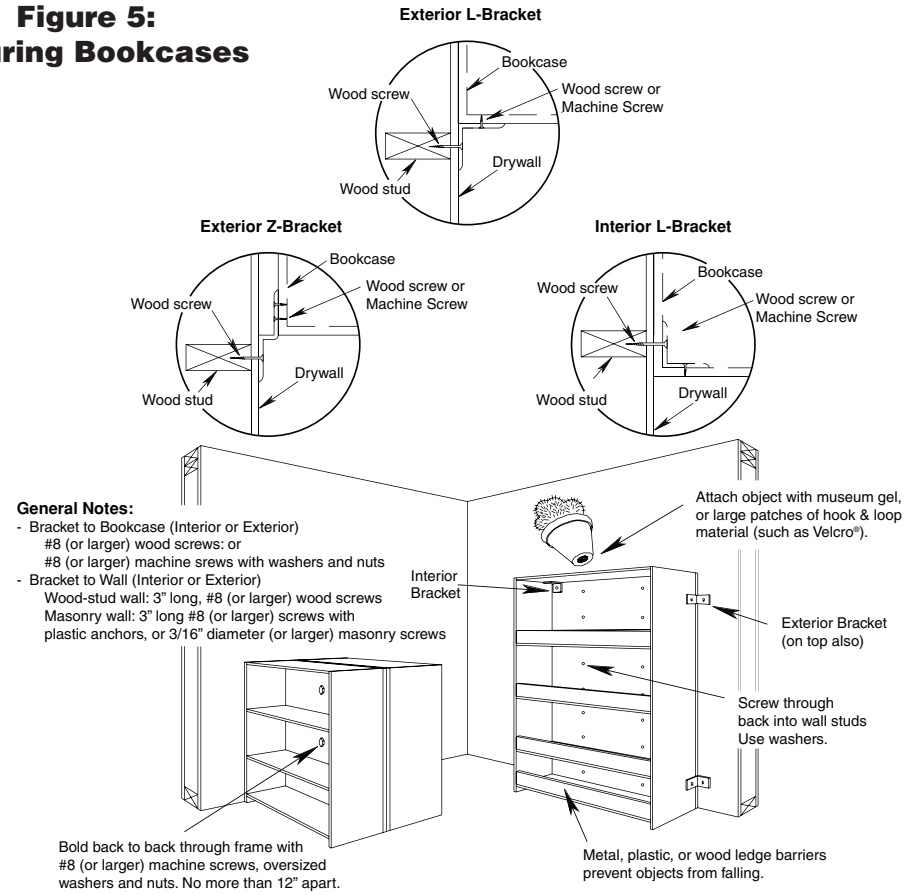
Start by looking for objects that could fall and break during an earthquake. Consider items such as water heaters, bookcases, wall-mounted televisions and light fixtures, as well as items that are difficult to replace because they have monetary or sentimental value. As you conduct your inspection, think about ways in which you can protect them from damage. If you have any questions about the changes you should make, contact a professional engineer, architect or contractor.

Bookcases

It's true that bookcases are great for storing books, toys and supplies. They can, however, shake and tip over in an earthquake, causing considerable damage or injury. For this reason, make sure all bookcases are securely fastened to nearby walls.

➢ One way to do this is to attach either L-brackets or Z-brackets or seismic straps to the bookcase and the wall after pre-drilling holes in each. Be sure to use a bracket that can accommodate the fasteners you are using. See **Figure 5** for details.

Figure 5: Securing Bookcases



Attaching the bracket or seismic strap to the bookcase:

- For wooden bookcases, attach the bracket with #8 (or larger) woodscrews. The screw should be long enough to secure the bracket to the shelf without punching through and creating a sharp edge.

- For plastic and metal bookcases, use #8 (or larger) machine screws with washers and nuts to ensure that the bracket will stay in place. The screw should be long enough to accommodate the bracket, shelf, washer and nut.

- Make sure that the location that is chosen on the bookcase is strong enough to resist the significant forces the books will produce.

Attaching the bracket or seismic strap to the walls:

- For wood stud walls, use 3-inch long #8 (or larger) wood screws to attach each bracket to the wall. Locate screws in the wood studs, not just the wall sheathing to assure that they can properly hold the bookcase. Use a stud locator to find the best places.

- For stone or masonry walls, place plastic anchors in the holes before you screw in 3-inch long #8 (or larger) screws or consider using 3/16-inch diameter (or larger) masonry screws.

➢ For a bookcase with a solid back, you can pass screws directly through the back into the wall. Use washers to spread contact over a larger area between the screw and the bookcase. Make sure that the back of the bookcase is securely attached to the shelves. If you are working with a wood stud wall, use a stud locator to find the best locations for the 3-inch long #8 (or larger) wood screws. For a stone or masonry wall, use plastic anchors with the #8 (or larger) screws or use 3/16-inch diameter (or larger) masonry screws.

➢ You can prevent items on shelves from falling by installing ledge barriers made from strips of wood, metal or plastic. Cut them to fit the shelf and attach them with glue or mechanical fasteners. You can finish the barriers to match the shelves. See **Figure 5** for details.

➢ Place heavy items on lower shelves to reduce the tipping effect.

➢ You can stabilize bookcases that are not against walls by attaching them back-to-back with #8 (or larger) machine screws, oversize washers and nuts, as shown in **Figure 5**.

➢ Affix large, heavy items, such as plants and aquariums, and other breakables directly to the shelf to keep them from falling. You can apply hook and loop material (such as Velcro®) or museum gel (or museum wax) to secure these items. For added protection, use metal, plastic or wood ledge barriers. See **Figure 5** for details.

Necessary Tools and Materials

- L- or Z-brackets
- Fasteners
- Plastic anchors for masonry walls
- Variable speed drill and bits
- Screwdriver
- Stud locator
- Wood, Plastic or metal strips
- Paint or wood finish
- Hook and loop material (Velcro®) or museum gel/wax

Cabinets and Drawers

Like bookcases, cabinets can tip over and their doors can open, spilling their contents. Furthermore, the drawers, which sometimes have sharp edges, can slide out and hurt you, or cause injuries.

➢ To secure cabinets, do the following:

- Attach cabinets to the wall and floors using L-brackets or Z-brackets or seismic straps. Again, be sure to use brackets that can accommodate the diameter of the fasteners and that the fasteners are located in the studs of the wall. You should follow the specific directions given in **Figure 6** and in the "Bookcases" section for securing the bracket to the wall and cabinet.

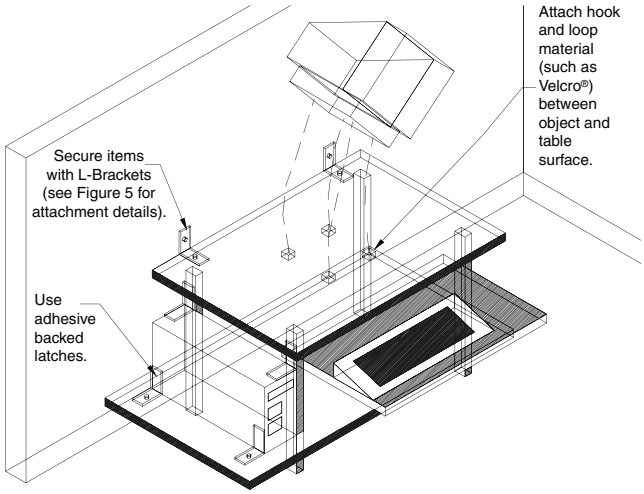
- You can fasten several units together to form a wider footprint using #8 (or larger) machine screws.

➢ Attach simple mechanical or self-locking latches to cabinet drawers so they cannot slide open.

➢ Install mechanical or self-locking latches to prevent cabinet doors from swinging open and spilling their contents. Your local hardware store has a large variety of latches, many of which are small, unobtrusive and easy to operate. See **Figure 6** for details.

➢ Most of us place heavy objects such as televisions, computers and stereos on top of cabinets, bookcases and tables. You should fasten these items down so they will not slide off during an earthquake. Several methods of attachment are shown in **Figure 7**.

Figure 7: Secure Cabinets and Drawers



Necessary Tools and Materials

- L- or Z-brackets
- Fasteners
- Door or drawer latches
- Plastic anchors for masonry walls
- Variable speed drill and bits
- Screwdriver
- Stud locator

Picture Frames and Bulletin Boards

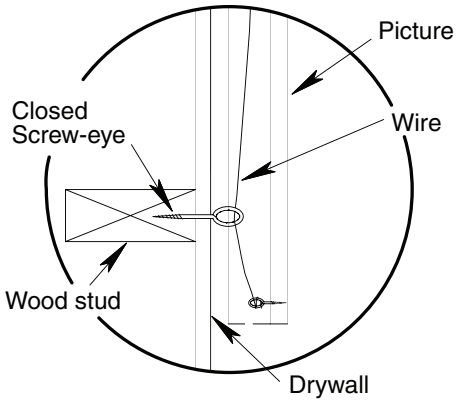
The photographs, bulletin boards and artwork you display add character to the surroundings. But these items can easily fall during an earthquake if they are not properly fastened to the wall. Follow these steps to secure these hanging items: :

➢ Use closed screw-eyes, instead of traditional picture hangers, for securing picture frames, bulletin boards and mirrors.

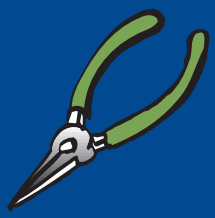
- Depending on the weight of the object and the screw-eye's maximum weight limit, screw one or more closed-screw eyes into wall studs. Use a stud finder to find the most secure location to attach them to the wall.
- Attach picture wire to one side of the frame, and thread the wire through the closed screw-eye, fastening it securely to the other side of the frame as shown in **Figure 8**.
- If you use an open screw-eye instead of a closed screw-eye, be sure to close it with pliers once you have hung the picture.

