



Residential Seismic Strengthening

Methods to Reduce Potential Earthquake Damage

Portland and the surrounding communities are located in a seismically active region.

Although most Oregonians have not witnessed a large earthquake in this region, large earthquakes have occurred in the past. The Cascadia Subduction Zone lies off the Oregon and Washington coasts where two sections of the earth's crust (tectonic plates) are colliding, with one plate sliding beneath (subducting) the other. Subduction zones have produced some of the most powerful earthquakes ever recorded, often having magnitudes of 8 to 9 or larger. The 2004 Great Sumatra-Andaman (magnitude 9.1) earthquake occurred on a subduction zone. Studies have found evidence that very large earthquakes have occurred repeatedly in the past on the Cascadia Subduction Zone, most recently in January, 1700. Scientists believe the Cascadia Subduction Zone is likely to produce large earthquakes in the future. Extensive damage to buildings as a result of strong and sustained ground shaking is expected in the Portland area in the event of a Cascadia Subduction Zone earthquake.

Oregon also has many crustal faults. These faults typically occur in the earth's crust, at shallow depths of 6 to 12 miles below the surface. The two largest earthquakes in recent years in Oregon, the Scotts Mills (magnitude 5.6) and the Klamath Falls (magnitude 5.9 and magnitude 6.0) earthquakes of 1993 occurred on crustal faults. Recent geophysical studies and subsurface investigations indicate the presence of at least three crustal faults beneath the Portland metropolitan area which could generate much more damaging crustal earthquakes of magnitude 6.5 or larger. Although crustal earthquakes are not expected to be as large as earthquakes on the Cascadia Subduction Zone, their shallow depth and close proximity to people and developed property could result in as much or more damage to structures.

Earthquakes are a natural occurrence caused by the constant motion of the Earth's crust. This motion creates the buildup of pressure along faults which is released in the form of an earthquake. Earthquakes are sudden and without warning. Strong ground shaking can cause severe damage to buildings, cracking walls, toppling chimneys or even shifting buildings off their foundation. Older buildings and homes are especially at risk because they often lack adequate anchorage to their foundation and were not designed to resist the shaking and movement expected from earthquakes today. Identifying potential hazards ahead of time, strengthening

homes, buildings and utilities can reduce damage and the dangers of serious injury or loss of life from an earthquake. Modified from www.oregongeology.org/sub/earthquakes/EQs.htm

The City of Portland, Bureau of Development Services has a program to help you make your home more secure in our next earthquake.



Purpose

The strengthening methods described by this program are intended to reduce the likelihood of your home being severely damaged by being displaced from its foundation or cripple walls in an earthquake, however these measures will not bring an existing building up to current code.

The information provided in this brochure and accompanying standard plan is intended to provide a prescriptive method for one, two and three story one and two family residential buildings if they meet the following criteria:

- One and two family dwellings
- Buildings not over 3 stories in height. In 3 story buildings, cripple wall stud height shall be maximum 14 inches.
- Cripple walls not exceed 4 feet in height in one and two story buildings.
- Continuous concrete foundation around the entire building perimeter.
- Foundation sub grade not steeper than 3 horizontal to 1 vertical at any point.

You will need to hire an engineer or architect to design improvements to buildings that do not meet all of the above listed criteria.

You will need to hire an engineer or architect when you have special conditions like a stone or brick foundation, poor quality concrete, cripple walls more than four feet in height, or your home is built without a continuous foundation or on a grade steeper than three horizontal to one vertical.

Common Construction Problems

Many homes were built using older construction techniques which are inadequate for the forces we now know earthquakes can cause; but, these older homes can be reinforced easily and inexpensively.

Older homes are typical victims...

Many homes built prior to 1960 were built without being bolted to their foundations. Without this anchorage, a large earthquake can move the ground and the foundation right out from under the house. Older homes have been damaged or destroyed in every major earthquake on the west coast.



...but earthquakes can damage newer, anchored homes too

Some wood frame homes built as recently as the 1970s were shaken off their foundations in recent earthquakes. Even though these modern homes were bolted down, they failed because of weak bracing materials on the cripple walls. The cripple wall is a short wall that connects the foundation to the first floor of the house and encloses the "crawl space." Weak bracing materials, like cement plaster (stucco) or wood siding, are not strong enough to survive the force of moderate to strong earthquakes.

