



Earthquake Safety Guide for Homeowners

FEMA 530 / September 2005



FEMA





Publishing Information

The Homeowner's Guide to Earthquake Safety was originally developed and published by the California Seismic Safety Commission. This modified version of the Guide was developed by FEMA in cooperation with the California Seismic Safety Commission staff. The original guide was prepared for publication by the staff of the Collaborative for Disaster Mitigation, San Jose State University.

Ordering Information

Copies of this publication are available from the FEMA Distribution Facility. To order, call 1-800-480-2520 and ask for FEMA publication 530.

On the cover:

Taken in Atascadero, California, on January 25, 2004, the photograph shows a home that slid 2 feet off its foundation as a result of the 6.5 San Simeon Earthquake.

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California Homeowners: This Guide does **not** cover real estate disclosure requirements and related recommendations as described in the California Seismic Safety Commission publication *The Homeowner's Guide to Earthquake Safety*. To obtain that guide, go to <http://www.seismic.ca.gov/sscpub.htm>.

ACKNOWLEDGMENTS

Department of Homeland Security, Federal Emergency Management Agency

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The Commission gratefully acknowledges the assistance of the following:

American Red Cross

American Society of Home Inspectors

Association of Bay Area Governments

Building Education Center

California Association of Realtors

California Building Officials

California Council of the American Institute of
Architects

California Geological Survey

California Real Estate Inspection Association

California Governor's Office of Emergency
Services

City of Los Angeles

Earthquake Engineering Research Institute

Humboldt Earthquake Education Center

International Code Council

SBC

San Diego Association of Governments

Southern California Association of Governments

Southern California Association of Residential
Retrofit Professions

Southern California Gas Company/Sempra

Structural Engineers Association of California

Committee on Earthquake Safety Issues for
Gas Systems

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INTRODUCTION

Earthquakes, especially major ones, are dangerous, inevitable, and a fact of life in some parts of the United States. Sooner or later another “big one” will occur.

Earthquakes:

- Occur without warning
- Can be deadly and extremely destructive
- Can occur at any time

As a current or potential owner of a home*, you should be very concerned about the potential danger to not only yourselves and your loved ones, but also to your property.

The major threats posed by earthquakes are bodily injuries and property damage, which can be considerable and even catastrophic.

Most of the property damage caused by earthquakes ends up being handled and paid for by the homeowner.

- In a 2000 study titled *HAZUS 99: Average Annual Earthquake Losses for the United States*, FEMA estimated U.S. losses from earthquakes at \$4.4 billion per year.
- Large earthquakes in or near major urban centers will disrupt the local economy and can disrupt the economy of an entire state.

However, proper earthquake preparation of your home can:

- Save lives
- Reduce injuries
- Reduce property damage

*For the purpose of this document, “home” includes single-family residences, duplexes, triplexes, and fourplexes.

As a homeowner, you can **significantly reduce** damage to your home by fixing a number of known and common weaknesses.

This booklet is a good start to begin strengthening your home against earthquake damage.

It describes:

- Common weaknesses that can result in your home being damaged by earthquakes, and
- Steps you can take to correct these weaknesses.

There are no guarantees of safety during earthquakes, but properly constructed and strengthened homes are far less likely to collapse or be damaged during earthquakes. FEMA advises you to act on the suggestions outlined in this booklet and make yourself, your family, and your home safer.

EXAMPLES OF DAMAGE TO SINGLE-FAMILY HOMES



Pacific Fire Rating Bureau

Figure 1 - San Fernando Earthquake, Feb. 9, 1971 Severely damaged split level one- and two-story wood frame dwelling. The one-story portion dropped about 3 feet.



FEMA News Photo

Figure 4 - Northridge Earthquake, Jan. 17, 1994 Chimney collapse - common type of damage to unreinforced masonry.



Robert A. Eplett, OES

Figure 2 - Loma Prieta Earthquake, Oct. 17, 1989 Home moved off of its foundation and was considered a total loss.



Dane Golden, FEMA News Photo

Figure 5 - San Simeon Earthquake, Dec. 22, 2003 This home slid 2 feet off its foundation due to inadequate nailing of walls to its sill plates.