➢ Always mount heavy or sharp wall hangings away from areas where they could fall.

Figure 8: Secure Picture Frame to Wall



Necessary Tools and Materials



- Stud locator
- Screwdriver
- Variable speed drill and bits
- Screw-eyes
- Heavy picture wire
- Pliers

Ceiling Lights, Suspended Ceilings, and Hanging Fixtures

If they aren't well attached and supported, ceiling lights, suspended ceilings, and hanging fixtures, such as chandeliers and ceiling fans, can fall in an earthquake and seriously injure those below. Here are some ways to protect yourself:

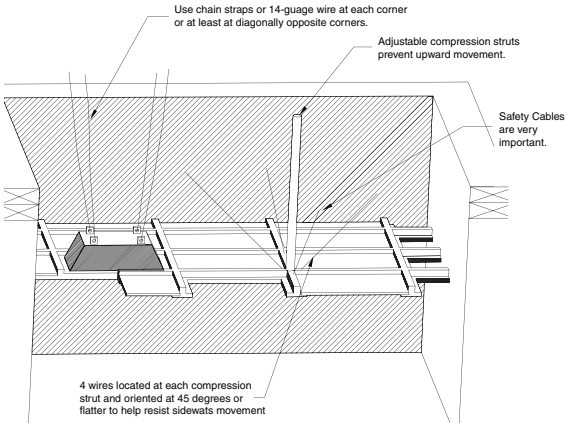
➢ Secure ceiling lights to supports using safety cables.

- Use a chain strap or a minimum 14-gauge wire to attach the light fixture to a nearby ceiling joist or support. Locate the support visually or use a stud locator. Be sure to leave the safety cables slack as shown in **Figure 9**; they should not support the weight of the lights under normal circumstances.
- If your ceiling light has a cover, keep it from falling during an earthquake by fastening it to the fixture itself or to the home's permanent structure.
- Pay special attention to fluorescent lights. Installing plastic sleeves over the fluorescent light tubes will keep the glass from scattering if they break. As an alternative, consider using Teflon® fluorescent lights, which are shatter-resistant.

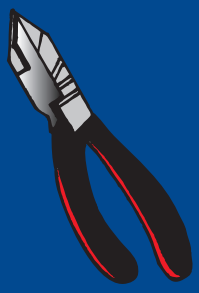
➢ Use safety cables every few feet to attach suspended or false ceilings to the structure:

- Use chain straps, plumber's strapping (metal strapping with holes) or heavy wire (minimum 14-gauge) to secure suspended or false ceilings as shown in **Figure 9**.

Figure 9: Secure suspended or false ceilings



Necessary Tools and Materials



- Safety cables, chain straps, heavy wire or plumber's strapping
- Fasteners
- Adjustable compression struts
- Screwdriver
- Variable speed drill and bits
- Stud locator
- Plastic sleeves for florescent lights
- Light covers

- Use screws, bolts or other appropriate fasteners to attach the safety cables to both the suspended ceiling and the permanent structure.

- You can prevent the ceiling panels from flying upward by installing adjustable compression struts. Contact your suspended ceiling's manufacturer for details. As shown in **Figure 9**, lateral bracing for the ceiling can be achieved by using four wires from the compression strut to the walls or ceiling joists at 45 degree angle or flatter.

➢ Make sure chandeliers, ceiling fans, other suspended fixtures, and hanging plants are safely secured to the permanent structure.

- Connect all suspended items to strong supports with safety cables capable of supporting each item's entire weight. Each cable should remain slack and should not support the item's weight under normal circumstances.

- Keep in mind that hanging items tend to sway easily. Make sure these objects will not collide with anything if they swing in an earthquake.

Windows and Doors

Windows and glass doors can break explosively in an earthquake, seriously injuring anyone nearby. One way to protect yourself and your family from broken glass is to apply safety film to windows and glass doors:

➢ Use a protective film (minimum thickness of 4 mils) on all types of glass, including tempered glass and annealed glass. You can buy it in rolls at your local hardware and home improvement stores, or contact the International Window Film Association for the nearest distributor. Be sure to install the film according to the manufacturer's instructions.

➢ As an alternative, consider professional installation.

Necessary Tools and Materials

- Coated wire cable or other strapping system
- Screwdriver
- Variable speed drill and bits
- Stud locator
- Screw-eyes
- Hook fasteners
- Flexible connectors
- Plastic anchors

Large Appliances

An earthquake can cause refrigerators, washing machines and other large appliances to slide or fall over. Heavy objects on wheels may roll if brakes or stops are not provided and locked. To secure these items:

➢ Anchor large appliances to walls using safety cables or straps. The restraint should be located in the mid- to upper-portion of the appliance.

Use the following method:

- Choose a screw-eye that is sized appropriately for the appliance. For example, use a 3/8-inch diameter screw-eye (or larger) for a refrigerator.
- For wood stud walls, use a stud locator to find the best wall location to install the screw-eye. For stone or masonry walls, place plastic anchors in the pre-drilled holes before you install the screw-eye.
- Connect coated wire cable to the screw-eye at one end and to a snap-hook fastener at the other end.
- Attach the cable to the appliance with the snap-hook fastener.

➢ Replace rigid water or gas connections on large appliances with flexible connectors.

- Check to see if your local building codes allow you to use flexible connectors and whether a professional must install them.

➢ Always lock the rollers of any large appliances or pieces of furniture.

Water Heaters

Water heaters can move or tip over in an earthquake and the broken water pipe can cause a flood, destroying ceilings, floors, walls, furniture, artwork and family photos. If your heater runs on flammable gas and the gas line breaks, the situation becomes far more serious.

In many areas of the country where earthquakes are common, local building codes may require that water heaters be laterally braced or strapped to resist seismic forces. Most hardware stores sell retrofit kits for different-sized water heaters. In addition, several generic restraint systems are available. **Before you decide on a retrofit method, check with your local building department and make sure that it is approved for use in your area or superior what is required by your local building code.**

➢ Secure water heaters (up to 50 gallons) to stud walls using the simple, generic method detailed in **Figures 10 through 12**, or investigate the option illustrated in **FEMA 232 Home Builders' Guide to Seismic Resistance Design and Construction.**

- You can anchor the water heater using items that are readily available from the local hardware store.
- To begin: fasten two 2 x 4 wood blocking strips to the nearby wall - one at a height within the upper one-third of the water heater and the other within the lower one-third of the water heater. The lower 2 x 4 should be at least four inches above the water heater control. If you are working with a wood or metal stud wall, attach the blocking directly to the studs. Use a stud locator to find the studs.

- Fasten heavy-duty shelving brackets to the wood blocking. These brackets should fit snugly against the water heater.

- Wrap plumber's strapping (metal strapping with holes) around the heater and secure it to the brackets.

➢ Remember: Use flexible, not rigid, water and gas connectors and check with local building code officials to see if you must hire a licensed plumber to modify the connections.

➢ Make certain all adult and teenage family household members or employees know where to locate the gas shut-off valve and how to operate it.

Figure 10: Retrofitted Water Heater

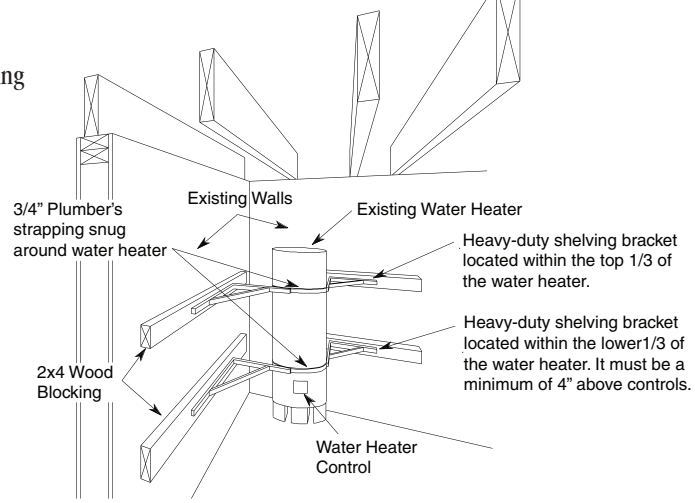
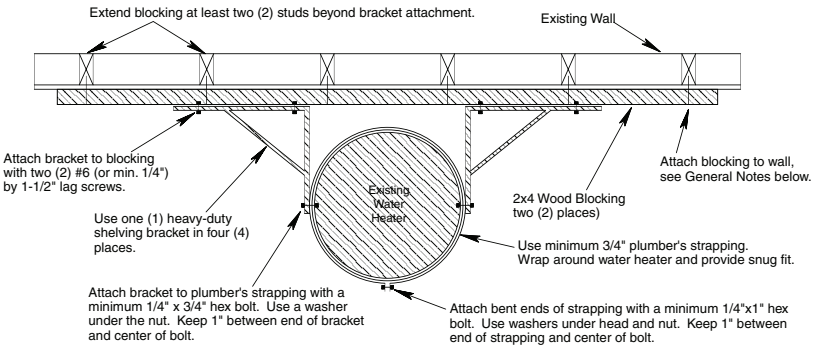


Figure 11: Straight Wall Configuration

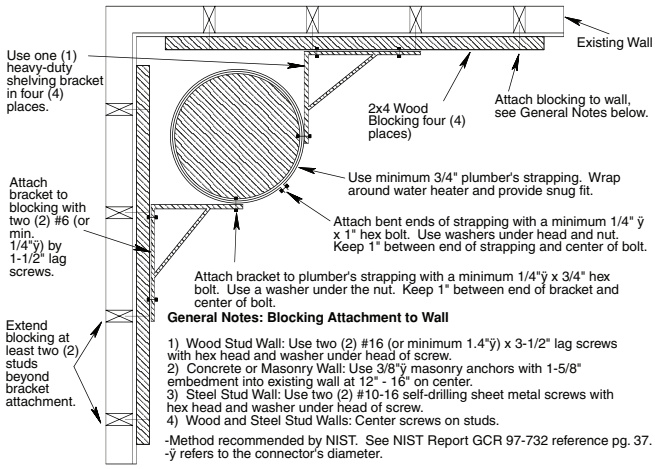


General Notes: Blocking Attachment to Wall

1) Wood Stud Wall: Use two (2) #16 (or minimum 1/4") x 3-1/2" lag screws with hex head and washer under head of screw.
2) Concrete or Masonry Wall: Use 3/8" masonry anchors with 1-5/8" embedment into existing wall at 12" - 16" on center.
3) Steel Stud Wall: Use two (2) #10-16 self-drilling sheet metal screws with hex head and washer under head of screw.
4) Wood and Steel Stud Walls: Center screws on studs.