The cripple wall must be braced with stronger materials like plywood. If not, the next earthquake may damage the cripple wall and move your home off its foundation, even if you've bolted it down.

Conduct Your Own Survey

What to look for

To check your home's earthquake fitness, all you need is a flashlight and a willingness to get a little bit dirty. The place to start is in the crawl space underneath your home.



1 Is your house properly bolted down to its foundation?

The most important and cost effective step you can take to help prevent or minimize earthquake damage to your home is to make sure it is adequately connected to the foundation.

The wood that rests directly on the foundation is called the mud sill. Until the 1950's, home builders often did not bolt the mud sill to the foundation. This creates a serious structural weakness that can allow your home to slide off its foundation during an earthquake. The mud sill should be bolted at four to six-foot intervals and within one foot of every joint, but no closer than nine inches to the end of the board.

2 Do you need plywood on your cripple wall?

Weak cripple walls are the second most common structural weakness resulting in damage from earthquakes.

Check to see if you have a cripple wall and if it is braced with plywood. If the cripple wall is covered on the exterior with only stucco or wood siding, it is not strong enough to resist earthquakes. You will need to add plywood. The Bureau's Standard Plan shows you how much.



3 Check for faulty materials in the concrete and the wood framing.

The foundation is a common area of structural weakness. When concrete foundations are porous or crumbly, they will not provide adequate strength to resist earthquakes. Unreinforced brick or stone masonry may need to be replaced or strengthened. An engineer or architect is required to design these types of repairs.

Check to see if there is insect damage or dry rot in the wood. You will need to replace or repair any faulty wood before you can proceed. Hiring a pest control company and fixing water leaks may be required.

Bolting your mud sill to the foundation and adding plywood to the cripple walls are the two most cost-effective



steps you can take to strengthen your home for earthquakes. Bolts secure your home's mud sill to the concrete foundation. The mud sill should be anchored as specified on the Bureau's Standard Plan.

Sheets of plywood nailed to the cripple walls help to prevent damage from shaking in this weak area of your house. Cross-bracing within the framing is not enough.

Faulty materials such as rotten wood and porous concrete should be replaced. Risky conditions in concrete include cracks wider than one-eighth inch, large voids, or "honeycomb" concrete. If the concrete chips or flakes when you poke it with a screwdriver, it may be unsafe. NOTE: If you suspect faulty material, you may need the assistance of a licensed engineer or architect to design a solution.

Prepare Your Plans and Get a Building Permit

DO I NEED A BUILDING PERMIT?

Yes. The building permit process protects your interests by providing building inspection. Our knowledgeable and well-trained inspectors will check the quality and quantity of the work. This helps you make sure the job is done right.

You will also have a permanent record in the Bureau of Development Services that the work was permitted and inspected. You should keep the final inspection card for additional proof.



HOW DO I GET A BUILDING PERMIT?

The City of Portland wants to simplify your home earthquake strengthening project. As part of this comprehensive program, we have developed a sample plan and details that can be used for "prescriptive" projects that are within the guidelines of this brochure. You can download a copy online at our website: www.portlandoregon.gov/bds/53562. You will need the plan along with this brochure in order to create the plan for your house.

- First, prepare your plan. Someone will need to crawl under your home to see what details your plan will use. Refer to the sample plan to draw a plan to show the configuration and dimensions of your foundation. Then select the applicable details that apply to your home, and indicate the details you will use by referencing them on your foundation plan. Print out each detail, the general notes, and compile these with your foundation plan to create a complete set of plans for permitting, installation and inspection purposes.
- Second, bring your completed plan to the Development Services Center for review by our helpful and friendly staff. We can answer any questions you have, and help you complete your plan.
- Third, pay a permit fee. The fee will cover our costs to review and approve your plans, inspect the work and keep a permanent record of it.

How to Bolt Your Home to Its Foundation

The first step to take if you find your home does not have anchor bolts, or has too few, is to install them! Because anchor bolts cost as little as several dollars each, the perimeter of the average size home can be bolted down by the do-it-yourselfer for a minimal cost. To install them, follow the procedure below and on the Bureau's Standard Plan.

