WYOMING STATE GEOLOGICAL SURVEY
Lance Cook, State Geologist

HOW TO MAKE YOUR WYOMING HOME MORE EARTHQUAKE RESISTANT

by
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Prepared for the Wyoming Earthquake Program with funding from the Federal Emergency Management Agency and the Wyoming Emergency Management Agency.

Information Pamphlet 5 (revised)

LARAMIE, WYOMING
2001

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Printed on 50% recycled fiber paper. Revised edition of ? copies printed by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

Front cover: Pen and ink sketch of a typical Wyoming home, by Phyllis A. Ranz.

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Acknowledgments

This pamphlet was prepared under the auspices of the Wyoming Earthquake Program, with grant funding provided by the Federal Emergency Management Agency (FEMA) and the Wyoming Emergency Management Agency (WEMA). We would especially like to acknowledge Ed Wallace and Pat Bersie of WEMA for their review of the manuscript. We also appreciate the assistance of the Governor's Office of Emergency Services for the State of California, EQE International, the U.S. Department of Housing and Urban Development (HUD), and Wiss, Janney, Elstner Associates, Inc.

Introduction

Damaging earthquakes can occur in any part of Wyoming. By analyzing known active faults and the earthquake history of Wyoming, we have determined the potential for earthquakes in each region of the state as summarized below.

- In western Wyoming, the largest expected earthquake would have a magnitude of 7.5 and could produce ground shaking so intense that most masonry and frame structures in the vicinity of the epicenter could be destroyed.
- In central Wyoming, the largest expected earthquake would have a magnitude of 6.75 and could produce significant damage. Chimneys may fall, panel walls may be thrown out of frame structures, and partial collapse may occur in ordinary substantial buildings.
- In northern, eastern, and southern Wyoming, the largest expected earthquake would have a magnitude of 6.5. This could result in moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures.

Obviously, people can be hurt in their homes if the structure partially or completely fails during an earthquake. Mobile, modular, or manufactured homes can be dislodged from their support systems and fall to the ground, breaking gas lines and damaging attached structures. People can also be hurt in their homes from non-structural damage such as lights falling, bookcases tipping, free-standing wood stoves shifting, water heaters overturning, and natural gas connections breaking. In fact, in the United States, much of the personal injury that occurs during an earthquake is tied to non-structural damage to buildings.

This report is divided into two parts: Part I deals with conventional homes built on foundations, along with sections on securing wood-burning stoves, propane tanks, and objects in the home; Part II deals with the problems unique to manufactured, modular, and mobile homes.

Part I:
Making Your Wyoming Home More Earthquake Resistant

Introduction

There are actions that a home or building owner or contractor can take to reduce potential building damage and personal injury from either structural or non-structural causes. These actions are presented and explained below. It may be necessary to contact a contractor for unusual construction or situations. A completely risk-free environment is not possible and cannot be guaranteed, but if any of these suggestions are correctly implemented in your home, the chances of personal injury or property loss will be reduced.

More detailed information can be obtained from the Wyoming State Geological Survey (WSGS), the Wyoming Emergency Management Agency (WEMA), the Federal Emergency Management Agency (FEMA), the U.S. Department of Housing and Urban Development (HUD), or select offices of the Red Cross.

Mitigation of Structural Damage

If a house is not securely attached to its foundation, it could slip off the foundation during an earthquake. Although most new homes are securely attached, some new homes and many older homes may not be properly attached. If the foundation is sound, the home can be attached by bolting the sill plate to the foundation. Cripple walls (between the foundation and the floor joists) can be braced to accomplish the same attachment to the foundation.

Bolting a sill plate to its foundation

The sill plate is the lowermost horizontal wooden member of the frame of the house and it bears the upright portion of the frame. The sill plate should be bolted to the foundation by the following procedures:

Step 1 Drill $1/2$" or $5/8$" diameter holes about $8\ 1/2$" deep into the sill plate and concrete. These holes should be spaced every 4' to 6' along the sill plate (**Figure 1a**). The $1/2$" holes may be adequate for a typical one-story house. If the house is near an active fault, or is larger than one story, the $5/8$" holes may be preferable. Blow all the dust from the holes with a rubber tube (**Figure 1b**). Wear goggles and a dust mask.

Step 2 Tap a $^1/_2$" or $^5/_8$" diameter expansion bolt, 7" to 8 $^1/_2$" long, with a washer and nut attached, into the hole (**Figure 1c**) and tighten the nut down (**Figure 1d**). Do not over-tighten or the bolt will be damaged. For a $^1/_2$" diameter bolt use a 2"x 2"x $^3/_{16}$" plate washer and for the $^5/_8$" bolt, use a 2 $^1/_2$"x 2 $^1/_2$"x $^3/_{16}$" plate washer.