-Method recommended by NIST. See NIST Report GCR 97-732 reference pg. 37.
-ÿ refers to the connector's diameter.

Figure 12: Corner Wall Configuration



General Notes: Blocking Attachment to Wall

1) Wood Stud Wall: Use two (2) #16 (or minimum 1.4"ÿ) x 3-1/2" lag screws with hex head and washer under head of screw.
2) Concrete or Masonry Wall: Use 3/8"ÿ masonry anchors with 1-5/8" embedment into existing wall at 12" - 16" on center.
3) Steel Stud Wall: Use two (2) #10-16 self-drilling sheet metal screws with hex head and washer under head of screw.
4) Wood and Steel Stud Walls: Center screws on studs.

-Method recommended by NIST. See NIST Report GCR 97-732 reference pg. 37.
-ÿ refers to the connector's diameter.

Wall Mounted Flat Screen Television

Flat screen televisions are often bolted on a support bracket assembly that is in turn mounted on interior drywall finished walls. In many instances, the support bracket is firmly attached to only a single framing stud behind the drywall. In some cases, the bracket may be partially or exclusively anchored to the drywall. There is a good chance that any of these attachment methods will be inadequate when an earthquake strikes and these wall mounted televisions will fall off the wall in an earthquake.

The retrofit procedure outlined below focuses on the connection of the mounting bracket to the wall and distributes the weight of the television over at least two (2) framing studs behind the drywall. The wall framing stud can be either wood 2x members or light gauge steel studs spaced no more than 24" apart. The retrofit targets televisions with a unit weight of 110 lbs or less where the existing mounting bracket is not connected to two or more wall framing members. Heavy-duty support bracket systems are available that may be suitable for your television or for heavier sets. Nevertheless, make sure that they attach to more than one framing member and check to make sure that they have a building code product approval for your area. Then be sure that the heavy-duty bracket is installed according to the manufacturers' recommendations.

For wall mount brackets that you are only able to attach to a single wall stud, you can retrofit the attachment using items that are readily available from a local hardware store. Before you start retrofitting, confirm the following:

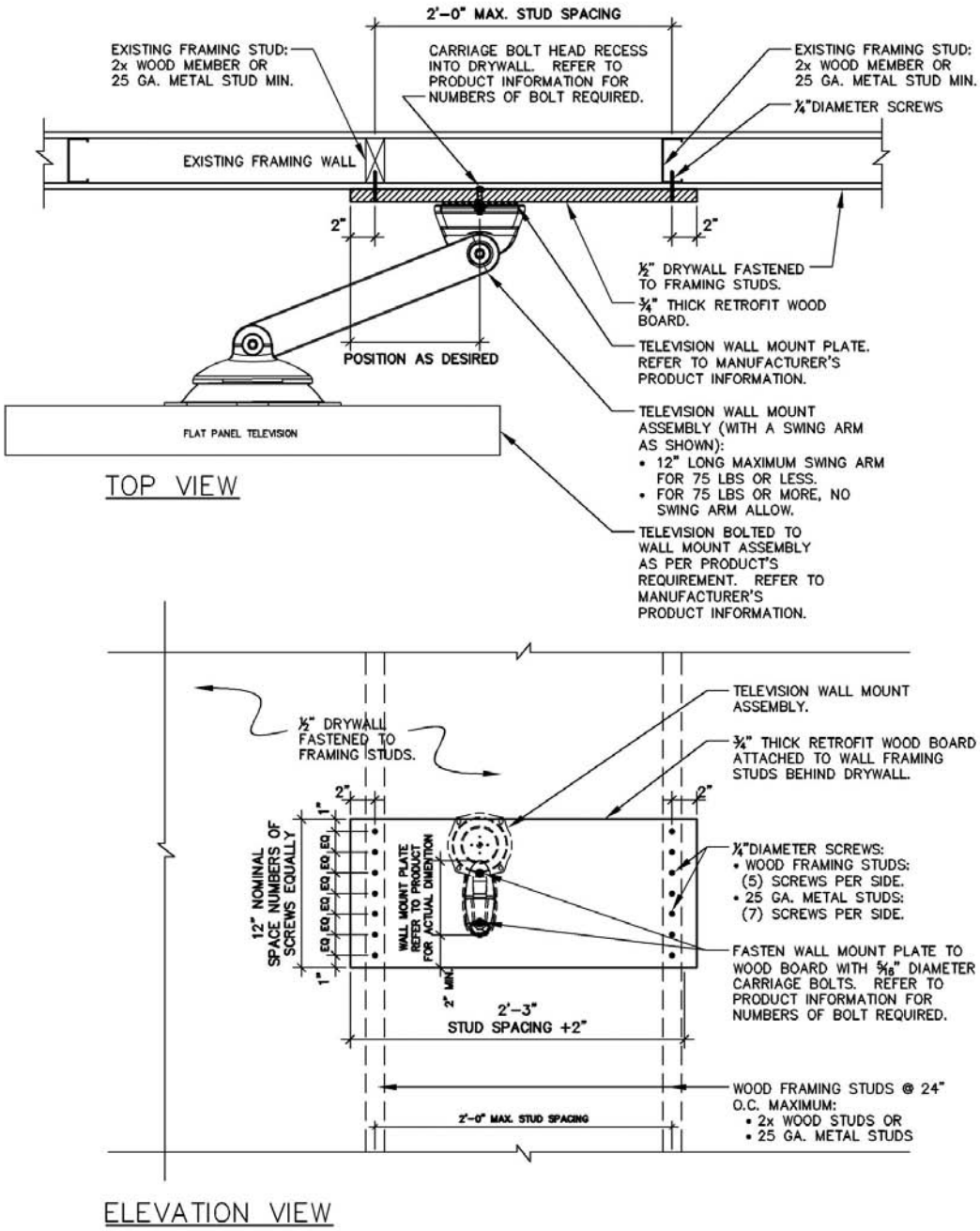
- The television must be less than 110 lbs, usually 60-inch diagonal screen size or smaller.
- Framing studs behind the drywall are not more than 24" o.c. apart.

If one or more of these conditions is not met; have the television professionally installed.

Material required for retrofitting:

- Stud finder
- A drill plus ⅛", ¼" and ⅜" diameter drill bits.
- ¾" thick x nominal 12" wide x 28" long (minimum) wood board (plywood or solid wood; NOT OSB; or particle board). Refer to Figure X prior to cutting the wood backing.
- For wood stud applications, use ten (10) #14 or ¼" diameter – 3-inch wood or deck screws. For metal stud applications, use (14) ¼"diameter x 2-inch self-tapping screws intended for sheet metal applications.
- (2) or (4) 5/16" diameter carriage bolts at least 1 inch (or longer depending on the thickness of the wall mount bracket) with flat washers and lock washers or lock nuts: depends on how many bolts are required for the wall mount bracket.

Figure 13: Television Wall Mount Retrofit



Procedure for retrofitting:

1. Cut a wood board, meeting the requirements listed above, to be the anchored to two (2) adjacent studs.

   a) Use a stud finder to locate two (2) framing studs where the television is to be mounted. Make sure the studs are no more than 24" apart. (Note: you may have to use a metal detector to find locations of metal studs)

   b) Measure the existing television wall mount plate. The width of the wood board should be at least two (2) inches greater than the vertical plate dimension, refer to Figure 13. The minimum nominal width of the wood board must be 12" (actual width 11-1/4" for solid wood board).

2. Pre-drill holes in the wood board.

   a) Draw straight lines perpendicular to the long side of the board near each end of the wood board so that the distance between these two lines is the spacing between the center lines of two framing studs previous located in the wall. Maintain a minimum 2" edge distance between each line and the edge of board.

   b) Position the television wall mount plate on the wood board at the desired location and outline the plate and locate the bolt holes. Use the 3/8" drill bit to create the bolt holes for the 5/16" diameter carriage bolts to secure the wall mount assembly to the wood board.

   c) Measure and locate wood screw installation holes along the two (2) lines near each end of wood board as shown Figure X. Use the ¼" drill bit to create holes in the board for the screws that are used to attach the board to the wall.

3. Locate the board on the wall.

   a. Position the wood board (with predrilled holes described in Step #2) vertically at the desired position and with the two lines near thee ends of the board aligned with the centers of the two wall studs.

   b. Mark locations where carriage bolt heads will come in contact with the drywall.

   c. Mark the locations of the screws that will be used to fasten the board to the wall studs.

   d. Pre-drill pilot holes for the screws using the 1/8" drill bit.

4. Pre-drill the holes on the wall and recess drywall to accommodate carriage bolt heads.

   a) Use the 1/8" diameter to create screw holes along two framing stud locations. There should be more resistance to the drill when it hits the wood or metal stud behind the drywall. All ten (10) holes [wood studs] or fourteen (14) holes [metal studs] must catch the framing stud behind the drywall, otherwise relocate the board.

b) Use a hard object with a small diameter to create a recess in drywall at the locations marked for the head of each carriage bolt.

5. Bolt the television wall mount plate to the wood board using the 5/16" diameter carriage bolts. Use an appropriately sized flat washer next to the metal wall mount plate followed by the lock washer and nut or the lock nut.