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Figure 3 - Northridge Earthquake, Jan. 17, 1994 Single-family residence damaged due to failure of multiple elements.

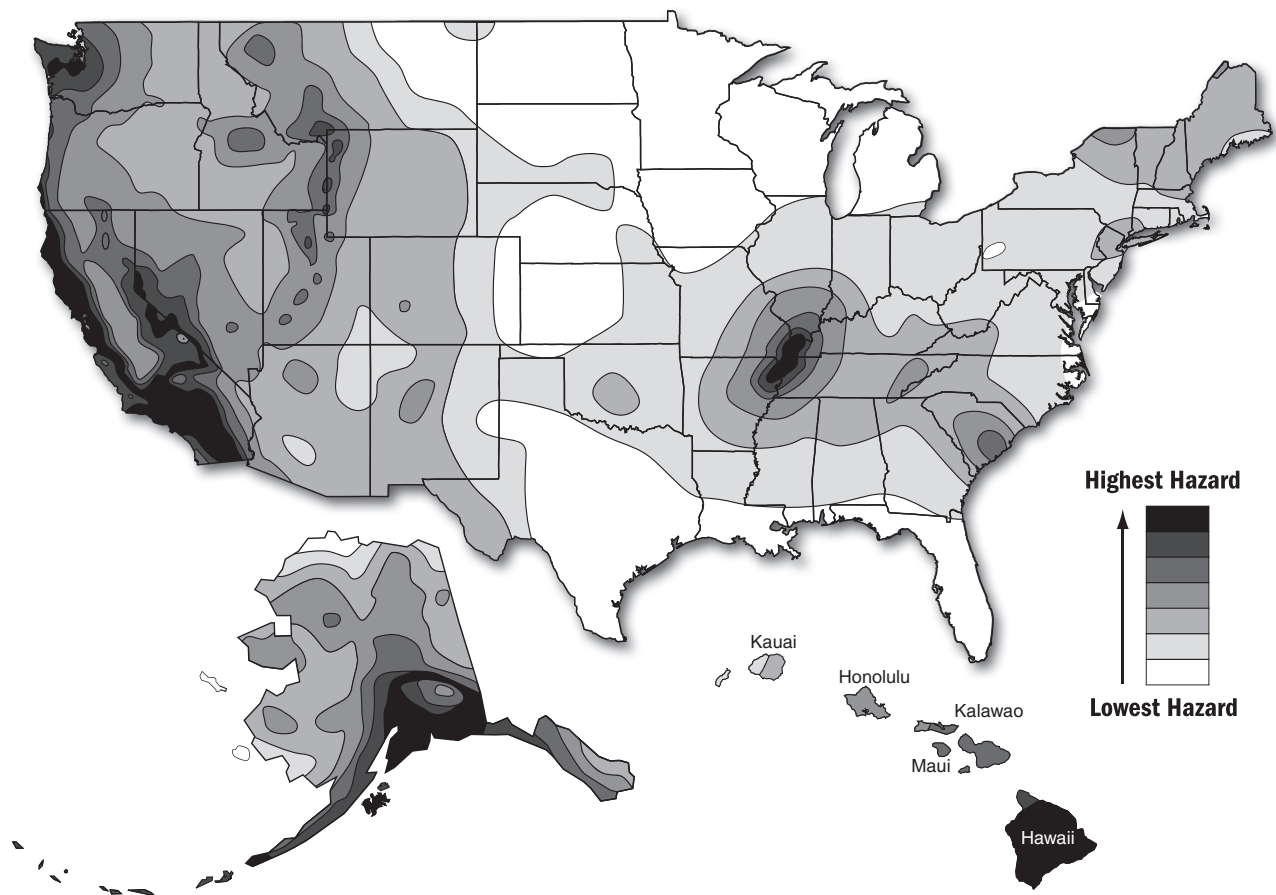


Gina Salvaduray

Figure 6 - San Simeon Earthquake, Dec. 22, 2003 The collapsed porch was not adequately attached to this single-family residence.