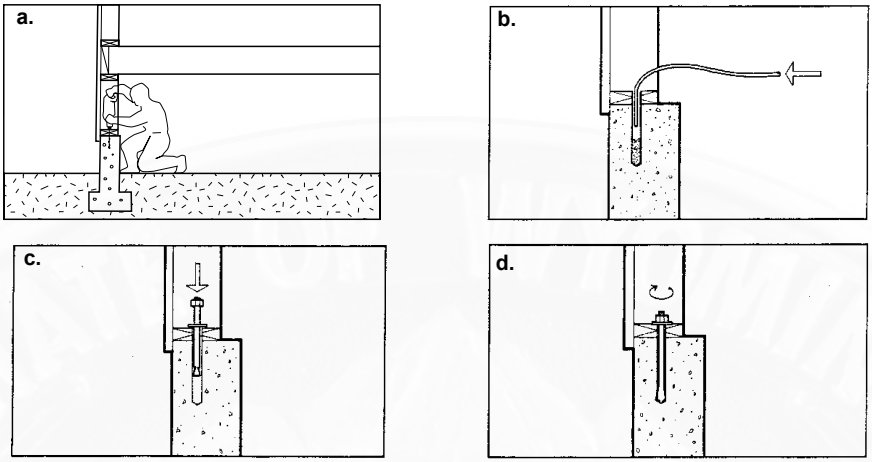


Figure 1. Bolting the wood frame (sill plate) of a house to its concrete foundation. Reproduced with permission from: Governor's Office of Emergency Services-State of California, Beat the Quake, Sacramento, California. Illustrations redrawn by Kit Wong, taken from Mary Comerio and Sanford Hirshen, The Earthquake Advisor's Handbook for Wood Frame Houses, a National Science Foundation funded project.

Further data for attaching a sill plate can be found in Idaho Bureau of Disaster Services (1992) and the Governor's Office of Emergency Services-State of California and the Federal Emergency Management Agency (1995).

Sheathing of cripple walls

Some Wyoming homes have short wood frame walls between the concrete foundation and the floor joists. These short walls are called cripple walls. If the cripple wall is not adequately braced, the home can shift sideways during an earthquake. The shifting can be minimized if the cripple wall is braced by attaching plywood sheathing to the vertical studs attached to the sill plate. Apply this sheathing as follows (**Figure 2**):

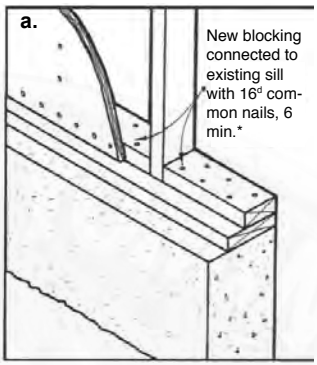
Step 1 If the sill plate is wider than the studs, install a horizontal block of wood as a bottom nailer between all of the studs. The bottom nailer must have the same width as the studs, and must be firmly attached to the sill plate (**Figure 2a**).

Step 2 Cut sheets of $^1/_2$" structural grade plywood so that the exposed portion of the cripple wall can be covered. If the cripple wall is

longer than the sheets of plywood, cut the plywood so that the adjacent sheets meet at the centerline of a stud.

Step 3 Nail the plywood to the studs by placing an 8d nail every 3" around the perimeter of each sheet, making sure that the nails are driven into the studs. Then place an 8d nail every 6" along each stud within the perimeter of the sheet (**Figure 2b**).

Step 4 Between each stud, drill a $1\,{}^{1}/_{2}$" ventilation hole at the top and the bottom of the plywood sheath. Position the holes a few inches up from the sill plate and a few inches down from the top plate.



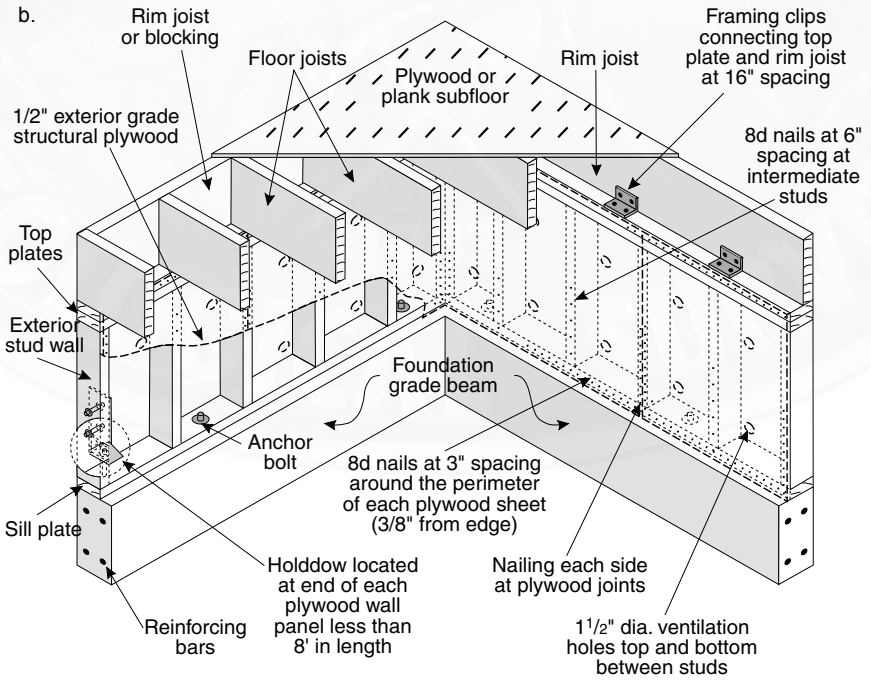


Figure 2. Sheathing of cripple walls. a. Sill plate detail; b. Wall detail. Reproduced with permission from: EQE International, 1995.