6. With only the television wall mount assembly bolted to the wood board, secure the wood board to the wall framing studs with all the screws (ten wood screws for wood stud walls and fourteen self tapping screws for metal stud walls).

7. After the wood board is secured to the wall, the television can be bolted onto the wall mount assembly following the manufacturer's recommendations.

Structural Retrofits

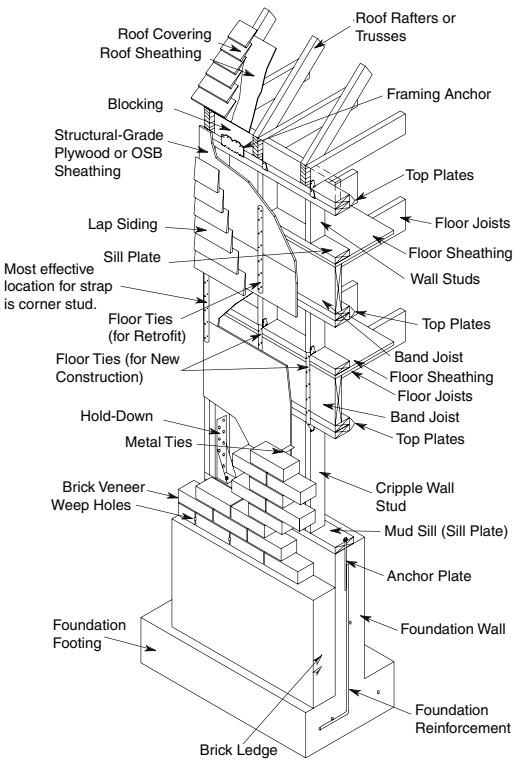
When an earthquake strikes, the structure is put to the test. The skeleton must absorb the earthquake's energy and provide a stable path to transfer the forces back into the ground. For this to happen, the structure must be *tied together*; that is, the home's roof should be tightly attached to the walls, and your walls should be fastened to each other, braced and anchored to a strong foundation. **Figure 14** shows how the components of a struture can be secured to each other, so that they function as a single unit during an earthquake, transferring the forces in the upper stories through a continuous load path to the foundation.

Keep in mind that the purpose of this section is to help you identify key areas of your structure that are susceptible to earthquake damage. If you are uncertain about what you see, or if you decide to have the work done, enlist the help of a professional architect, engineer, building contractor or your local building department.

Remember that an ideal time to inspect and retrofit a building is when you are making a significant change to your home or business such as adding on a room, remodeling, or re-siding the exterior. In either case, it is important that your work conforms to local building code requirements. Although the existing portion of your building may not need to be upgraded to current code requirements, now may be a good time to do so. This is also a good time to consider upgrading your home to comply with the latest building codes. Check with your local building department to see what permits, if any, are required and to become more familiar with the local code requirements. Even if your area doesn't follow a building code, implementing the seismic provisions of the International Residential Code during a major renovation is a good way to protect your home against earthquake damage. Contact your local building code official to find out what is required for your project.

As discussed earlier, the lower floors of houses in North America are typically relatively soft in the lower stories and this is where most of the damage to houses occurs. Therefore, the best return on the investment of retrofit efforts is found by addressing the lower portions of the house first. Therefore, the most important improvements to focus on are those related to the foundation, cripple walls, and first-story walls of the house.

Figure 14: Typical Wood-frame House



Foundation Systems

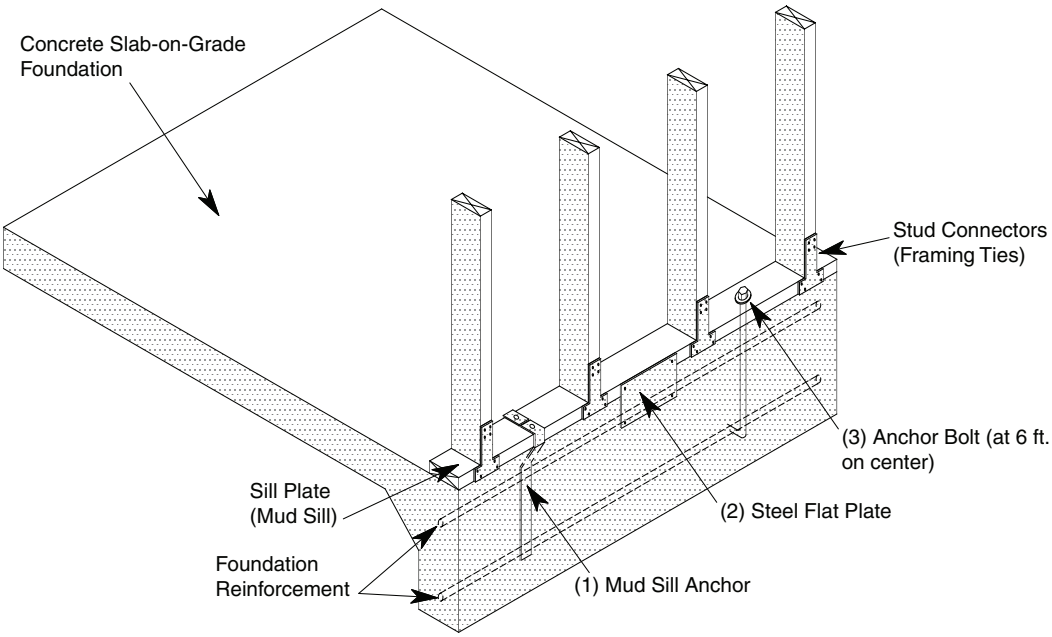
Earthquakes can create ground motion in any direction. During a quake, the foundation moves with the earth, but the rest of your home reacts more slowly due to its inertia. See **Figure 4** on page 5. This creates a tremendous amount of stress on the connections between the foundation and the remaining structure. This is the location where the forces experienced during an earthquake are the highest. If these connections are not strong enough, your home may slide or fall off its foundation. In fact, this is one of the most common and costly types of structural damage. Depending upon the foundation, however, this deficiency is often relatively easy to fix.

Slab-on-Grade Foundations

Slab-on-grade foundations are just that: concrete slabs that rest on the ground. In an earthquake-prone area, a home's wood- frame structure should be connected to the slab with either *anchor bolts* or other *steel connectors* (including steel plates and straps). **Figure 15** illustrates several types of connections.

Gaining access almost always requires that you remove an inside or outside finished wall, so consider doing this when remodeling your house. Your inspection should reveal minimum 1/2-inch diameter anchor bolts with washers and tightened nuts connecting the sill plate to the foundation. These bolts should be spaced no more than six feet apart. Make sure that the bolts are in good

Figure 15: Concrete Slab-on-Grade Foundation



Note: Three different methods of hold-down are presented here. However, only one system is usually required.

condition and show no rust, and that the nuts are tight. The concrete surrounding the bolt should be strong and free of any severe cracks (wider than the edge of a dime).

Steel plates often connect the home's sill plate to the foundation. Carefully inspect the plates along the outside perimeter of the structure. This may require removing the exterior cladding. Both the plates and fasteners should be in good condition. Look for rust or signs of poor workmanship. The plates should be no more than six feet apart. Next, take a close look at the foundation. Are there severe cracks (wider than the edge of a dime) in the concrete? There shouldn't be.

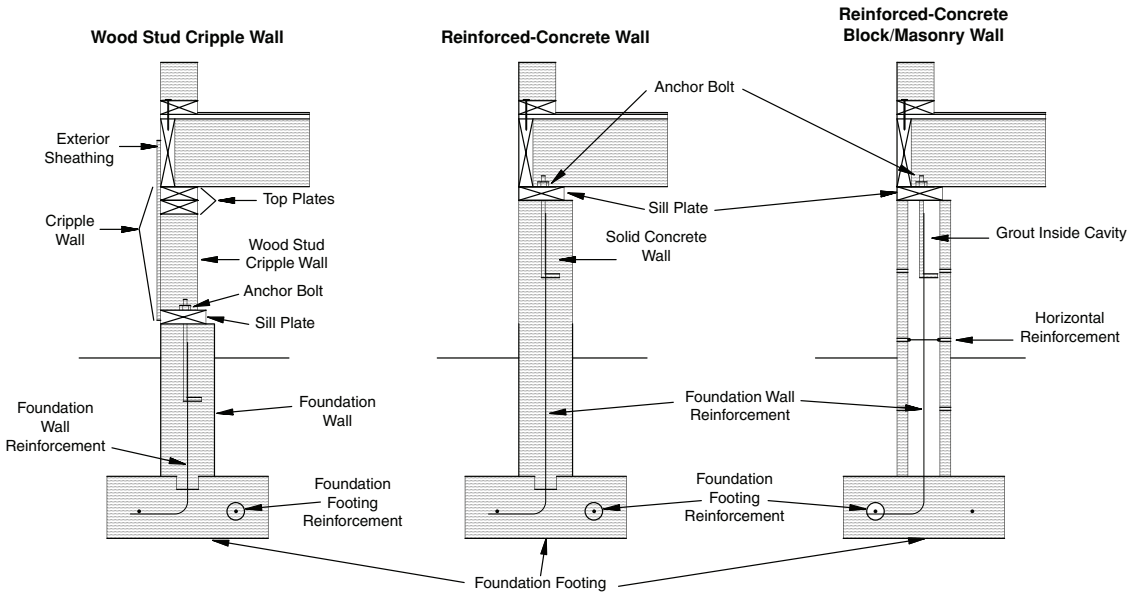
If the foundation is in poor condition or you must add additional anchorage, ask a professional engineer for help.

Crawl Space and Basement Foundations

A foundation with a *crawl space* or *basement* typically has enough room underneath the first floor so that you can inspect the foundation and the underside of the floor-framing members, or *joists*, as long as the space is unfinished. The main difference between a crawl space and a full basement is the amount of headroom available.