EARTHQUAKE HAZARDS IN THE UNITED STATES

Earthquakes strike suddenly, without warning. Earthquakes can occur any time of the year and at any time of the day or night. On a yearly basis, 70 to 75 damaging earthquakes occur throughout the world. Estimates of losses from a future earthquake in the United States approach \$200 billion. Forty-five states and territories in the United States are at moderate to very high risk from earthquakes, and they are located in every region of the country.



Earthquake hazards in the United States. This map is based on seismicity and fault-slip rates and takes into account the frequency of occurrence of earthquakes of various magnitudes. Locally, the hazard may be greater than that shown, because site geology may amplify ground motions. Based on U.S. Geological Survey National Seismic Hazard Map for the Conterminous United States (http://eqhazmaps.usgs.gov/html/map_graphic.html).

EARTHQUAKE WEAKNESSES

The earthquake weaknesses identified in this section, if not corrected, can result in one or more of the following:

- Injury to occupants
- Severe damage to your home
- Broken gas and utility lines
- Fires from broken gas lines
- Damage to floors, walls, and windows
- Damage to the contents in the house
- Damage to the foundations



Please remember that:

- Retrofitting before an earthquake is relatively cheap.
- Doing major structural repairs to your home after an earthquake is very expensive.
- Sometimes the damage is extensive enough to require the entire house to be demolished.
- After an earthquake, there is usually a shortage of available licensed contractors and engineers in the impacted area, because of the sudden high demand for their services.
- An appropriate seismic retrofit will reduce damage and save you money.

Please consult your local Building Department and/or a licensed architect or engineer for more detailed information.

The Problem

If water heaters are not properly braced, they can topple over during an earthquake, causing:

- Broken gas lines and gas leaks
- Fires resulting in major damage to homes
- Broken water lines and flooding

How to Identify

- ✓ Is the water heater freestanding?
- ✓ Are there straps or other types of restraints securing the water heater?
- ✓ Are there straps or restraints bolted to the studs?
- ✓ Are there flexible pipes for water and gas connected to the water heater?

Remember

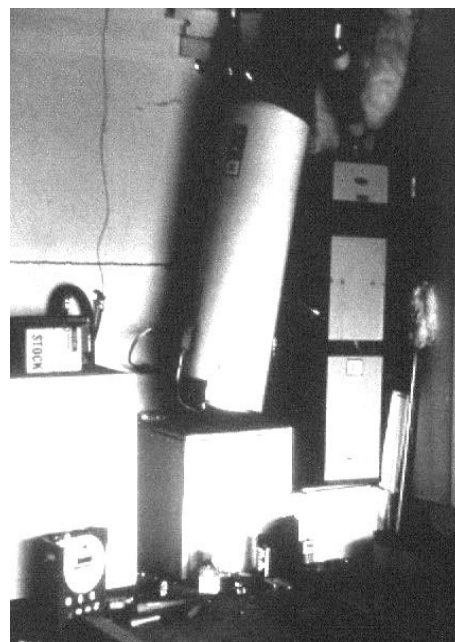
- Replacing a water heater after an earthquake can cost more than \$500.
- Repairing fire damage and flooding damage can cost several thousand dollars, including the entire cost of your home!
- There are many different ways of strapping a water heater. One example is shown on the next page.
- Check with your local Building Department for details of local requirements.
- Know where your main water valve is so that you can shut it off if you have a water leak.
- Know where your main gas valve is so that you can shut it off if you hear or smell a gas leak. (See page 25)

Water heater



Governor's Office of Emergency Services

Figure 7 - The unbraced water heater in this home fell during an earthquake; the resulting fire destroyed the home.



Guna Selvadurai

Figure 8 - This unstrapped water heater tipped over during the 1984 Morgan Hill Earthquake. Fortunately, gas and water lines were not ruptured.

Water heaters must be braced (securely attached) to the studs in a wall.

The Solution

There are many solutions – all relatively inexpensive.

- Purchase and install a strap kit or bracing kit from your local hardware store.

Other options include:

- Have a licensed plumber strap your water heater according to code.
- Use metal tubing or heavy metal strapping and lag screws and washers to secure the water heater to the wall studs.

The gas and water lines should also have flexible pipes. These are safer than rigid pipes during an earthquake.