1 Measure and mark

When you can easily drill the hole in the concrete, the concrete strength is low. Use the adhesive type of anchor when the concrete strength is low.

Mark the places for each bolt on the mud sill. Make the first mark between nine and twelve inches from the end of any piece of mud sill and then mark every six feet for one-story and every four feet for two- or three-story homes.

How to Bolt Your Home to Its Foundation

Continue this pattern along all of the exterior foundation walls. Make sure you mark each end of the mud sill at stepped foundations. A small investment in bolts can prevent many thousands of dollars of earthquake damage and possibly allow a homeowner to still live in their home after an earthquake.

2 Drill the holes

Use the drill bit diameter specified by the anchor manufacturer. The hole in the concrete will be the same diameter as the anchor for the expansion anchor and slightly larger for the adhesive anchor. The hole must be deep enough to exceed the minimum depth approved for the anchor, but at least 4 inches deep for expansion anchors and six inches deep for adhesive anchors.

3 Clean the holes

Follow the manufacturer's instructions on how to clean out the hole. Holes for adhesive anchors need careful cleaning. Some products require water cleaning and others use only a blower and nylon brush. Holes for expansion anchors do not need to be cleaned if they can be drilled deeper than required. This allows the drilling dust to settle out of the way.

4 Install the expansion anchors

Place the plate washer on the anchor and then thread the nut on the anchor. Place this anchor assembly into the hole and hammer on the nut to drive the anchor into the hole. Hammer the anchor down until the nut stops at the plate washer on top of the mud sill. Now tighten the nut down on the plate washer to connect your mud sill to the foundation. When you tighten the nut on an installed expansion anchor, the anchor's other end expands to grip the concrete. You will feel it grab the foundation as you tighten the nut. If the concrete breaks during tightening of the expansion anchor, the concrete strength is low and you will need to use an adhesive anchor. When your concrete has enough strength, the expansion anchor is easier and cheaper to install than the adhesive anchor.

Adhesive anchors require more care but are as strong as expansion anchors. Follow the manufacturer's directions on how to clean the drilled hole and how to mix and place the chemical. Always use a fully-threaded rod in the hole. Check for the hardening time and after the chemical has set, tighten the nut firmly with a wrench.

Note: Manufactures installation instructions must be followed for all anchors, whether expansion or adhesive type.

Checklist

- 1/2" or 5/8" diameter anchors with nuts and square plate washers
- Rotary hammer drill with a 1/2" or 5/8" by 9" carbide tip drill bit
- Adjustable wrench
- Measuring tape
- Torque wrench
- Dust mask and goggles
- Short-handled sledge hammer for setting expansion bolts
- Respirator, air blower
- Nylon brush for adhesive anchors

