# Bracing for the Big One

*Earthquake damage to this historic house occurred where it had settled, due partially to over-watering of the lawn. Temporary shoring prevented additional damage and the house was repaired using several of the retrofit techniques described in this brochure.*

## Prepare your house to weather an earthquake.

Old buildings and earthquakes can be a deadly, and costly, combination. Owners need to know how to upgrade historic buildings to improve their chance of surviving a major earthquake.

The primary goals of a seismic retrofit project are to improve life safety and minimize damage to the building from a strong earthquake. This information will help you plan and carry out a seismic upgrade while preserving the important features and character of your historic house.

## Earthquake Risk in Utah

While thousands of Utah's historic buildings are located along the Wasatch Front, an area of high seismic risk, the earthquake near St. George Utah in September 1992 damaged many houses and showed that buildings throughout Utah are vulnerable to earthquakes. Most Utahns live in an area of earthquake risk similar to much of California — only the eastern edge of Utah is at low risk.

## Utah's Historic Houses

Historic buildings, particularly houses, are an important part of nearly every community in Utah. Over two thousand have been listed on the National Register of Historic Places. Thousands more add to the character and quality of our communities and provide important housing. Historic houses often have features, materials, craftsmanship, and style impossible to duplicate. Many have been restored or rehabilitated, often by dedicated, do-it-yourself homeowners. Rare antique or reproduction furnishings are often showcased in these historic houses. The financial and emotional investment can be substantial.

Historic houses were constructed without the knowledge of modern seismic building codes and many materials are weaker than today's equivalent. However, with careful, sensitive retrofitting, historic buildings can be made much safer while maintaining their architectural integrity and historic character.