Be sure to check the straps once a year. They may come loose due to vibrations, or other causes.

How-to Resources

- Your local home improvement store
- Go to www.fema.gov, and under the Earthquake section, search for “Brace Hot Water Heaters” for specific bracing instructions.
- Publication: [Guidelines for Earthquake Bracing of Residential Water Heaters](http://www.documents.dgs.ca.gov/dsa/pubs/waterheaterbracing_08-11-04.pdf). Department of General Services, Division of the State Architect, revised August 11, 2004. Available online at http://www.documents.dgs.ca.gov/dsa/pubs/waterheaterbracing_08-11-04.pdf.

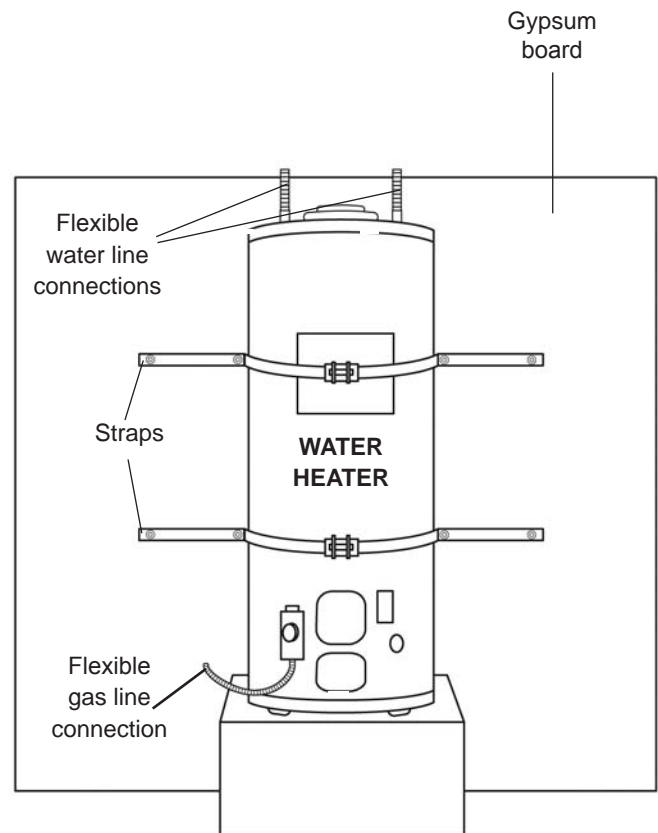


Figure 9 - One method of water heater bracing. Straps and screws visible with water heater in a garage installation.

Comparison of Cost: Preventing vs. Repairing Earthquake Damage

Project Cost

\$20 to \$200

Cost to Repair After an Earthquake

\$500 to total value of home (if completely destroyed)

The Problem

Houses that are not bolted to the foundation can move off their foundations during earthquakes.

How to Identify

- ✓ Go down into the crawl space – the area between the first floor and the foundation – to find out if your house is bolted to its foundation.
- ✓ Look for the heads of anchor bolts that fasten the sill plate – the wooden board that sits directly on top of the foundation – securely to the foundation. (See Figure 11a, page 8)
- ✓ You should be able to see the large nuts, washers, and anchor bolts, installed at least every 4 to 6 feet along the sill plate. Steel plates are sometimes used instead of anchor bolts. (See Figure 11b, page 8)

Remember

- It is very expensive to lift a house, and place it back on its foundation.
- Homes moving off their foundations can cause gas lines to rupture, which in turn can result in fires.



Figure 10 - This home wasn't bolted and slid off its foundation. Sometimes the damage can be so bad that houses have to be demolished.

If your home has no foundation, or an old concrete foundation, see page 23.

Slab Foundations

Some homes are built directly on concrete slabs. These houses do not have crawl spaces and foundation walls.

Nearly all homes with slab foundations that were originally built to code will have anchor bolts or straps.

However, if the house is not bolted to the slab, you have an earthquake weakness.

Newer homes generally have anchor bolts or straps.

If you have an unfinished garage, you may be able to see the anchor bolts.