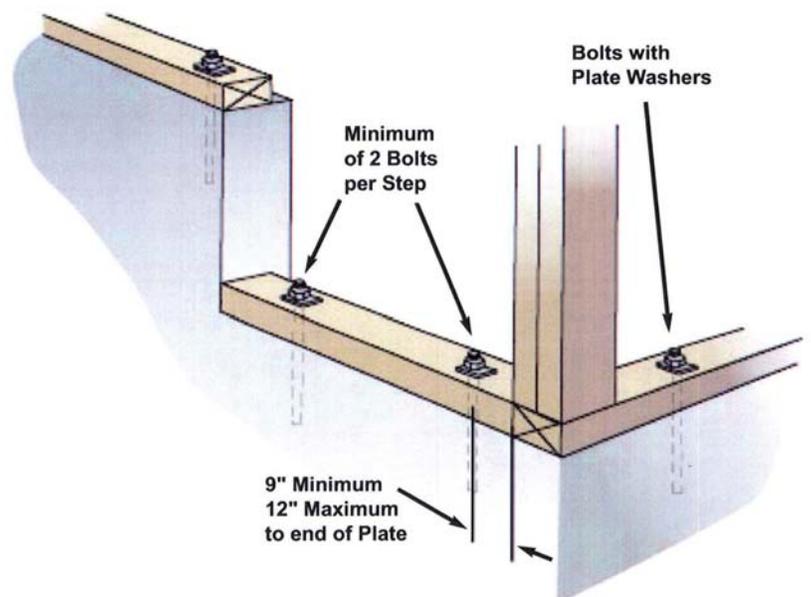
Stepped foundation

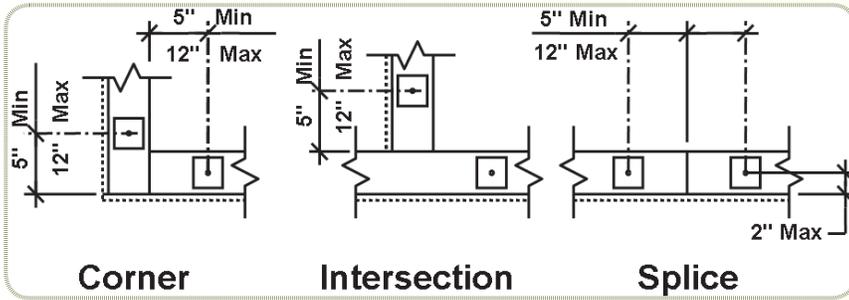
If your house is built on a hill or even a slight grade, you probably have some step-like offsets in your foundation. On every step, the mud sill must be bolted down at each end and along its length.

Requirements:

- Minimum of 2 Bolts per Step
- Bolts with Plate Washers
- 9" Minimum 12" Maximum to end of Plate

CAUTION: An engineer or architect must prepare the construction plans for the strengthening of homes built on hills steeper than three horizontal to one vertical because there are additional anchorage requirements.





Retrofit foundation plates

Some floors are supported directly on the foundation without cripple walls. This makes anchoring the mud sill difficult because of the lack of drilling space. Plates can be used to anchor your mud sill from the side. The plates attach to the side of the mud sill with wood screws and anchor to the concrete with either expansion or adhesive anchors.

The mud sill must be predrilled before the lag or wood screws can be installed. This helps prevent splitting of the wood. The Bureau's Standard Plan has more information on plates and proper installation methods. Be sure to use the type and length of screw recommended by the plate manufacturer.

How to Strengthen Wood Walls

1 Plywood

Figure out how much plywood you will need on each cripple wall and where it should be placed. Plywood coverage is based on the number of stories. Plywood wall bracing is required at each wall end and for 40 percent of the length

CHECKLIST

- 1/2" CDX five-ply plywood (do not use shop-grade plywood)
- 8-penny, 10-penny and 16-penny common nails
- Drill
- Saw
- Hammer
- Nail gun
- Measuring tape
- Chalk line
- Dust mask and protection for eyes and ears
- Blocking lumber
- Framing anchors

for one-story homes, 50 percent for two-story homes, and 80 percent for three-story homes. Use sheets at least four feet in length. An easy way to distribute the plywood is to put one-third of the required length on each wall end and the remaining one-third at the center of the wall. For example, if you have a single-story home with 60 feet of cripple wall on one side, at least 24 feet of plywood is required for that side. You can put two eight-foot sheets of plywood on each end and one eight-foot sheet near the middle

of the wall. Or you can use six four-foot sheets evenly distributed along the wall with one panel at each end. This second alternative will allow you to avoid any piping, chimneys or ventilation holes at the cripple wall.