The walls that rise from the foundation footings to the first floor are called *foundation walls*. They are typically made with masonry blocks or concrete. In some cases, a short wood stud wall, or *cripple wall*, is positioned above ground between the top of the concrete or masonry foundation wall and the first floor. Cross sections of the three basic types of wall systems are highlighted in **Figure 16**.

Figure 16: Three Types of Foundation Walls



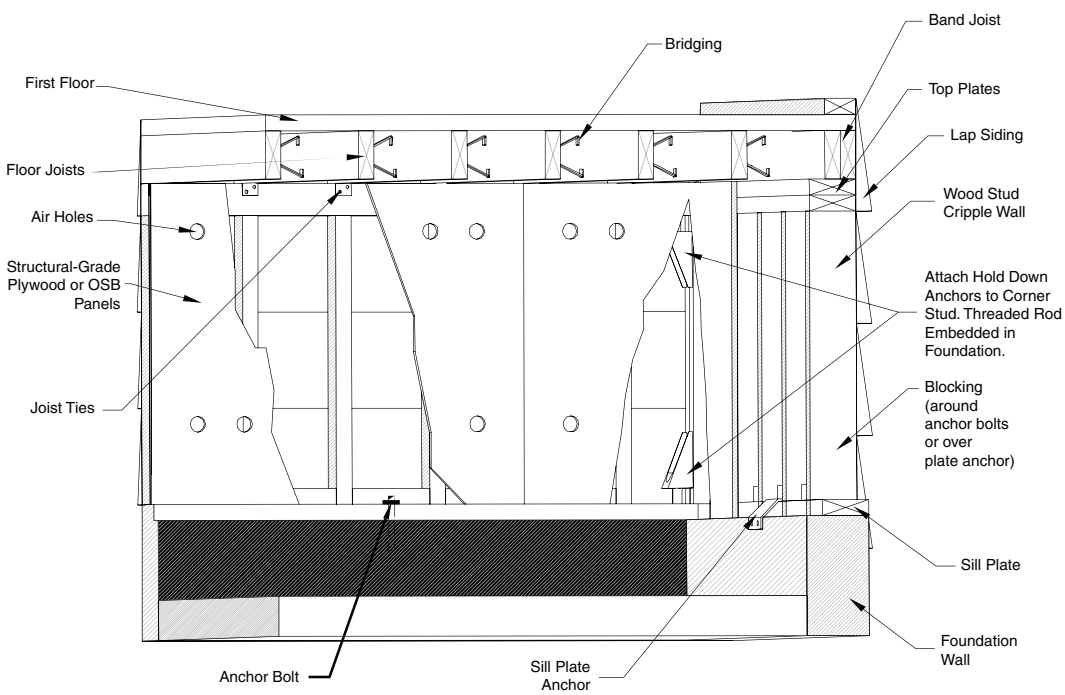
Connections

➢ Steel plates or minimum 1/2-inch diameter anchor bolts should connect the wood-framing sill plate to the concrete or masonry wall. These connections should be spaced no more than six feet apart. All components should be undamaged and rust free. Also, examine the overall condition of the foundation wall. Make sure you don't see any severe cracks (wider than the edge of a dime) in the masonry or concrete. If a wood cripple wall is present, it should show no evidence of termites or decay.

➢ If the foundation wall needs repair, or you need to add additional anchorage, check with a professional engineer for a suitable retrofit method.

➢ Ideally, a direct tie between the corner stud of the first floor wall will be made to the foundation. This is usually accomplished with a hold-down anchor attached to the stud and a rod extending from the hold-down anchor into the foundation, but straps are also used. If cripple walls are used, the tie is made between the first floor wall stud and the top of the stud in the cripple wall, and then between the bottom of the cripple wall stud and the foundation as shown in **Figure 17**.

Figure 17: Bracing Cripple Walls



Bracing

➢ For cripple walls, exterior lap siding alone cannot adequately resist the earthquake's lateral forces. Reliance on exterior lap siding has been one of the more frequent causes of failure of foundation walls. You may need to add interior bracing, if it is not already there, to prevent the cripple wall from collapsing in an earthquake:.

To add interior bracing:

- Nail 3/8-inch minimum structural-grade plywood or oriented strand board (OSB) sheathing to the inside of the wall using 8d nails spaced at 4-6 inches around the perimeter of the sheathing panels. Ideally, the entire wall length should be covered. However, if you have limited access, place sheathing in each corner of your home. While the sheathing panels can be oriented in any direction, take care to ensure that each edge is supported by a stud or solid blocking. **Figure 17** illustrates this method. If you have any questions about bracing weak cripple walls, contact a professional engineer.

➢ Adequately reinforced concrete foundation walls do not typically require additional bracing. Masonry foundation walls, however, may benefit from an upgrade. Because of the difficulty in evaluating masonry walls, consult a professional engineer.

Post-and-Pier Foundations

A structure can also be supported by a *post-and-pier* foundation (**Figure 18**). Large *beams* run under the home's floor *joists* and are held up by *posts*. Each post rests on a separate concrete footing or *pier*. Some post-and-pier foundations are hidden from view by a cripple wall that runs around the outside perimeter. This type of foundation is very susceptible to collapse during an earthquake. To better resist seismic forces, all of the foundation's components, including the beams, posts and piers, must be securely tied together.

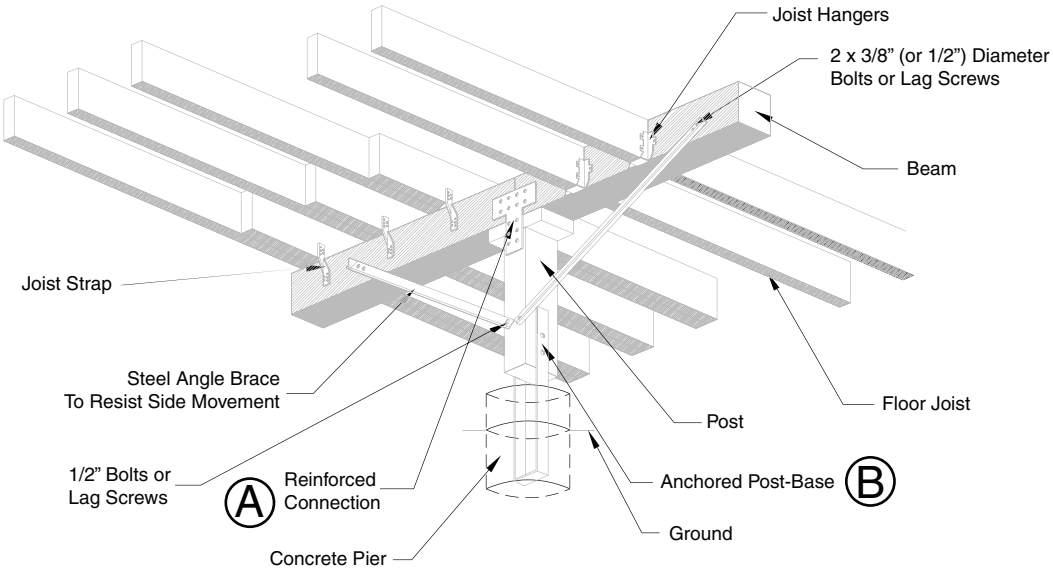
When inspecting the foundation for possible problems, carefully examine the way the components are connected together. The connection between the beam, and the post should be strong and without rust, rot or evidence of poor workmanship. One way to help your structure better withstand an earthquake is to have the connection reinforced with steel plates or with plywood or OSB connectors. Pre-manufactured metal straps or fixtures are available at most hardware stores ("A" in **Figure 18**). This reinforcement is especially important if the joint in the beam falls on top of the post. Knee braces, such as those shown In **Figure 18**, are also needed to prevent side sway of the post and to stiffen the house's resistance.

The other critical joint in this foundation lies between the post and the pier. Examine this area carefully. The post should be securely fastened to the pier, and all components should be well constructed, free of rust, severe cracks (anything wider than the edge of a dime) and rot. Most new construction will have the post attached to the block with a built-in metal fixture ("B" in **Figure 18**). In older construction, the post may simply rest on the top of the block. Reinforce the connection by nailing heavy-gauge straps onto at least two sides of the post and then bolting them into the concrete block.

Keep in mind that strong connections between the various components may not be enough - the earthquake's movement may still knock the structure off its foundation. That is why extra connections and lateral bracing may be necessary. If your home has an exterior cripple wall, bracing and anchoring it further can provide the necessary protection. Refer to the previous discussion on cripple wall foundations for inspection and retrofit techniques.

If your structure does not have an exterior cripple wall, lateral bracing and strong connections between the posts are critical. Simple toe nailing is not sufficient. Since the seismic evaluation of post-and-pier foundations is complex, you should consult a registered design professional.

Figure 18: Post-and-Pier Foundation



Floor Systems

An earthquake exposes the floor to substantial forces that can distort and damage the floor system, jeopardizing the strength of your home. The floor system typically consists of *floor joists*, *floor sheathing* and *band joists*, which are located along the floor's perimeter (**Figure 19**).