Masonry chimneys

Unreinforced masonry chimneys can topple or move during an earthquake. The part of the chimney that projects above the roof line most commonly fails, and can either topple to the ground or fall onto or through the roof. The safest approach with an unreinforced masonry chimney is to remove the chimney and replace it with a prefabricated metal flue system with a wood enclosure. This is most advisable in moderate to high seismic hazard areas. In lieu of replacing the entire chimney, the top part can be removed and replaced with a metal flue with a wood frame or by building a reinforced masonry portion that is tied into the roof.

If the chimney is located such that no property would be damaged or person would be injured if it fell, plywood can be added at the roof or attic level to protect the occupants of the home (EQE International, 1995). Replacing or stabilizing a chimney, however, usually requires professional expertise to ensure the system is properly installed and that all building codes are followed. It is not recommended that the homeowner or occupant undertake such an activity.

There are a few publications available that provide guidance to professional contractors or builders to make a chimney more earthquake resistant. A FEMA report (SOHA Engineers, 1998) and a State of California report (Governor's Office of Emergency Services-State of California and the Federal Emergency Management Agency, 1995) provide detailed information on stabilizing a chimney.

Mitigation of Non-structural Damage

Gas connections

Fires can cause significant damage after an earthquake. In homes, most fires start as a result of a broken or cracked gas line connected to an appliance, furnace, or water heater that moves during an earthquake. Although most newer homes have flexible gas supply lines connecting appliances, furnaces, or water heaters to the main gas line, many older homes may have solid pipes serving as the connection. Those solid connections should be replaced with a flexible connector that meets current building code standards. A licensed contractor should do the work.

Gas shut-off valves control the flow of gas into a home. A special seismic gas shut-off valve can be installed outside a home where the regular valve was located. Although the valves can be costly, they will automatically shut off the gas supply during an earthquake. The valves should be installed by a licensed plumber or contractor. Additional information on seismic gas shut-off valves may be obtained from a local building official, gas company, or from the WSGS. The City of Los Angeles has a web site on

seismic gas shut-off valves and manufacturers approved by the City of Los Angeles. The web address is: *http://www.socalgas.com/residential/safetyinfo/cityordman.html*.

Securing the water heater

During an earthquake, water heaters can be overturned which may result in a gas leak, a fire, or even an explosion. You can reduce these potential problems by anchoring the water heater to nearby walls and by anchoring the water heater to the floor, if possible. **It is also advisable to contact a licensed plumber to have a flexible gas connector installed from the supply line to the water heater.**

The following instructions* are for a 30- to 40-gallon water heater located within 12 inches of a stud wall (see **Figure 3**):

Materials needed:

(2) 6′ lengths of 1 1/2″ 16 gauge pre-drilled strap
(1) 10′ length 1/2″ EMT tube conduit
(4) 5/16″ x 3″ lag screws with washers
(4) 5/16″ x 3/4″ hex head machine bolts with 4 nuts and 8 washers
(2) 5/16″ x 1 1/4″ hex head machine bolt with 2 nuts and 4 washers

Tools needed:

Tape measure	Power drill
Hammer	3/8″ Drill bit
Hack saw	3/16″ Drill bit
Crescent wrench	Center punch
Vise or clamp	

Step 1 Mark the water heater 6″ down from the top and about 18″ up from the bottom, at least 4″ up from the controls. In the walls next to the water heater, locate the closest wood stud to the right side of the heater and the closest wood stud to the left side of the heater. Do not use studs located directly behind the water heater, however. Once the studs have been located, transfer the marks on the water heater directly across to the wall. There should be a total of four marks, with two on each stud.

Step 2 Drill a 3/16″ diameter hole 3″ deep through the wall sheathing and into the center of the wood studs at the four marks made in Step 1.

Step 3 Measure around the water heater and add 2″ to the measurement. Using a hack saw, cut two pieces of 1 1/2″ x 16 gauge metal straps