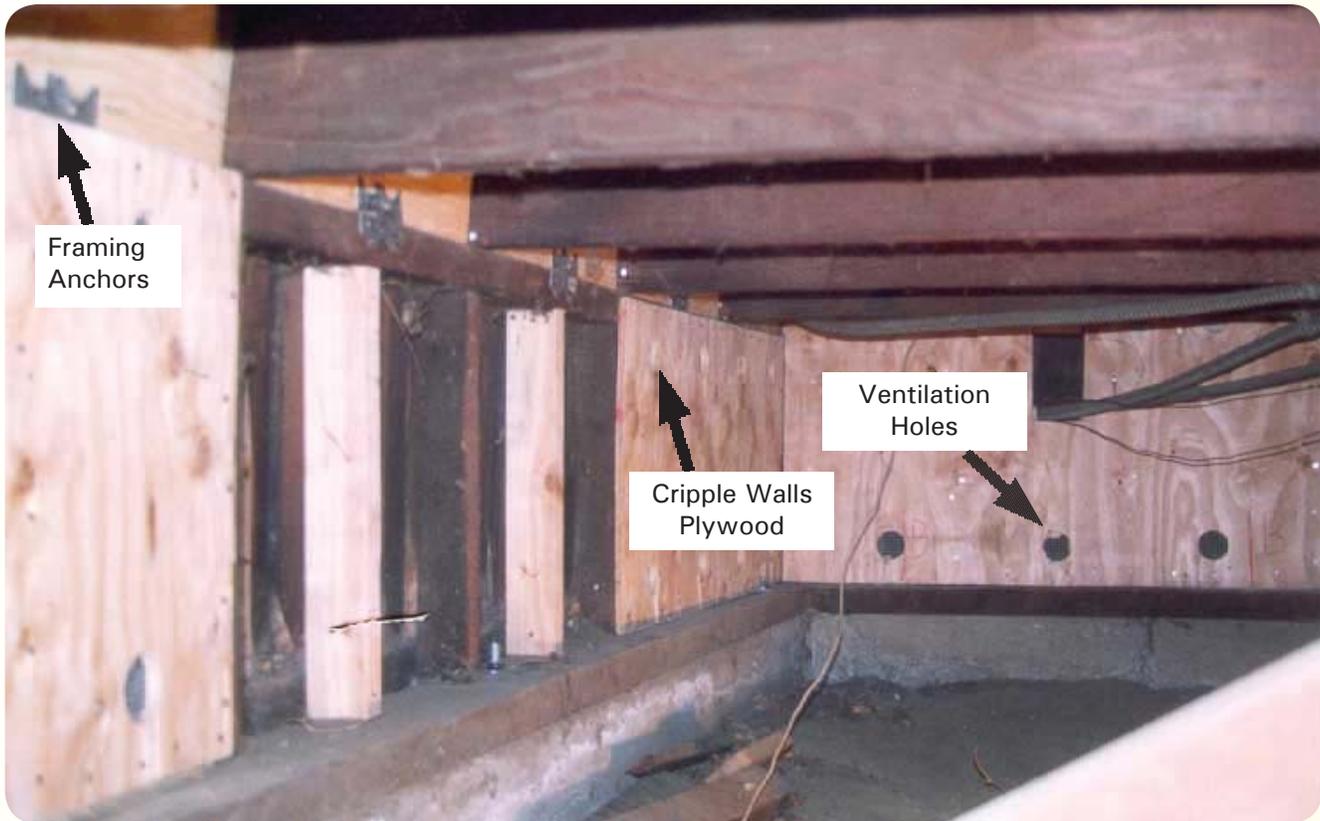
2 Blocking

Frequently lumber has to be added in the crawlspace for the new wall bracing or to attach the floor to the cripple wall. These lumber pieces are called blocking. They provide nailing surfaces for the plywood and framing anchors. The plywood braces the walls and the framing anchors connect the floor to the cripple wall or mud sill.

Cripple walls are usually built with studs that are four inches wide. The mud sill is usually six inches wide. This difference in width requires blocking to be added to the top of the mud sill. The blocking provides a nailing surface for the plywood at the bottom of the sheet. Some floor



members sit on top of mud sills or cripple walls without blocking between them. The lack of blocking can cause the floor members to fall over sideways in an earthquake. It also makes it difficult to connect the floor to the cripple wall or mud sill. If the blocking is missing between the floor members, it must be added to help put the earthquake forces into the strengthened wall.



3 Framing anchors

Framing anchors are small sheet metal connectors used to fasten wood members together. They are used to connect your floor framing to the newly strengthened foundation or cripple wall. Although the existing floor is connected with nails, these nails tend to rust and loosen over time. The nails may also be driven at an angle which is not as strong as nails driven straight in the framing anchors. The addition of framing anchors helps to make sure the building is properly connected to the newly strengthened part.

Framing anchors are a minimum of four-and-one-half inches long and use at least twelve 8d nails. They may be attached at the top of the cripple wall or to newly added blocking. Framing anchors are not required when the plywood can attach directly to the floor members. For detailed information see the Bureau's Standard Plan.