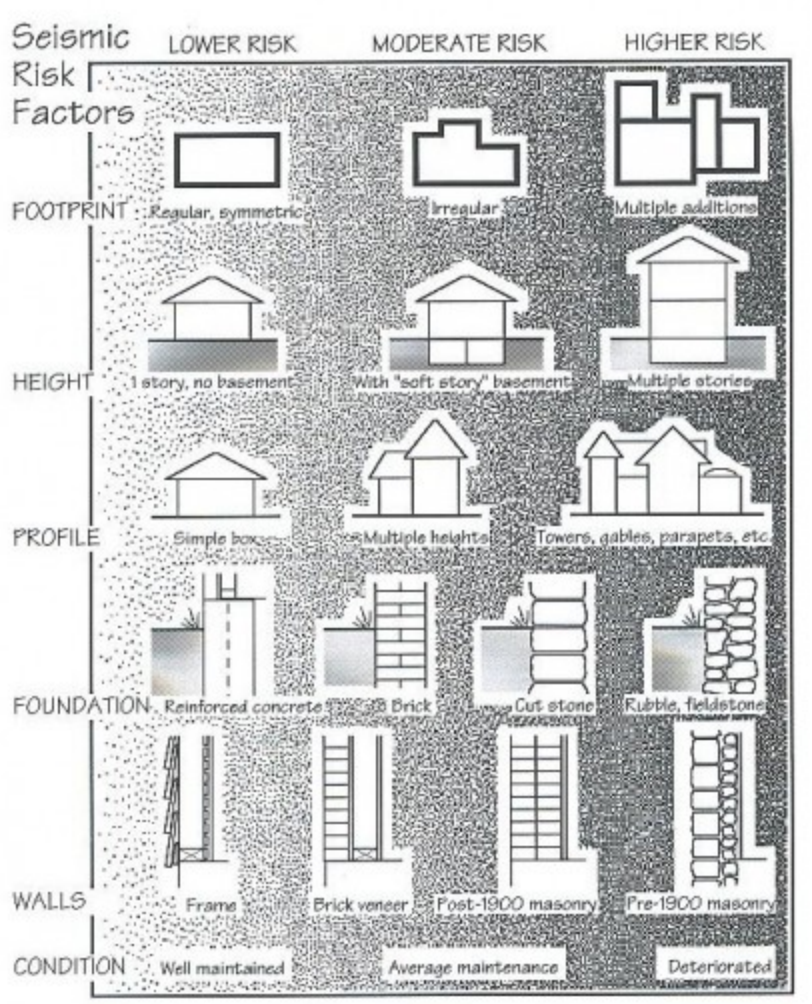
## Reducing the Risk

Many of the techniques described in this brochure were used in the seismic retrofit of four older houses in Ogden Utah, during the summer of 1992. The solutions are typically low or moderate in cost and can often be performed by the experienced, do-it-yourself homeowner. Including seismic upgrading as a part of other repair or rehab work, as was the case in these demonstration projects, will minimize total cost.

The demonstration retrofit work also was sensitive to the historic character of the houses. With careful investigation, planning, and retrofit work, you can improve your personal safety and the seismic performance of your historic house.

# Understanding Earthquakes & Historic Houses

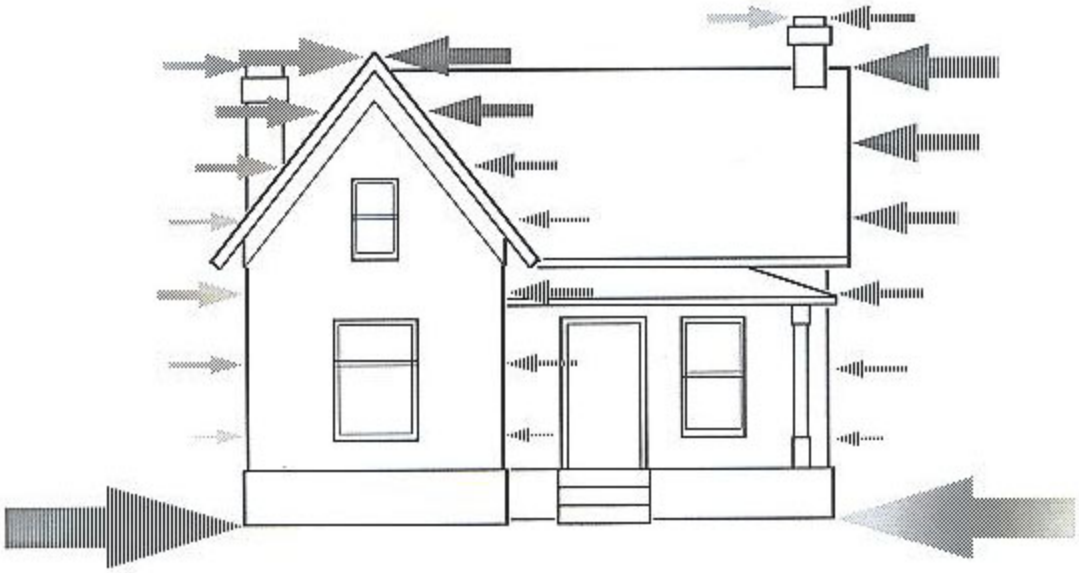
## Risk Assessment




Most of the damage buildings suffer during an earthquake is due to the ground shaking back and forth. Many houses, particularly older ones, were not built to withstand this shaking caused by earthquakes. Some houses are more resilient than others in an earthquake. Shape, height, materials, and construction techniques are important factors when evaluating seismic risk.

Compare your house to the seismic risk factors generalized in the accompanying table. (The table is for summary purposes only — the individual risk factors may not be equal.) Higher-risk houses may require more elaborate or complex retrofit solutions and professional assistance from an architect, engineer, and contractor experienced with historic structures.

Each part of the house must be able to resist the shaking and horizontal forces caused by the earthquake and transfer the resulting forces the next building element until these forces reach the ground.



Horizontal earthquake forces (back-and-forth shaking) create 'whipping' forces in all parts of a building. These forces must transfer between parts of the building to the foundation.