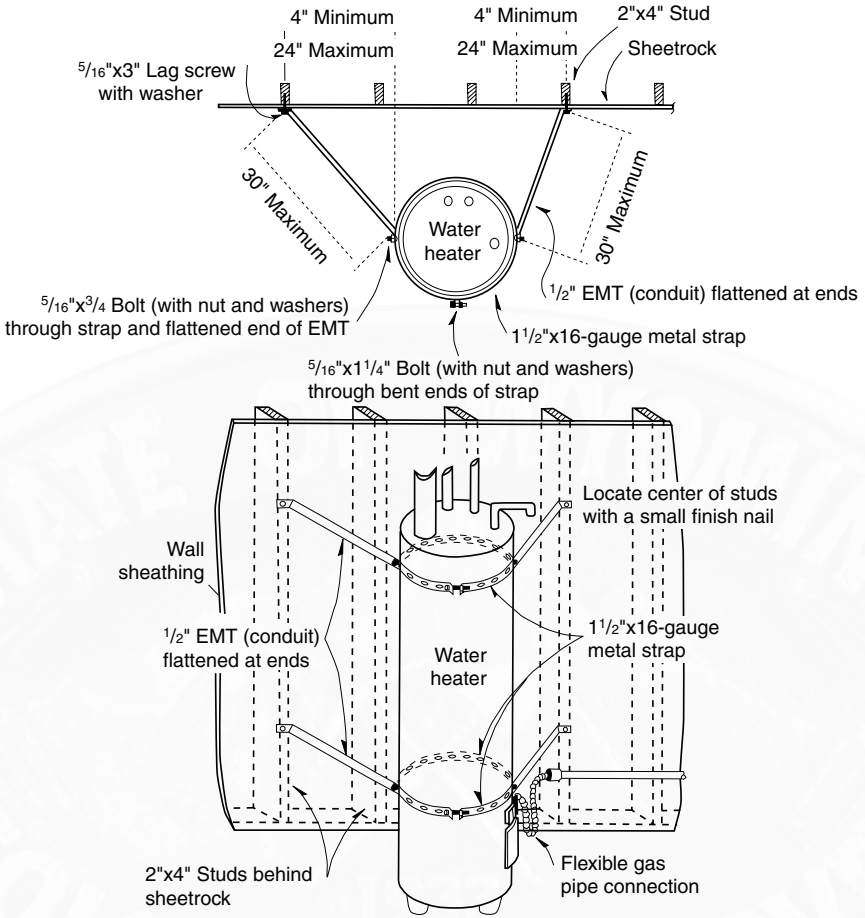


Figure 3. Securing a water heater, top and front views. Reproduced with permission from: EQE International, 1995.

to this length for encompassing the water heater. Mark 1 1/2" from each end of the straps and insert straps into a vise, or under a heavy object, and bend the ends to a 90 degree angle. Bend the straps into a curve for placement around the water heater.

Step 4 Measure the distance from each of the holes in the studs to a point midway on each side of the water heater where the straps will wrap. Mark this spot on the water heater for use in Step 6. Adding 1 1/2" to each measurement, cut a piece of 1/2" diameter conduit to length. Using a hammer, flatten approximately 1 1/2" at each end of the four pieces of conduit on a flat metal or concrete surface. Be sure both ends of conduit are flattened in the same plane.

Step 5 Insert the flattened ends of the conduit into a vise clamp and mark the center of the flattened area 3/4" from the end. Drill a 3/8" hole

at these marks. Measure in approximately 1" from the end of the conduit and bend the end up approximately 45 degrees (this angle may vary).

Step 6 Wrap each strap around the water heater, joining the bent ends at the front, and insert a 5/16" x 1 1/4" bolt with washers into the joined ends. Tighten nuts with fingers. Insert 5/16" x 3/4" bolts through the strap from the inside at the mid-point mark, made in Step 4, on each side of the water heater. Attach one end of each conduit to a protruding bolt, add a washer and a nut, and tighten with fingers. Insert a 5/16" lag screw in the opposite end of each conduit and insert into the holes in the wall studs. You may need to tap the lag screw gently into the hole to start it, then tighten with a crescent wrench.

Step 7 Adjust the straps to the proper height and lightly tighten all nuts.

In 2000, the Wyoming Energy Council received funding from WEMA to install a few water heater braces in homes in the Star Valley. They selected a prefabricated system built by Quake Safe and distributed by Quake Pro (Phone: 877-261-3897) in Salt Lake City, Utah. A diagram of the prefabricated system is shown to the right (**Figure 4**).

Figure 4. Prefabricated water heater brace built by Quake Safe and distributed by Quake Pro, Salt Lake City, Utah.

Securing wood-burning stoves

Freestanding wood-burning stoves are commonly used in Wyoming. Fire codes usually require a 36" clearance around an older unlisted stove and an 18" clearance around a single-wall stovepipe, except for zero clearance units, mobile home approved units, and other special applications. Many newer stoves, however, can be installed closer to combustibles, depending on the manufacturer's installation instructions. In any event, the stove is usually unsupported on all four sides and could easily tip over or slide during an earthquake. The stove could also be separated from the stovepipe. The following recommendations for stabilizing a wood stove are based on reports prepared by the Governor's Office of Emergency Services-State of California and the Federal Emergency Management Agency (1995); Wiss, Janney, Elstner Associates, Inc. (1994b); and the Idaho Bureau of Disaster Services (1994).

Stoves on a brick hearth

For stoves on a brick hearth, there are two options (see **Figure 5**):

Option 1. Use a masonry bit to drill a 1/2" diameter hole in the center of four new bricks. For each leg, insert a 3/8" diameter bolt (**A**, on **Figure 5**) through a brick and a 1/2" hole in the stove leg. Carefully tighten the bolt and brick (**B**) to the stove leg with a washer and nut. The bricks can now be grouted to the top of the hearth with 1" of new grout (**C**).

Option 2. New bricks can be placed around the stove legs (**D**) and grouted into place (**C**), leaving a pocket for each leg. The stove legs can then be secured to the hearth by filling the pockets with grout.

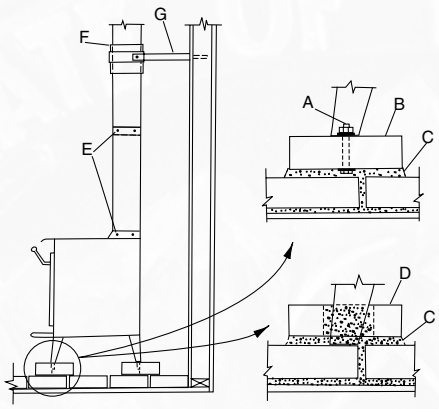


Figure 5. Securing wood-burning stoves. Letters on diagram are explained in the text. Reproduced with permission from: Governor's Office of Emergency Services-State of California and Federal Emergency Management Agency (1995) and Wiss, Janney, Elstner Associates, Inc. (1994b).

Stove Pipes

Secure stovepipes to the flue exit and fasten pipe segments together with sheet metal screws (**E**, **Figure 5**). The screws must not penetrate the inner pipe wall if the pipe is of double wall construction.