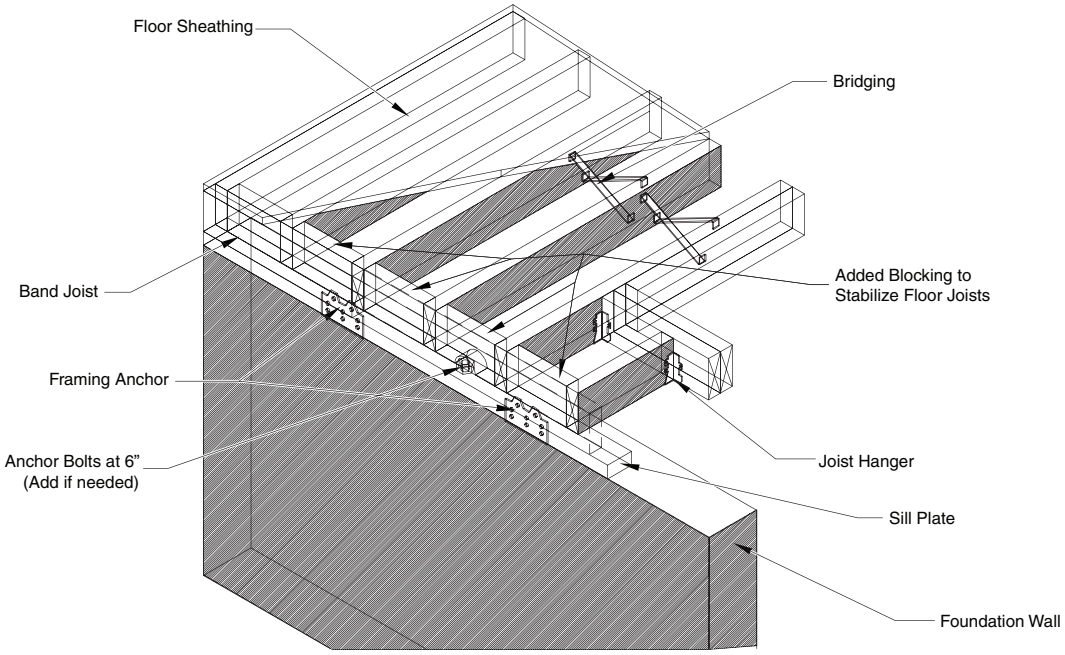
If you have access to the underside of your floor, make sure that your floor system is tied together and that the sub-floor is securely connected to the underlying floor joists. To reduce the possibility of rotation in an earthquake, each joist should be nailed to a band joist. *Blocking or bridging* can also easily be placed between joists to keep them from falling over. The forces absorbed by the band joist or blocking must, in turn, be transferred to the foundation. Secure this connection by using metal ties or framing anchors. Finally, make sure you do not find any evidence of poor workmanship, rust or decay.

It may be difficult for you to access these areas. Often, the best time to evaluate your floor system is when you are planning to remodel. If your inspection reveals any problems, consult a professional engineer for the best way to retrofit your floor system.

Wall Systems

During an earthquake, the walls in your home, especially the exterior walls, play an important role in preventing it from collapsing. The walls along with the floors and roof create a box. As the ground shakes, the floors and roof sway back and forth, while the walls in between try to stop your structure from deforming too far, and the walls are the path which transfers the forces from the roof and upper floors to the foundation. To do their job, your walls must be strong and securely tied to the roof, floor and foundation.

Figure 19: Recommended Floor System



Wood-framed Walls

Traditionally, the exterior walls of wood-frame houses are supported with wood studs attached to structural-grade plywood, Oriented Strand Board (OSB) or diagonal wood sheathing. To protect the exterior walls from the elements, they are covered with lap siding, stucco, stone or brick veneer. In order for this system to resist damage from earthquake forces, it must be well designed with the appropriate hardware in place to ensure a strong connection between all of the elements. See **Figure 14** (see page 18) for details. Most single-family houses do not have the hold-down anchors that are shown in the corner of the wall system in **Figure 14**. Adding these connectors to the corners improves the performance significantly. In a study for the FEMA 232 document, adding these connectors is estimated to reduce the probable damage by one full level (i.e., from collapse to moderate damage, or from moderate to immediate occupancy).

Also, consider the number, size and location of the windows and doors, including garage doors. This is the cause of the typically weak or soft story response. People tend to like large openings on the first floor of houses for views and easy access to the outdoors. However, too many windows and doors can weaken your walls and lead to possible collapse in an earthquake. Imagine a closed box with several openings: it will cave in much easier than one with no openings.

Unlike wood siding, brick and stone veneers require special attention because of their weight. During an earthquake, this heavy veneer can fall off, causing injury and significant damage, or more importantly, the weight of the veneer can cause the walls of the house to fail. It is very important that these veneers be *tied* to the wood-frames behind them with simple metal ties secured in the mortar, and the walls themselves be constructed strong and stiff enough to support the forces that result. Sound building practices usually provide sufficient ties, but the spacing should be checked when possible.

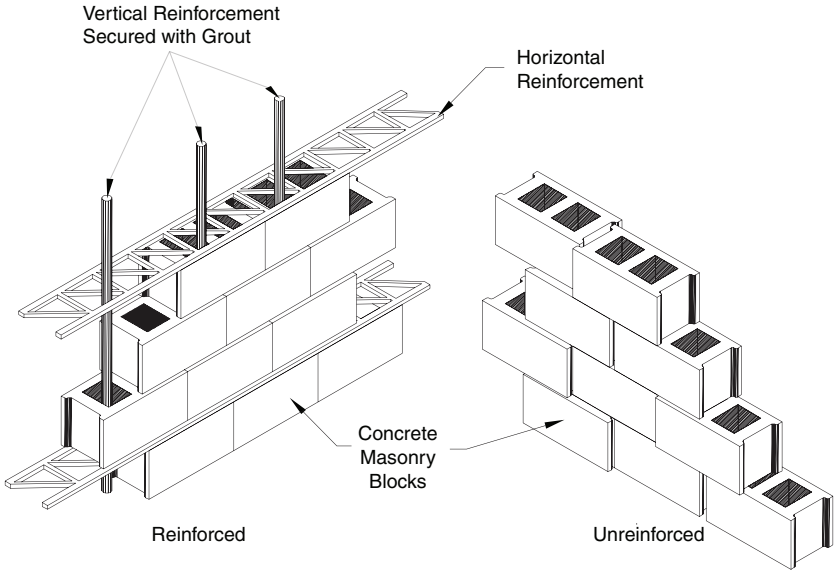
Because it is difficult to access these areas, the best time to inspect is while you are remodeling or adding on. If you have any concerns about your exterior walls, openings or veneer, contact a registered design professional, who can determine well your walls can withstand an earthquake and recommend necessary retrofit measures. Also, if only part of the house can be upgraded, the focus on upgrading the lower floors, if only part of the house can be improved. should be to upgrade the lower floors.

Unreinforced Masonry Walls

If your walls are made entirely of brick, stone, clay tile, concrete block or adobe, they could be susceptible to earthquake damage. In some newer masonry homes, these types of walls are often reinforced with steel bars grouted inside the walls. If the walls are reinforced and well anchored to the foundations, floors and roofs, they can usually withstand an earthquake. But masonry that is in poor condition, unreinforced or not securely tied to the rest of the structure, has the potential to collapse. **Figure 20** highlights the differences between reinforced and unreinforced concrete block masonry walls.

A proper retrofit generally requires anchorage designed specifically for earthquakes. Since evaluating structural masonry walls for general soundness and specific seismic features is quite complex, it would be best to consult a professional engineer.

Figure 20:
The Wall System



Roof Systems

For your structure to adequately resist the force of an earthquake, the roof structure must function like the top of a box, keeping the walls tied together and preventing your home from coming apart at the seams. The typical rood system includes a *roof covering, roof sheathing* and supporting *roof frame.*

Start by inspecting your roof covering - it should be in good condition with no evidence of excessive wear and tear. Nonstructural lightweight coverings, such as wood or asphalt shingles, usually perform well during an earthquake. Tile and slate coverings, which are heavy can add stress to the structure, tend to tax your entire earthquake-resisting system and are also susceptible to sliding or falling off the roof during an earthquake.

Next, consider what lies beneath the roof covering - the roof sheathing. Both plywood and OSB roof sheathing give the roof strength regardless of the roof style. Roofs fully sheathed with structural grade plywood or OSB tend to provide the greatest stability to the overall structure.

Horizontal board sheathing is not as earthquake resistant as plywood and OSB sheathing, but may be adequate in smaller homes. Consult a registered design professional for more specific information. Also, keep in mind that large dormers, skylight openings, and any other features that interrupt the sheathing can weaken your roof structure.

Remember: sheathing can only do so much. You must also consider the roof system's framing - the *trusses* or *rafters* - that supports the roof covering and sheathing. Similar to floor systems, roof-framing systems can rotate or fall over when your home starts to move in an earthquake. To prevent this, blocking can be placed between the rafters or trusses where they rest on the wall. Blocking is shown in **Figure 21**. Vents can be drilled into the blocking to provide attic ventilation. Metal strap connectors or properly placed toe-nailing ensure that the blocking is adequately connected to the wall and rafters.

You may not be able to thoroughly examine your roofing system due to limited access. The best time for a complete inspection is just before you re-roof. If you have any concerns about your roof's covering, sheathing, openings, or framing members, talk to a registered design professional or qualified roofing contractor.

Unreinforced Chimneys

Unless specifically designed and reinforced for lateral forces, brick or stone chimneys often fail and/or topple during an earthquake, causing serious damage and injury. Usually, only the top portion of the chimney breaks apart during an earthquake; however,, in some cases the entire chimney peels away from the side of the structure.

Inspect or hire someone to inspect the top of your chimney to be sure it is free of severe cracks (anything wider than the edge of a dime). Take a close look at the mortar between the bricks. The mortar should not scrape away easily with a metal tool. Even if your chimney is in good condition, it may still be at risk, especially if it is tall and slender. Some chimneys have metal straps that hold them to the side of the home. Carefully inspect these fastenings. They should be in good condition with not evidence of poor workmanship or rust.

If you are uncertain about what you see, consult with a registered design professional. The engineer may recommend adding a brace between the top portion of the chimney and the roof. You may also need to use metal straps at several points to anchor the chimney to your structure as shown in **Figure 22** (see page 24).