Horizontal forces on chimneys must be transferred to bracing and the roof structure; the forces on the roof must be transferred to the walls; the walls also receive the forces from ceilings and floors; forces in the walls must be transferred to the foundation and back to the ground. Similar force transfers must happen between almost every building part. If any part is weak or poorly connected it may fail and other members or connections must pick up the extra load.

Earthquake forces exploit any weak or damaged “link.” A thorough investigation and understanding of the structure of a house is required to identify, and then strengthen, these weak links.

## Investigating Your Historic House

A complete evaluation of the materials, structure, and historic features of a house should extend from roof top to foundation, on all sides, and from within every space, from attic to basement or crawlspace. In addition to the building’s structure, investigate the ability of furniture, cabinets stored or displayed objects, and other interior features to: resist horizontal forces. These items can be particularly dangerous in an earthquake end comprise a large part of the total value of a house. Photograph all parts of your historic house when you inspect it to document its construction, condition, and contents. The checklist on the next page will help guide your whole-house seismic inspection.

# Inspection Checklist

## Finding the Weak Links

### Foundation

- Are there any signs of settlement or movement?cracks. sloped floors, leaning walls?
- With brick or stone foundations, is the mortar loose or missing? On a concrete foundation. is it deteriorated, spalling, etc.?
- Is there any sign of deteriorating wood, termites, or water damage?
- Do the downspouts dump water near the foundation or does the ground slope toward the foundation, allowing water to “pond” next to the building and accelerate deterioration of the foundation or cause settlement?

### Walls & Columns

- Are columns, particularly in the basement, rotted, undersized, or poorly attached to the basement floor or the wood beams they support?
- Is there a “soft” story?weak, undersized, unbraced walls or columns such as a garage or an open basement supporting a heavy, solid portion of the house?
- Are there any “cripple” walls (i.e., wood studs without structural sheathing or plywood) supporting floors or walls above?
- Is there any cracking in the brick walls (i.e., cracks through the individual bricks or substantial movement), particularly above, below, or between windows or doors?
- Are there any masonry parapets or gables?
- Are bricks cracked, loose, spalled, or missing?
- On multiple wythe masonry walls (multiple layers of brick), are header bricks (narrow end facing out) absent?
- Are there large openings in the exterior walls, or openings which were added or enlarged?
- Are any additions to the house not securely attached to the house or pulling away due to settlement or a poor foundation?
- Are porch columns angled, shifting, unsecured to porch deck or roof, or “punching through” the porch deck?

### Floors & Ceilings

- Is the bridging between the joists poorly secured, absent, or spaced more than 8 ft. apart?
- Are the floor joists simply resting on the foundation, in joist pockets, or only toe-nailed to walls?
- Have any joists been substantially cut away, particularly where plumbing, wiring, or ductwork was installed?

- Are any joists split, twisted. or rotted?

**Roof**

- Are there rafters or trusses that are not attached with fasteners to the load bearing (usually exterior) walls?
- Is the roof decking only boards with gaps between (skip sheathing) instead of continuous plywood?
- Are there heavy roofing materials such as tile or slate?
- Are masonry chimneys, parapets, or gables unbraced, unreinforced or not secured to roof or ceiling structure?
- Is the mortar on the chimney deteriorated?

**Historic & Interior Features**

- Is the plaster cracked (more than hairline or seasonal cracking)?
- Are there tall furnishings unsecured to walls?
- Could hanging or tall light fixtures swing into walls or fall if they swing?
- Is the water heater freestanding, not secured to the building structure? Is the gas supplied through a rigid pipe?
- Do cabinet doors swing free (i.e., not secured with latches)?
- Are valuable objects, knickknacks, or equipment (computers, etc.) unsecured or on open shelves?

**Site & Building History**

- Are there parts of neighboring buildings or site features (e.g., chimneys or retaining walls) which could damage your house if they collapsed?
- Has the house been damaged by previous earthquakes or ground settlement?
- Has there been heavy, repeated shaking of the ground by heavy equipment?
- Has the house been poorly maintained over time?