Install one mid-height support if the stovepipe is unsupported for more than 8′ between the stove and ceiling. Do this by running the stovepipe through a ready-made attic radiation shield with a pipe clamp (**F**) that is braced to the wall using two Simpson WTT187 tension ties (**G**) or equivalent. Attach the tension ties to a wall stud with 3/8"x 3" lag screws to prevent lateral movement.

Stoves on a concrete slab

Anchor stoves on a concrete slab on grade directly to the concrete using 3/8" diameter expansion anchors embedded 3" into the concrete.

Stoves approved for mobile homes

These units usually come with pre-drilled holes in the legs. The legs can be safely anchored to the underlying floor framing using 3/8" diameter bolts and an oversized 2" diameter fender washer on the underside of the wood flooring.

Other stove configurations

For configurations other than the ones discussed above, consult your stove vendor and/or local fire department.

Securing propane tanks

Many rural homes use propane to provide fuel for heating, cooking, and the operation of gas appliances. Propane tanks can slide, rock, or overturn during an earthquake, which could break the supply line and/or rupture the tank. The following information on securing a propane tank (see **Figure 6**) is derived from Governor's Office of Emergency Services-State of California and the Federal Emergency Management Agency (1995); Wiss, Janney, Elstner Associates, Inc. (1994b); and the Idaho Bureau of Disaster Services (1994).

Step 1 Mount the tank on a continuous concrete pad that is 6" thick and 1 foot wider than the tank on either side (**A, Figure 6**). Attach the tank legs to the pad with 1/2" diameter bolts (**B**) embedded a minimum of 3" into the concrete pad. For an existing pad, use a masonry drill to drill holes 4" to 5" deep for 3/8" expansion anchors.

Step 2 Provide a flexible hose connection between the tank and the rigid supply line (**C**), and where the supply line enters the house.

Step 3 Clear the area around the tank of tall or heavy objects that could fall and rupture the tank or supply line. Keep a wrench tied on a cord near the shut-off valve and instruct others how to turn off the supply line if they smell gas.

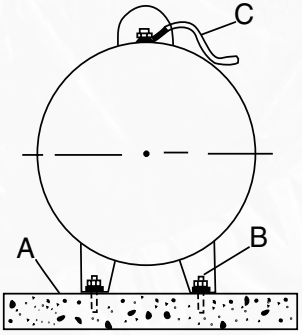


Figure 6. Securing a propane tank. Letters on diagram are explained in the text. Reproduced with permission from: Governor's Office of Emergency Services-State of California and Federal Emergency Management Agency (1995) and Wiss, Janney, Elstner Associates, Inc. (1994b).

A special seismic shut-off valve can be installed for large tanks. Although the valves can be costly, they will automatically shut off the gas supply during an earthquake.

Securing objects in the home

Falling, tipping, or overturning objects often cause personal injuries during an earthquake. Overturned objects may also block hallways and doorways making it difficult to enter or exit. There are many simple things you can do to reduce the possibility of such injury or blockage.

Hanging pictures and mirrors

Hanging pictures or mirrors that dislodge and fall during an earthquake can cause personal injury, especially if they are near a sitting or sleeping area. In turn, broken glass resulting from the fall can cause injury after an earthquake. In many cases, pictures may also be valuable or irreplaceable. Much of this risk can be minimized by hanging pictures on hooks screwed into wood members only (stud or ceiling joists) (**Figure 7**). Close the hooks used for hanging pictures and mirrors to prevent the objects from falling.

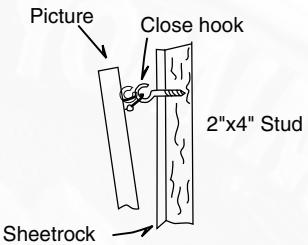


Figure 7. Hanging pictures and mirrors. Reproduced with permission from: EQE International, 1995.

Cabinets and drawers

Cabinets and drawers often contain glassware, household chemicals, sharp objects, or food. Securing the cabinets and drawers may prevent injury and reduce financial loss after an earthquake. The installation of positive catching latches (such as childproof latches) secures the cabinets and drawers. Many types of latches, as illustrated in **Figure 8**, are available at hardware stores, lumber yards, and cabinet shops.

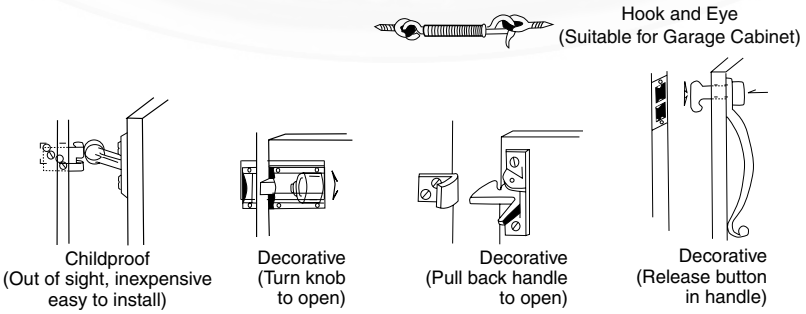


Figure 8. Types of positive catching latches for cabinets and drawers. Reproduced with permission from: EQE International, 1995.

Tall furniture

Tall furniture, such as a bookcase, can easily tip over during an earthquake. Stabilize these objects by installing metal "L" brackets or "Z" clip brackets between the furniture and wall studs, preferably at the top of the unit (**Figure 9**). The "L" bracket can be installed upside down so that it will be hidden from view. For freestanding units, attach brackets to the base of the unit and to the floor.