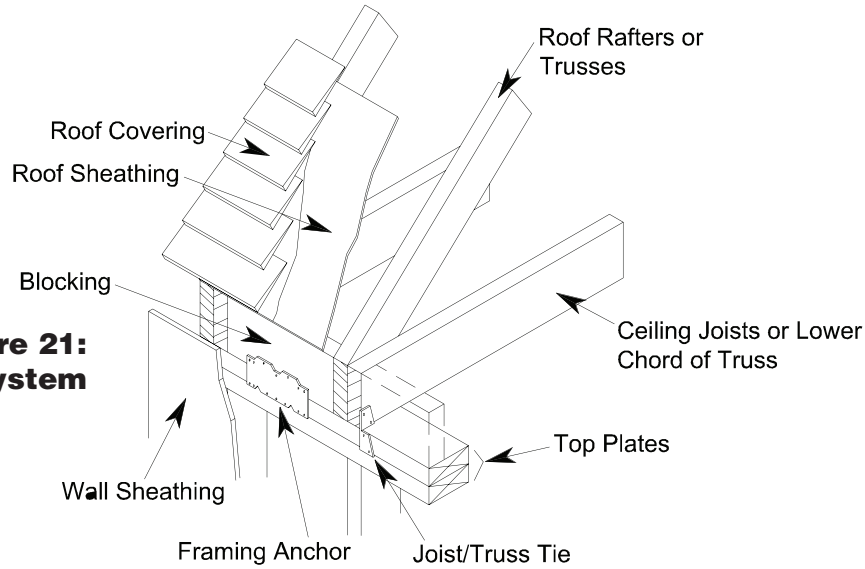


Figure 21: The Roof System

Garages

Garages are particularly vulnerable to earthquake damage. The situation becomes especially serious if the large garage door opening removes almost an entire side of the box configuration and requires the remaining narrow walls on either side to support the roof and extra rooms. If these walls are not carefully designed to handle the situation, the entire structure may collapse when an earthquake strikes.

Strengthening the narrow garage walls generally requires engineering details, such as specially detailed plywood panels, steel bracing or a steel frame. If the other three walls are to be used to resist the torsion response, the ceiling, floor above, and/or roof structure needs to be designed to transfer the loads from the front to the sides and back walls. A registered design professional can help you decide what will work best for your structure.

Structural changes that increase the risk of earthquake damage include:

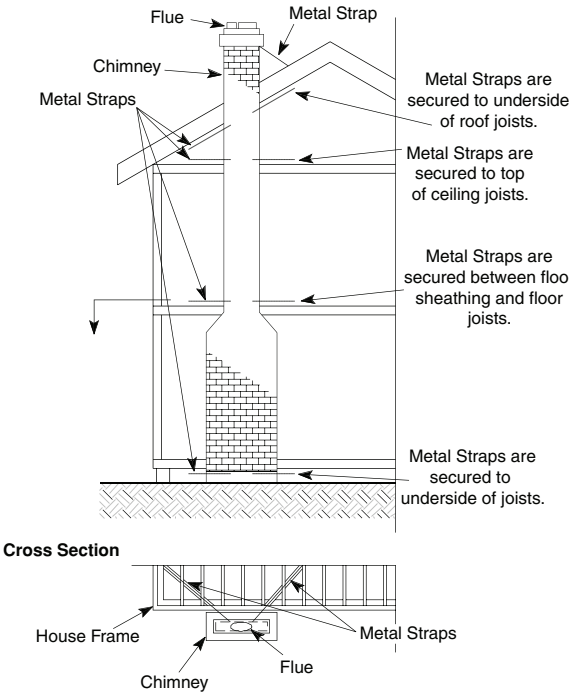
- Replacing large portions of walls with windows or glass doors;
- Adding large skylights or additional stories;
- Opening large portions of existing floors; or
- Additions that create an "L" configuration.

Room Additions

If you've put on an addition or made other modifications in the past, you may have unknowingly weakened your structure's earthquake resistance. Sometimes, structures that were originally very simple and structurally sound undergo changes that make them bigger or larger or more complex, and consequently fancier, also more prone to earthquake damage. Examples of weakening include removal of walls (or portions), large openings in roofs for skylights, or added weight due to added second or third stories.

If you are planning to make major changes to the structure of your house, or if you suspect existing features lack good engineering details, consult a professional engineer.

Figure 22:
How to Reinforce a Chimney



Note: (1) Wood blocking should be added to joists underneath metal straps.

Suggested Order of Priority

1. Anchoring the structure to the foundation:
   - locate 1/2-inch bolts every 4-6 ft along foundation;
   - add hold-down anchors in the corners of the building.

2. Strengthening cripple walls
   - Add hold-down anchors that tie cripple wall corner studs to foundation and first floor studs in the corners of the building;
   - Attach the floor above to the top plate using either metal clips or properly installed toe nails;
   - Sheath the inside (and outside if possible) with 3/8 inch plywood or OSB that is nailed to the top plate and mud sill. The nails should be 8d minimum and spaced at 4-6 inches on center around the perimeter of each panel of sheathing.

3. Anchoring the first floor walls:
   - Add hold downs to the corner studs of the building that tie the stud to the foundation or cripple wall stud below;
   - Add connections between the base of the walls to the floor system (16d nails at 16 inches on center into floor framing not just sheathing);
   - Increase the density of nailing for the plywood or OSB sheathing (not closer than 3 - 4 inches on center).

4. Strengthening first floor:
   - Add blocking between each floor joist at the ends of the joists and interior bearing points;
   - Strengthen the connections between the joists and the mud sill or top plate of the cripple wall.

5. Add inter-story ties (straps) between the first floor and second floor or higher floors. (Make sure that the straps are nailed to studs and not just the sheathing)

6. Strengthening connections between the roof and top floor walls:
   - Add blocking between roof joists;
   - Nail roof sheathing to the blocking and the blocking to the top plate of the wall;
   - Drill holes, if necessary, in blocking to provide attic ventilation;
   - Brace gable end framing for out of plane displacements.

7. Strengthening framing around large openings:
   - Add strapping and blocking;
   - Add hold-down connectors to the studs on each side of openings.

Secure Your Space Project List

This list of improvements divides the different retrofits into cost categories. The categories reflect the cost of each individual item. The cost will be slightly higher if you hire someone to complete the work. You or your contractor can tackle these projects one at a time, but remember, the more you do the stronger your structure becomes. When prioritizing, remember the biggest return on investment will come from strengthening the foundation and lower stories.

Category $ (<$300)

- Fasten bookcases and cabinets to nearby walls;
- Install latches on cabinet doors and drawers;
- Secure electronic equipment, artwork and other breakable items to the tops of bookcases and cabinets;
- Anchor large appliances to nearby walls;
- Secure wall-mounted televisions;
- Secure pictures and bulletin boards to walls;
- Attach safety cables to light fixtures, suspended ceilings and other hanging items;
- Apply safety film to windows and doors;
- Secure water heater to nearby wall.

Category $$ ($300-$1500)

- Reinforce cripple wall, including adding hold-down connectors in the corners of the house;
- Strengthen narrow walls on either side of garage opening;
- Anchor unreinforced chimneys.

Category $$$ (>$1500)

- Add anchor bolts or steel plates to foundation;
- Add hold-down anchors to tie first floor corner studs to foundation
- Secure post-and-pier foundation;
- Modify floor system;
- Strengthen wood-framed walls;
- Reinforce masonry walls;
- Retrofit roof system;
- Evaluate unique room additions.

Before, During and After: Be Completely Prepared

You will give yourself and your family a better chance of escaping harm during an earthquake by taking as many of the precautions outlined in this brochure as possible. But, these steps are only the beginning. To protect yourself as completely as possible, here are some added suggestions:

Before Earthquake Strikes:

- Teach everyone to drop to the floor, take cover under a desk or table, and hold on to the item covering them when an earthquake strikes. Remember the phrase: "Duck, Cover and Hold."
- Learn first aid and CPR.
- Put together an emergency kit that includes at least a three-day supply of drinking water and food that needs no refrigeration and, generally, no cooking; emergency cooking equipment, if required; a portable NOAA weather radio; first aid supplies and medications; basic tools, such as a wrench, a flashlight and gloves; portable lanterns and batteries; credit cards and cash; and important documents, including insurance policies.
- Know where your gas, electric and water main shut-off controls are and how to turn them off if there is a leak or electrical short. Make sure all adult and teenage members of your family know how to shut off each utility.
- Become familiar with your community's disaster preparedness plans and create a family plan. Know where the closest police, fire and emergency medical facilities are located.
- Plan an escape route from your home or business and neighborhood and designate an emergency meeting place for the family to reunite. Establish a contact point to communicate with concerned relatives.
- Periodically review your insurance policy with your insurance agent or company to make sure that, if you are the victim of a disaster, you have enough coverage to rebuild your home and life. The typical homeowner's insurance policy does not include earthquake coverage. If you are in an earthquake-prone area, you should consider purchasing earthquake insurance.

During an Earthquake:

- If you are indoors, "duck, cover and hold" until the shaking stops. Do not try and run out of a building – you may be hit by falling debris.
- If you are outdoors, move quickly and safely into the open, away from electrical lines, trees and buildings, and wait for the shaking to stop.
- If you are driving, carefully and slowly bring your vehicle to a stop at the side of the road away from traffic. Make sure that you do not stop on or under bridges. Do not stop under power lines or near roadway signs that might fall. Once the shaking has stopped, you can continue driving. Watch carefully for possible damage to the roadway.

After an Earthquake Strikes:

- Check for hazards, such as gas or water leaks and electrical shorts. Turn off damaged utilities. Have the fire department or gas and electric companies turn the utilities back on when the area is secured.
- Check for injuries and administer first aid as needed.
- Check your food and water supplies. Do not eat anything from open containers near shattered glass.
- Listen to and follow the advice and recommendations of local aid organizations, including the emergency management office, the fire department and the utility companies.
- Keep roads and phone lines clear for emergency use.
- Be prepared for aftershocks.