You are not required to remove siding, drywall, or plaster to determine if your house has anchor bolts.

The Solution

Drill holes through the sill plate into the foundation and install anchor bolts. (See *Figure 11a*)

If there is not enough room to drill, you can attach steel plates to hold the sill plate to the foundation. (See *Figure 11b*)

Anchor bolts have to be installed properly for them to be effective.

You must obtain the proper permits from your local Building Department before beginning work.

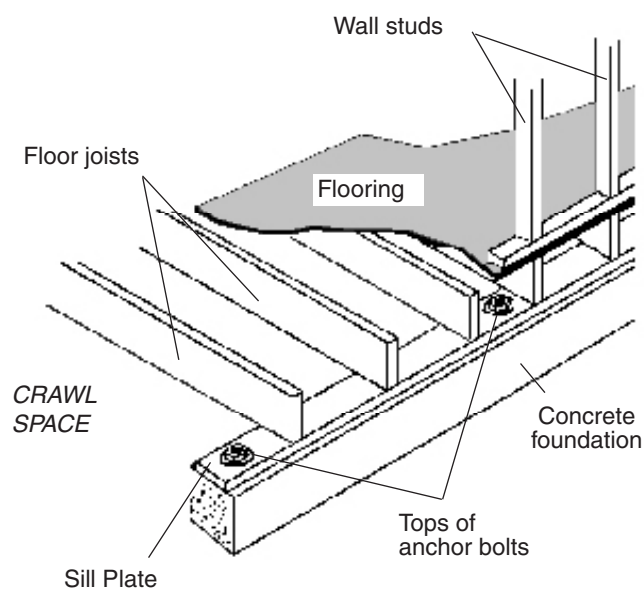


Figure 11a

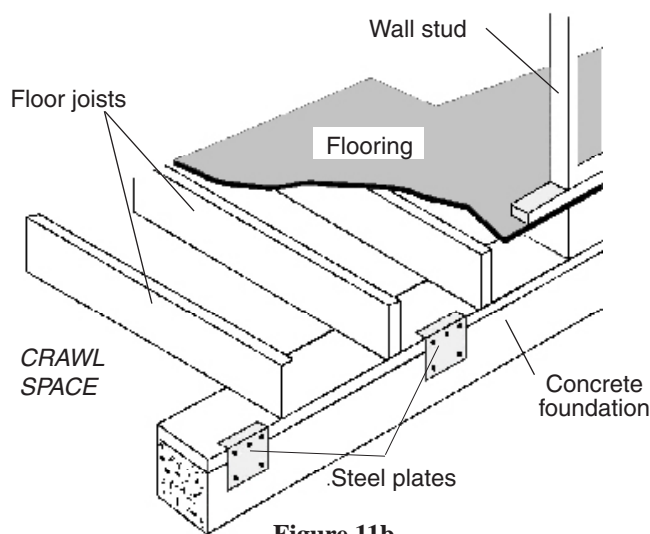


Figure 11b

How-to Resources

- Detailed information for do-it-yourselfers or engineers can be found in the [International Existing Building Code](#), published by the International Code Council.
- Go to www.fema.gov, and under the Earthquake section, search for “Strengthen Foundation Walls” for specific anchoring instructions.

Figure 11 - Anchor bolts or steel plates. A home’s crawl space may be formed by a wood stud wall (see next page for description) between the foundation and the floor joists or the floor joists may rest directly on the sill plate. In either case, you should be able to see the heads of anchor bolts or steel plates installed at appropriate intervals. These fixtures fasten the sill plate to the foundation.

Comparison of Cost: Preventing vs. Repairing Earthquake Damage

Project Cost	Cost to Repair After an Earthquake
\$250 to \$5,000	\$25,000 to total value of home (if completely destroyed)

The Problem

Wooden floors and stud walls are sometimes built on top of an exterior foundation to support a house and create a crawl space. (See Figure 14, page 10)

These stud walls carry the weight of the house.

During an earthquake, these walls can collapse if they are not braced to resist horizontal movement.

If the wall fails, the house may shift or fall.