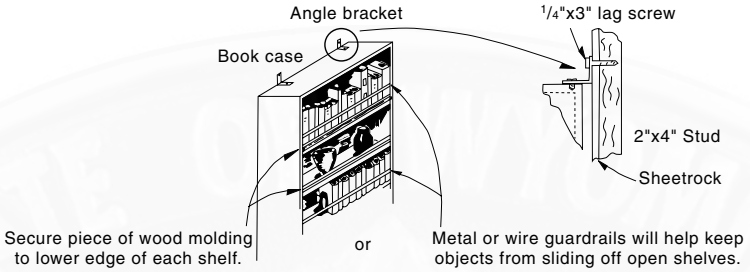


Figure 9. Securing tall furniture and open shelves. Reproduced with permission from: EQE International, 1995.

Open shelves

Keep the top shelves free of heavy items, especially if located near a sitting area or a bed. Place heavy objects on lower shelves. Install a guard across the shelf. A wood molding attached to the front lower edge of each shelf will also help to prevent objects from sliding off the shelf (**Figure 9**).

Part II.
Making Your Manufactured, Modular, or Mobile Home More Earthquake Resistant

Introduction

While the frame constituting the structure of manufactured, modular, and mobile homes is typically earthquake resistant, the method of mounting the home at its site makes this type of construction especially vulnerable and particularly susceptible to damage during moderate and major earthquake activity. Even moderate earthquakes may dislodge these homes from their support systems (piers), allowing the homes to fall to the ground. When this happens, gas lines inside or outside the home can break, and structures such as awnings, decks, and skirting may be damaged beyond repair. Even

homes that are braced typically utilize unconventional material such as blocks of wood or flat rocks for piers, which in turn contribute greatly to the structure's instability.

For specific instructions on mitigating structural damage to a manufactured, modular, or mobile home, see the discussion below. While the guidelines for mitigating non-structural damage given in **Part I** (above) can be applied to a manufactured, modular, or mobile home, additional precautions and instructions for gas appliances in manufactured, modular, or mobile homes is given below in the section on **Mitigation of Non-structural Damage**.

Principal considerations in preparing manufactured, modular, or mobile homes to resist earthquakes include:

- Preventing the home from falling to the ground by installing one of a number of braced foundation support designs that are available.
- Preventing the movement of gas-burning appliances by using correct bracing.
- Installing flexible gas lines into the home and to gas appliances.

This section outlines ways to reduce or prevent damage to both new and existing manufactured, modular, or mobile homes. While these suggestions do increase the cost of home installation, they can–if implemented properly–provide significant savings by reducing or eliminating the cost of repairing the home after an earthquake.

Mitigation of Structural Damage– Bracing Systems

There are a number of actions that a homeowner or contractor can take to minimize the movement of manufactured homes and accessory structures during an earthquake. These actions can be as complex as installing an engineered earthquake resistant foundation or as simple as leaving the axles and hitch attached to the home. More detailed explanations and instructions can be found in Steven Winter Associates, Inc. (1995) and in Wiss, Janney, Elstner Associates, Inc. (1998). A summary of key items from the reports is presented below, with the actions ranked from most effective to least effective.

Earthquake resistant foundations

Earthquake resistant foundations are usually designed with perimeter walls and footings, and may be built similar to foundations for conventional housing. In addition, earthquake-resistant piers should be placed under

the main beams of the home and under the marriage walls for double-wide units. Greater detail can be found in University of Illinois at Urbana-Champaign, School of Architecture-Building Research Council, (1996). The 1997 Uniform Building Code also provides guidance on attaching homes to permanent foundations.

Additionally, homes located in areas that are both seismic prone and subject to snow loads in excess of 30 pounds per square foot (psf) should be installed on permanent foundations (Steven Winter Associates, Inc., 1995).

Earthquake Resistant Bracing Systems

Earthquake Resistant Bracing Systems (ERBS) can range from a system that serves to catch a home if it falls off its piers during an earthquake, to a system that minimizes both horizontal and vertical movement of the home through connections between the bracing system, the home, and the footings. Due to their complexity, the homeowner should contact a qualified home installer or contractor for obtaining and installing ERBS. A list of bracing systems certified for use in California is included in the **Appendix.**

A useful publication on ERBS is *Manufactured Housing Earthquake-Resistant Bracing Systems Subjected to the Northridge Earthquake* (Wiss, Janney, Elstner Associates, Inc., 1994a). A copy of the publication is on file at the Wyoming State Geological Survey.

Engineered tie-down systems

Engineered tie-down systems are designed to anchor the home to modified piers, which in turn are attached to the ground in a variety of ways. The piers can be steel piers or concrete blocks. In 2000, the Wyoming Energy Council received funding from WEMA to install an engineered tie-down system to a number of mobile homes in the Star Valley, western Wyoming.

The system, called Vector Dynamics, was designed by Tie Down Engineering, Inc. It consists of piers composed of concrete blocks that are placed on steel foundation stabilizer pads with flanges that are driven into the soil. Piers are placed opposite one another under the support beams of the home, with the piers separated and attached to one another by a compression brace. Steel straps are then used to tie the pier system together and to attach the piers to the support beams. The straps extend from the inside lower edge of each pier to the outside edge of each opposing pier, and cross over the support beams in order to attach the system to the home. The Wyoming Energy Council (Phone: 307-742-0313) can provide additional data on the system.