Checklist

How well will your home or business resist damage during a 3.0 earthquake? How about one that is a 6.0 or greater? Most structures typically will need some type of reinforcement to withstand a major earthquake. Here is a checklist that will help you focus on how to strengthen your home.

To answer some of these questions you may need to enter uncomfortable or small spaces. You may want to have an experienced inspector or professional engineer or architect check your home, instead. Whatever choice you make, take some time to do this before the next earthquake strikes.

Observation	Recommendation	Page
Unsecured bookcases and cabinets	Fasten to nearby walls	7
Cabinet doors and drawers that swing open easily	Install latches	10
Electronic equipment and artwork that can topple	Secure items to bookcases and cabinets	11
Pictures and bulletin boards that can fall	Fasten securely to walls	12
Hanging fixtures and suspended ceilings	Attach safety cables	13
Large appliances that can tip over	Anchor to nearby walls	15
Unprotected windows and doors	Apply safety film	15
Water heater that can tip over	Secure to nearby wall	16
Unsecured wall-mounted television	Bolt wall mount plate to the wood board and board to wall studs	14
Home not anchored to foundation	Add anchor bolts or steel plates	19
Weak cripple wall	Reinforce cripple wall	21
Unsound post-and-pier foundation	Secure post-and-pier foundation	23
Weak floor system	Modify floor system	24
Inadequate walls	Strengthen wood-framed walls	25
Unreinforced masonry	Reinforce masonry walls	26
Poor roof support	Retrofit roof system	26
Unsecured chimney	Anchor unreinforced chimney	27
Room over garage	Strengthen the support	28
Unique addition	Have engineer evaluate	28

References

APA: The Engineered Wood Association. ***APA Homeowner's Guide: Earthquake Safeguards***. Tacoma, WA: APA, 1997.

Association for Bay Area Governments. ABAG Home Quake Safety Toolkit <http://www.abag.ca.gov/bayarea/eqmaps/fixit/fixit.html>

California Governor's Office of Emergency Services and Federal Emergency Management Agency. *An Ounce of Prevention: Strengthening Your Wood-frame House for Earthquake Safety*. Sacramento, CA: California OES, 1993.

California Governor's Office of Emergency Services and Federal Emergency Management Agency. *Guide to Strengthening and Repairing Your Home Before the Next Earthquake*. Sacramento, CA: California OES, 1995.

California Seismic Safety Commission. *The Homeowner's Guide to Earthquake Safety*. Sacramento, CA: California SSC, 1998.

Federal Emergency Management Agency. *Reducing the Risks of Nonstructural Earthquake Damage*. FEMA 74. Washington, DC: FEMA, 1994.

Federal Emergency Management Agency. *Homebuilder's Guide to Seismic Resistant Construction*. FEMA 232. Washington, DC: FEMA, 2006.

Federal Emergency Management Agency. *Identification and Reduction of Nonstructural Earthquake Hazards in Schools*. FEMA 241. Washington, DC: FEMA, 1993.

Federal Emergency Management Agency. *FEMA: Mitigation "How To" Series*. <http://www.fema.gov/MIT/how2.htm>

Gray, Ralph Gareth. "Riding Out the Big One". *Fine Homebuilding*. Two Part Series: December 1990/January 1991.

International Code Council. *International Residential Code.* Falls Church, VA, 2006.

Kimball, Virginia. *Earthquake Ready: The Complete Preparedness Guide*. Malibu, CA: Roundtable, 1992.

Mroz, M.P., and T.T. Soong. *NIST GCR 97-732: Fire Hazards and Mitigation Measures Associated with Seismic Damage of Water Heaters*. Gaithersburg, MD: National Institute of Standards and Technology, 1997.

Southern California Earthquake Center. *Putting Down Roots in Earthquake Country*. 1995. http://www.scecdc.scec.org/eqcountry.html

Structural Engineers Association of California, *Commentary on Chapter 3, Guidelines for Seismic Retrofit of Existing Buildings. 1993.* http://www.seaoc.org/Pages/committees/extbldgpdfs/GSREBCh3_630.pdf .

Additional Sources of Information

APA - The Engineered Wood Association
P.O. Box 11700
Tacoma, WA 98411-0700
Tel: 253-565-6600
Help Desk: 253-620-7400
Fax: 253-565-7265
http://www.apawood.org/

American Society of Civil Engineers (ASCE)
1801 Alexander Bell Drive
Reston, VA 20191-4400
Tel: 703-295-6000
Fax: 703-295-6222
http://www.asce.org

American Red Cross
Check your local phone directory for
the chapter nearest you.
http://www.redcross.org

Association of Bay Area Governments (ABAG)
P.O. Box 2050
Oakland, CA 94604-2050
Tel: 510-464-7900
Fax: 510-464-7970
http://www.abag.ca.gov/

Applied Technology Council (ATC)
555 Twin Dolphin Drive, Suite 550
Redwood City, CA 94065
Tel: 650-595-1542
Fax: 650-593-2320
http://www.atcouncil.org/index.htm

California Division Of Mines and Geology
801 K Street, MS 14-33
Sacramento, CA 95814-3532
Tel: 916-445-5716
Fax: 916-445-1853
http://www.consrv.ca.gov/dmg

California Office of Emergency Services
1300 Clay Street, Suite 408
Oakland, CA 94612
Tel: 510-286-0895
Fax: 510-286-3581
http://www.oes.ca.gov/

California Seismic Safety Commission
1755 Creekside Oaks Drive, Suite 100
Sacramento, CA 95833
Tel: 916-263-5506
Fax: 916-263-0594
http://www.seismic.ca.gov

Consortium of Universities for Research in Earthquake Engineering (CUREE)
1301 S. 46th Street
Richmond, CA 94804-4698
Tel: 510-231-9557
Fax: 510-231-5664
http://www.curee.org

Center for Earthquake Research and Information (CERI)
University of Memphis
Memphis, TN 38152
Tel: 901-678-2007
Fax: 901-678-4734
http://www.ceri.memphis.edu/

Central U.S. Earthquake Consortium (CUSEC)
2630 E. Holmes Road
Memphis, TN 38118
Tel: 901-544-3570
Fax: 901-544-0544
http://www.cusec.org

Earthquake Engineering Research Center (EERC)
NISEE/EERC
1301 South 46th Street
Richmond, CA 94804-4698
Tel: 510-231-9403
Fax: 510-231-9461

http://eerc.berkeley.edu /
Earthquake Engineering Research Institute (EERI)
499 14th Street, Suite 320
Oakland, CA 94612-1934
Tel: 510-451-0905
Fax: 510-451-5411
http://www.eeri.org/

Federal Emergency Management Agency (FEMA)
P.O. Box 2012
Jessup, MD 20794-2012
Tel: 1-800-480-2520
http://www.fema.gov

Institute for Business & Home Safety (IBHS)
4775 E. Fowler
Tampa, FL 33617
Tel: 1-866-657-4247
Fax: 813-286-9960
http://www.ibhs.org

International Code Council (ICC)
5203 Leesburg Pike
Falls Church, VA 22041
Tel: 703-931-4533
Fax: 703-379-1546
http://www.intlcode.org

International Window Film Association
318-A Brown Street
P.O. Box 3871
Martinsville, VA 24115-3871
Tel: 540-666-4932
Fax: 540-666-4933
http://www.iwfa.com

Mid-America Earthquake Center
1241 Newmark Lab MC-250
205 N. Mathews
Urbana, IL 61801
Tel: 217-244-6302
Fax: 217-333-3821
http://mae.ce.uiuc.edu

Multidisciplinary Center for Earthquake Engineering Research (MCEER)
MCEER/IS
State University of New York @ Buffalo
304 Capen Hall
Buffalo, NY 14260-2200
Tel: 716-645-3377
Fax: 716-645-3379
http://mceer.buffalo.edu

National Information Service for Earthquake Engineering/California Institute for Technology (NISEE/CALTECH)
1301 South 46th Street
Richmond, CA 94804-4698
Tel: (510) 231-9403
Fax: (510) 231-9461
http://www.eerc.berkeley.edu

National Institute for Urban Search and Rescue (NI/USR)
P.O. Box 90909
Santa Barbara, CA 93190
Tel: 800-767-9983
Fax: 805-966-6178
http://www.niusr.org/

National Oceanic and Atmospheric Administration (NOAA), National Geophysical Data Center (NGDC)
325 Broadway
Boulder, CO 80303
Tel: 303-497-6826
Fax: 303-497-6513
http://www.ngdc.noaa.gov/ngdc.html

Nature of the Northwest Information Center
800 NE Oregon Street, Suite 177
Portland, OR 97232
Tel: 503-872-2750
Fax: 503-731-4066
http://naturenw.org

Pacific Earthquake Engineering Research Center (PEER)
Richmond Field Station
University of California, Berkeley
1301 S. 46th Street
Richmond, CA 94804-4698
Tel: 510-231-9554
Fax: 510-231-9471
http://peer.berkeley.edu

Simpson Strong-Tie
4637 Chabot Dr., Suite 200
Pleasanton, CA 94588
Tel: 925/460-9912
Fax: 925/847-0694
http://www.strongtie.com

Southern California Earthquake Center (SCEC)
University of Southern California
Los Angeles, CA 90089
Tel: 213-740-5843
Fax: 213-740-0011
http://www.scec.org/

University of California Berkeley Seismological Laboratory
202 McCone Hall
Berkeley, CA 94720-4760
Tel: 510-642-3977
Fax: 510-643-5811
http://www.seismo.berkeley.edu/seismo/

USGS National Earthquake Information Center (NEIC)
P.O. Box 25046 , Denver Federal Center
Denver, CO 80225
Tel: 303-273-8500
http://gldss7.cr.usgs.gov or
http://wwwneic.cr.usgs.gov/

Insurance Institute for Business & Home Safety
4775 E. Fowler Avenue, Tampa, FL 33617
(813) 286-3400
DisasterSafety.org

©IBHS
0810-ERQ-201