How to Identify

- ✓ Go under the house through the crawl space, to see if there are any wood stud walls.
- ✓ If there are such walls, check to see if they are braced.
- ✓ There should be plywood panels adequately nailed to the studs OR there should be diagonal wood sheathing. (See Figure 13)
- ✓ If you have neither of these, the walls are probably insufficiently braced or unbraced.
- ✓ Horizontal or vertical wood siding is not strong enough to brace these walls.

Remember

- It is very expensive to lift a house, repair these walls, and put it back on its foundation.



Office of Emergency Services

Figure 12 - Damage to home due to crawl space wall failure.

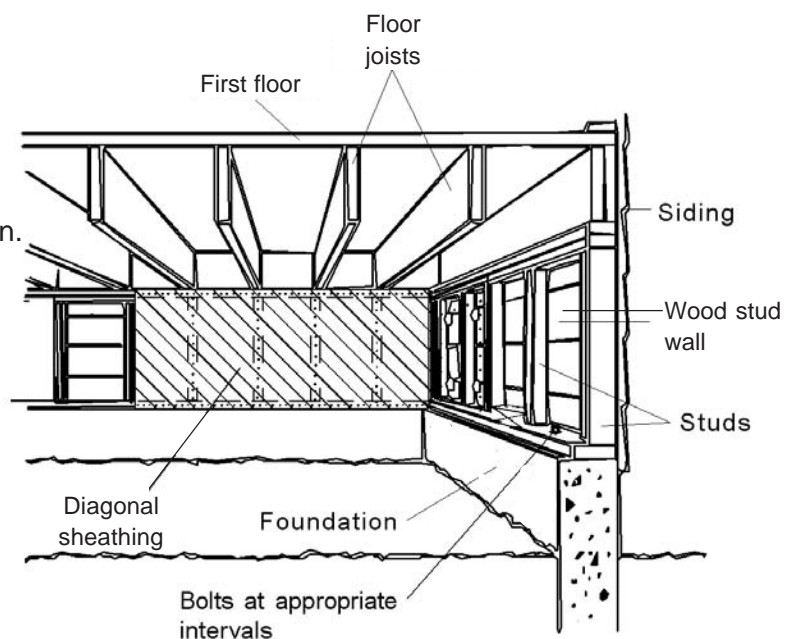


Figure 13 - Diagonal sheathing. Common in older homes.

The Solution

Plywood, or other wood products allowed by code, should be nailed to the studs.

The following are important:

- Type of wood product used
- Plywood thickness
- Nail size and spacing
- Not covering vents

Consult your local Building Department for permit requirements before starting work.

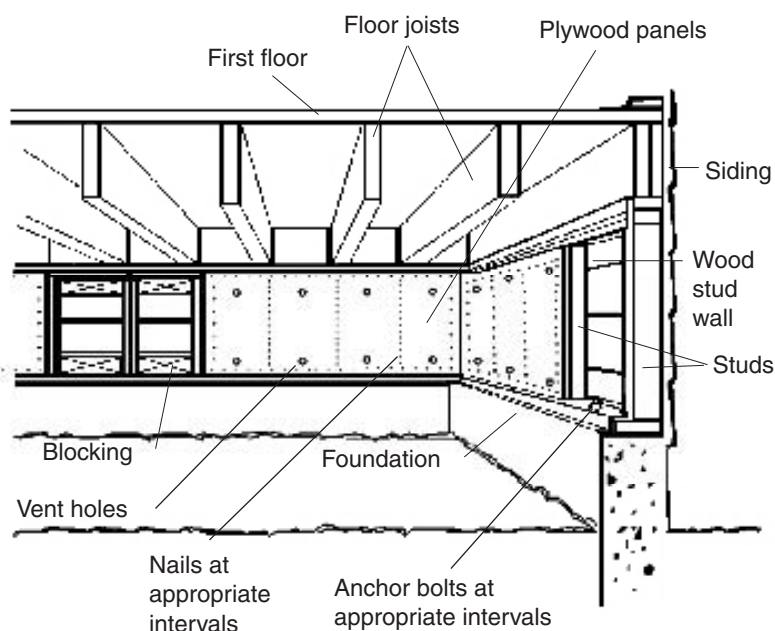
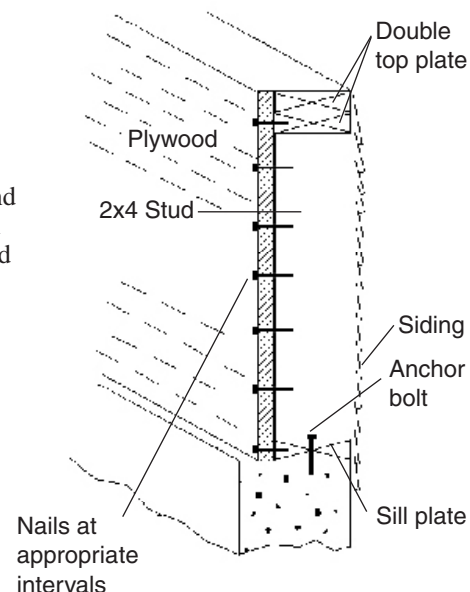