There are a variety of types of engineered tie-down systems. Some are composed of steel piers anchored in concrete and bolted to the frame. Others are composed of steel piers that are bolted to the frame and attached to base plates. The base plates are then attached to long rods driven into the ground. A current list of approved tie-down systems can be obtained from the State of California, Department of Housing and Community Development, Mobilehome Parks Program, Sacramento, California (Phone: 916-445-4782).

Ground anchors

Most homes have some type of anchors or straps that stabilize the home, primarily to resist wind storms. Ground anchors have not been fully tested under earthquake-like conditions and should not be solely relied upon for withstanding the effects of ground shaking associated with an earthquake. To a limited degree, however, they may help to stabilize a home during an earthquake when properly installed.

Unless other instructions or regulations are available, anchors and tie-down straps should be installed as follows:

1) Place anchors and tie-downs a maximum of eight feet on center on the sides of the home.

2) Install a minimum of two anchors on the ends of each home section near each frame I-beam.

Check with your local building department to determine if more stringent regulations apply.

Steel piers

Steel piers, which are typically easy to install and adjust, provide little bearing surface to properly support the home in the event of an earthquake. There are actions a homeowner can take, however, to increase pier stability and possibly prevent the home from jumping off its piers or footings. When steel piers are used, they should be bolted to the main beams of the home as well as fastened to their footings. Steel piers designed to be attached in such a manner are usually available through most home installers. More detail can be found in Steven Winter Associates, Inc. (1995).

Axles and hitches

Mobile home residents can somewhat minimize earthquake-related damage to their homes by simply leaving the axles and the hitch attached and under the home. This may prevent the home from falling completely to the ground and may make reinstallation easier and less expensive. The

axle and hitch may be removed, however, if an ERBS or other approved support system is used.

Additional information

For more detailed instructions and information on bracing systems, contact your local building department, local housing installers or contractors, HUD, or refer to the references and the list of certified bracing systems at the end of this publication.

Following an earthquake, visually inspect piers, anchors, and utility connections to the manufactured, modular, and mobile homes. If problems with the support system or the utility connections exist, do not attempt to correct these problems yourself. Contact a home installer or contractor for the necessary repairs to either the support system or to the utility connections of the home.

Mitigation of Non-structural Damage– Gas appliances

Earthquake-related fires are usually the cause of seriously damaged or destroyed manufactured, modular, or mobile homes. Most fires originate from a ruptured gas line when movement of a gas appliance during an earthquake breaks the gas connection. Gas water heaters can also topple out of manufactured, modular, or mobile homes through an exterior door or through an access panel to the water heater compartment. This often causes broken gas lines. Additionally, as homes fall from their foundations and support systems, they can break the gas meter or pipe leading to the home. The following suggestions, which are derived from Steven Winter Associates, Inc. (1995) and from Governor's Office of Emergency Services-State of California and the Federal Emergency Management Agency (1995), will help minimize potential damages:

- Secure all gas appliances, such as cook-stoves, water heaters, and furnaces to wall studs near the appliance. Utilize brackets to attach stoves and furnaces to nearby wall studs. In some cases, water heaters can be attached using instructions on page _ of this brochure. If the water heater is in a closet, however, it can be secured by wrapping two loops around both the upper and lower half of the water heater with 3/4" 24 gauge steel plumbers tape. Secure the ends of the four steel tapes to wall studs with 1/4"x 3" lag screws and washers (**Figure 10**).
- Make certain that all gas appliances have flexible connectors installed between the supply line and the appliance.

- Make certain that approved flexible gas connectors are installed between the gas meter and the home. This will allow limited movement of a home without significant damage to the gas system. It is recommended that the home be placed a minimum of three feet from the gas meter, when possible. The flexible connector length should be twice the distance of the home from the gas meter, which will increase the allowable movement of the home before damage occurs.
- Seismic motion detectors and gas detectors are available for consumer use to minimize the potential hazard of gas leaks. These devices will stop gas flow when either a gas leak is sensed or during seismic ground motion.

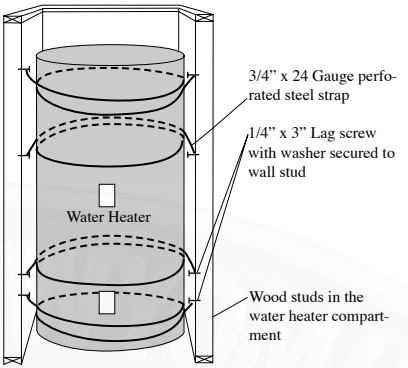


Figure 10. Securing a water heater located in a closet or confined space in a manufactured, modular, or mobile home. Reproduced with permission from Steven Winter Associates, Inc., 1995.

In the event of an earthquake, do not operate electrical switches if you smell gas. Natural gas is easily ignited by open flames that exist in a standing pilot light and by sparks from switches and other electrical devices. If you smell gas, leave all switches in their current position to avoid the possibility of electrical sparks.

Additional actions to maintain the water heater and its compartment include replacing deteriorated flooring and installing a drip pan beneath the water heater. The drip pan should have an exterior drain, if possible. Also, be sure to have the pressure relief valve tested and ensure it is plumbed through the floor.

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Appendix

List of certified Earthquake Resistant Bracing Systems (ERBS), Effective January 12, 2000. From State of California, Department of Housing and Community Development, Division of Codes and Standards.