4 Nailing

Nailing into old wood can cause splitting. Sometimes you will need to pre-drill holes when nailing the added blocking. If you blunt the end of the nails before you drive them, they will be less likely to split the wood.

Plywood nailing is usually done by contractors with nail guns to speed up the work, but it can be done by hand. Sometimes small working areas make hand nailing difficult. Wood screws can also be used, See the Bureau's Standard plan for more information.

Most of the strength of the wall bracing comes from the nailing of the plywood. Make sure you use 8d common nails with full heads on them. Place the nails at four-inch spacing along all edges of the plywood sheets. The middle of the sheets can be nailed every twelve inches into the studs.

5 Ventilation holes

With the plywood in place, drill two to three-inch ventilation holes in each sheet. These holes should be centered above any anchor bolts, between each set of studs, and one inch above the mud sill and two-and-one-half inches below the bottom of the top plate. The holes will provide ventilation and allow inspection of the cripple wall. Drill only one hole if the plywood sheet is less than 18 inches tall. If your wall has an exterior ventilation screen, you should cut a hole in the plywood opposite the screen and similar to it in size. Don't forget to add blocking around this vent hole and nail the plywood edges four inches on center.

Seismic Q&A

Q What are the benefits of strengthening my home?

A Strengthened homes are safer to live in and easier to sell and insure. Contact your insurance agent about other possible benefits and specific information regarding your insurance policy. Evidence from past earthquakes in California has shown that strengthened homes stayed on their foundations in the same neighborhoods where unstrengthened homes did not!

Q How much does seismic strengthening cost?

A The cost of the work varies. Some homes have cripple walls that need a lot of blocking while other homes do not have cripple walls. Some homes have plenty of access to the work area while other homes have limited access because of heating ducts or small access holes. The cost of the work will increase significantly if you need to replace an unreinforced masonry foundation or have a lot of termite or fungus damage to the wood. You will get an idea of the fair value of the work to be done by getting at least three different bids from contractors.

Q Should I hire a contractor?

A All of the work shown on the Bureau's Standard Plan can be done by a homeowner with basic carpentry skills. However, most homeowners are using contractors who specialize in this type of work. We recommend you consider your skills, available time and budget to decide.

Q How do I find a contractor, engineer or architect?

A Visit Web sites associated with the professions.

- Construction Contractors Board: www.oregon.gov/CCB
- Structural Engineers (SEAO): www.seao.org
- Architects (AIA): www.aiaportland.org

The Bureau of Development Services would like to acknowledge the City of Los Angeles, Department of Building and Safety for its assistance and permission to reproduce certain materials for this program.

Helpful Information

Bureau of Development Services

City of Portland, Oregon
1900 SW 4th Avenue, Portland, OR 97201
www.portlandoregon.gov/bds

General Office Hours:

Monday through Friday, 8:00 am to 5:00 pm
BDS main number: 503-823-7300

Permit Information is available at the following location:

Development Services Center (First Floor)
For Hours Call 503-823-7310 | Select option 1

Permitting Services (Second Floor)
For Hours Call 503-823-7310 | Select option 4

For more information about seismic hazards in the Portland area and Pacific Northwest, visit:

- www.oregongeology.org
- www.pnsn.org
- www.crew.org

Important Telephone Numbers

BDS main number	503-823-7300
DSC automated information line	503-823-7310
Building code information	503-823-1456
Planning and Zoning information.....	503-823-7526
Permit information for electrical, mechanical, plumbing, sewer and signs.....	503-823-7363
Permitting process and fee information.....	503-823-7357
Resources and records	503-823-7660
BDS 24-hour inspection request line (requires IVR number and three-digit inspection code).....	503-823-7000
Residential information for one and two family dwellings.....	503-823-7388
Green Building Hotline.....	503-823-5431
City of Portland TTY	503-823-6868
Multnomah County Taxation & Assessment.....	503-988-3326
Multnomah County Planning & Zoning.....	503-988-3043

For more detailed information regarding the bureau's hours of operation and available services;



Note: All information in this brochure is subject to change.