If you answered “yes” to any of these questions, your house may be at greater risk from an earthquake. Many possible repair or retrofit options are presented on the next pages and in greater detail in the sources listed on the last page. Much of this seismic retrofit work could be executed by the experienced, do-it-yourself homeowner with the right tools and good building repair skills. Be realistic about your abilities and available time. Have good lighting and tools, and always wear protective clothing (goggles, dust mask, gloves, etc.). Follow the manufacturers’ installation recommendations carefully.

Take advantage of other building repair projects to improve seismic strength. Replacing the roof? Add a new plywood roof deck, connections to walls, and chimney bracing. Removing lath and plaster? Install joist/wall seismic connectors, shear walls, etc.

Substantial retrofits such as adding new foundations or shear walls may require the professional assistance of a licensed engineer, architect, and/or contractor. Contact several firms and evaluate their experience with historic structures and residential seismic retrofits. Check their references. Have a clear, legal contract. Before starting any work, check with your local building official about required permits.

# Seismic Retrofit – Reducing the Risk

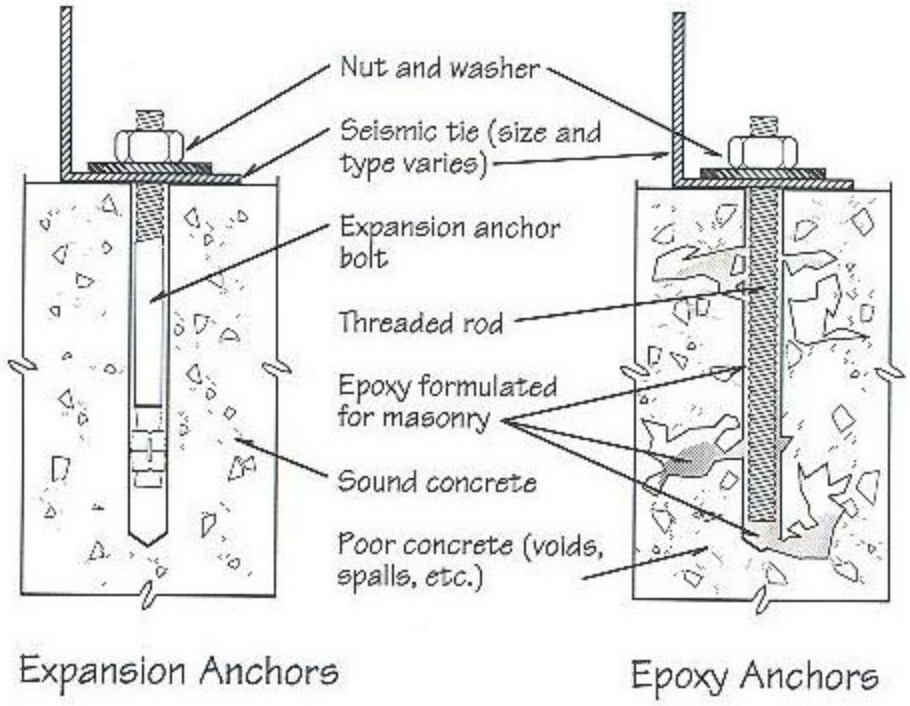
## Preserving Historic Integrity

Poorly planned or insensitive repairs can destroy the architectural integrity of a historic house. The Secretary of the Interior's "Standards for Rehabilitation" are a recognized approach to maintaining the important, character-defining features of a historic building when any repair, rehabilitation, or restoration work is performed. The "Standards" encourage the repair and retention of significant historic materials and features. They are used by many government agencies when planning, reviewing, or performing preservation work. (A copy of the "Standards and many other supporting materials can be obtained from the Office of Historic Preservation, Utah Division of State History.)

Identify and evaluate the important historic features in your house. How can they best be maintained? Can they be avoided in the seismic retrofit by opening the other side of the wall or ceiling? How can impact and damage be minimized? Repair any unavoidable damage with compatible materials and techniques.