Manufacturer:	American Foundation Systems
Model Number:	EL9
Product Name:	American Foundation
Listed By:	BSK & Associates
Listing Number:	F01600438
Telephone Number:	(805) 227-4547

Manufacturer:	Central Piers
Model Number:	CP Anchor Pier
Product Name:	CP Seismic Pier #1
Listed By:	Certified Testing & Consulting Services
Listing Number:	17-1428-01(CP)
Telephone Number:	(209) 268-0828

Manufacturer:	Central Piers
Model Number:	ERBS
Product Name:	CP Seismic Pier
Listed By:	
Listing Number:	CP 186.5
Telephone Number:	(209) 268-0828

Manufacturer:	C & R Pier Manufacturing
Model Number:	CRP-BI-L
Product Name:	Maxi-Pier
Listed By:	Preferred Construction Inspections
Listing Number:	3852-11
Telephone Number:	(714) 788-7810

Manufacturer:	C & R Pier Manufacturing
Model Number:	CRP-B2
Product Name:	Safe-T-Beam
Listed By:	Preferred Construction Inspections
Listing Number:	3852-12
Telephone Number:	(714) 788-7810

Manufacturer:	Die Namic Fabrication, Inc.
Model Number:	System 2000
Product Name:	Hedra X
Listed By:	

Listing Number:	Hedra X 2000
Telephone Number:	(909) 350-2870

Manufacturer:	Gus-Guard
Model Number:	2460-12G
Product Name:	Gus-Guard
Listed By:	BSK & Associates
Listing Number:	F94249-G
Telephone Number:	(209) 966-5540

Manufacturer:	Gus-Guard
Model Number:	TUF-1
Product Name:	Gus-Guard
Listed By:	BSK & Associates
Listing Number:	F94249
Telephone Number:	(209) 966-5540

Manufacturer:	Jordon Systems
Model Number:	GHF 31
Product Name:	Mattguard
Listed By:	Industrial Testing International
Listing Number:	17-1051-02
Telephone Number:	(831) 761-7990

Manufacturer:	Magnum Foundation Systems
Model Number:	300
Product Name:	Magnum Foundation Systems
Listed By:	BSK & Associates
Listing Number:	01600832
Telephone Number:	(541) 942-3465

Manufacturer:	Merriman's Inc.
Model Number:	MRMN-1
Product Name:	Quakemate
Listed By:	Preferred Construction Inspections
Listing Number:	4646-1
Telephone Number:	(714) 795-5361

Manufacturer:	Merriman's Inc.
Model Number:	MRMN-B2
Product Name:	Quakemate Pier
Listed By:	Preferred Construction Inspections
Listing Number:	4646-2
Telephone Number:	(714) 795-5361

Manufacturer: Mobile Home Foundation Products
Model Number: Super 6
Product Name: E R Brace
Listed By: Preferred Construction Inspections
Listing Number: 4148-1
Telephone Number: (909) 940-4066

Manufacturer: Mobile Home Foundation Products
Model Number: MHFP-SSJ
Product Name: Super Safety Jack
Listed By: Preferred Construction Inspections
Listing Number: 1055-1 (ABS Pier Pads)
Telephone Number: (909) 940-4066

Manufacturer: Pacific Bracing Co.
Model Number: 900110
Product Name: Homeguard
Listed By:
Listing Number: 4502-1
Telephone Number: (800) 368-3727

Manufacturer: Quake Master
Model Number: 1002
Product Name: Quakemaster
Listed By:
Listing Number: 54238 & 16286
Telephone Number: (714) 373-1950

Manufacturer: Quake Safe
Model Number: QS112191
Product Name: QS112191
Listed By:
Listing Number: 01600138
Telephone Number: (800) 726-5955

Manufacturer: Replacon
Model Number: RP1900 & RP2000 Series Pads & Stands
Product Name: BDB Polymer 2000 Systems
Listed By: BSK & Associates
Listing Number: F01601053
Telephone Number: (530) 633-2050
Manufacturer: Sure Safe Industries, Inc.
Model Number: 550
Product Name: Sure Safe Steel Butress System
Listed By: Preferred Construction Inspections

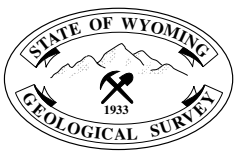
Listing Number:	1056-1 (M)
Telephone Number:	(800) 322-1999

Manufacturer:	Sure Safe Industries, Inc.
Model Number:	ERB 2-41
Product Name:	Sure Safe Isolator System
Listed By:	Preferred Construction Inspections
Listing Number:	4920.2
Telephone Number:	(800) 322-1999

Manufacturer:	Sure Safe Industries, Inc.
Model Number:	ERBS 550S
Product Name:	Sure Safe 550 ERBS Wood
Listed By:	Preferred Construction Inspections
Listing Number:	
Telephone Number:	(800) 322-1999

Manufacturer:	Stabilizer Systems, Inc.
Model Number:	GSSI-2871
Product Name:	SSI (ERBS)
Listed By:	Preferred Construction Inspections
Listing Number:	3973-2
Telephone Number:	(800) 558-1222

Manufacturer:	Western Ground-Loc Systems, Inc.
Model Number:	GL 200 E
Product Name:	Ground-Loc ERBS
Listed By:	Preferred Construction Inspections
Listing Number:	1145-1
Telephone Number:	(909) 464-0825



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