Figure 14 - Plywood or diagonal sheathing strengthens weak wood stud walls. If your home has a wood stud wall between the foundation and the first floor, and the wall is not braced with plywood or diagonal sheathing, the house may fall or shift off its foundation during an earthquake.



How-to Resources

- Detailed information for do-it-yourselfers or engineers can be found in the [International Existing Building Code](#), published by the International Code Council
- Go to www.fema.gov, and under the Earthquake section, search for “Strengthen Foundation Walls” for specific strengthening instructions.

Comparison of Cost: Preventing vs. Repairing Earthquake Damage

Project Cost
\$500 to \$2,500

Cost to Repair After an Earthquake
\$25,000 to total value of home (if completely destroyed)

The Problem

The outside of the house is supported by wood posts resting on unconnected concrete piers. Siding is often nailed to the outside of the posts, making them not easily visible.

During an earthquake these posts can fail, if they are not braced against swaying.

If the posts fail, the house may shift or fall.

How to Identify

- ✓ Go under the house to see if there is a continuous foundation under the outside walls.
- ✓ If you do not see a continuous foundation, you may have an earthquake weakness.
- ✓ If you see only unconnected concrete piers and wood posts, or only wood posts, supporting the outside walls, you have an earthquake weakness.

Remember

- Horizontal or vertical wood siding is not strong enough to brace pier-and-post foundations.
- Major structural repairs, like lifting an entire house to repair the posts and putting it back, are very expensive.



California Seismic Safety Commission



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Figure 15 - The pier-and-post foundation under this home shifted during a recent earthquake.

The Solution

Consult a licensed architect or engineer, and a licensed building contractor who specializes in foundations, to fix this problem.

It may be possible to make the foundation safer by bracing the posts.

You might be better off to add a new foundation and plywood walls in the crawl space to make sure that the house will not shift or fall off its foundation during an earthquake.

How-to Resource

- Detailed information for engineers can be found in the [International Existing Building Code](#), published by the International Code Council.

Comparison of Cost: Preventing vs. Repairing Earthquake Damage

Project Cost	Cost to Repair After an Earthquake
\$1,000 to \$25,000	\$20,000 to total value of home (if completely destroyed)

The Problem

Unreinforced masonry—brick, concrete block, or stone—foundations often cannot resist earthquake shaking. They may break apart, or be too weak to hold anchor bolts. Homes may shift off such foundations during earthquakes, damaging the walls, floors, utility lines, and home contents.

How to Identify

- ✓ If your home's foundation is brick or stone, and looks like one of the foundations shown in the photos here, it is probably unreinforced.
- ✓ If there is a space filled with grout between the inner and outer faces of a brick foundation (where anchor bolts and reinforcing steel could be installed), it may be reinforced.
- ✓ If the outside of the foundation is covered, you may have to look under the house to see the type of foundation you have.
- ✓ If you are not sure what to look for, seek the services of a licensed engineer to determine if your foundation is reinforced or not.

Remember

- It is cheaper to do this before an earthquake damages the house than after.



Figure 16 - This is an unreinforced stone foundation. They typically fail during earthquakes.



Figure 17 - Note the bricks exposed in this unreinforced masonry foundation.

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