## General Repairs

In a very basic sense, maintenance is preservation. Caring for all aspects of an historic building will help maintain its structural strength. Repointing mortar joints, replacing rotted wood members, and keeping wood and foundations dry will help preserve a building, even in an earthquake.



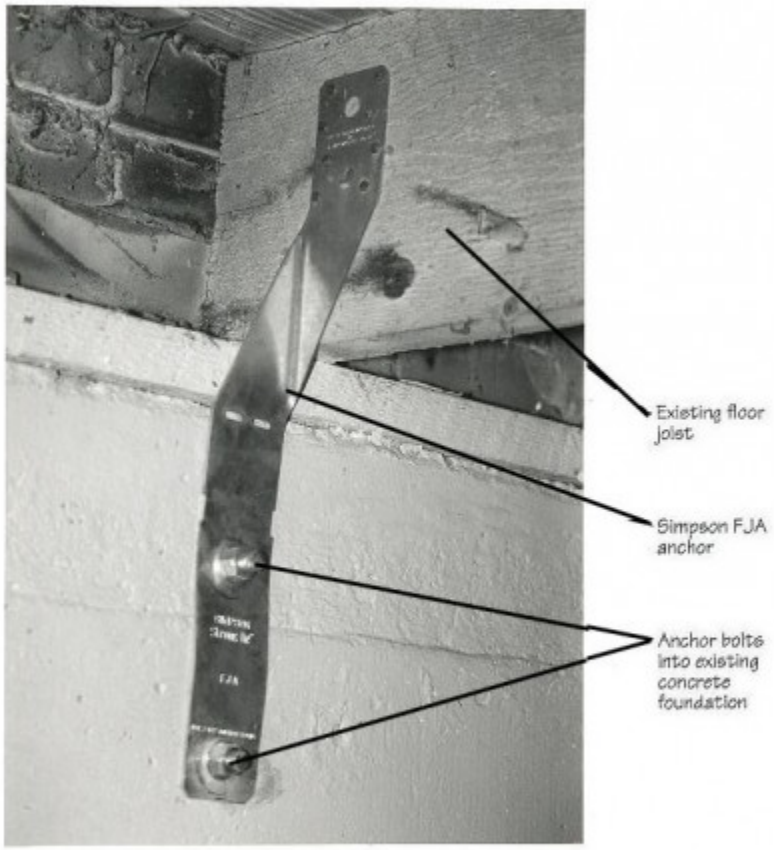

Water can create deterioration in many ways and locations. Keep your roof and eaves in good condition. Drain downspouts away from the foundation. Slope the surrounding ground away from the house. Minimize foundation plantings and irrigation. “Ponding” water can cause settlement that will weaken the building.

Repair or replace damaged joists or rotted members by adding new beam ends or “sistering” on new joists (i.e., attaching new joists alongside the old). If the existing basement columns have rotted, replace or install new columns, securing to beams and foundation with metal fasteners such as Simpson AC post caps.

Repoint cracked and open mortar joints, matching the historic mortar (color, composition, hardness, and profile). Add reinforcing when possible. Tight mortar joints keep water out of a wall, add strength to the masonry, and can secure individual bricks in an earthquake. Repointed chimneys performed better in the 1992 St. George earthquake than loose, deteriorated chimneys.

## Foundations

## Install Anchor Bolts




Foundation Anchors

Anchor bolts secure sill plates, seismic ties, etc. to masonry foundations. Expansion bolts can be used in strong concrete; epoxy anchors (e.g., Hilti HVA or Dur-O-Pair) should be used in poor concrete, brick, and some stone foundations. Typical spacing for anchoring sills and walls of lightweight, frame construction is about 4 feet on center; closer spacing will be needed with poor foundations or larger loads. Material cost varies, about $5-15 per anchor.

### Secure Joists to Foundation

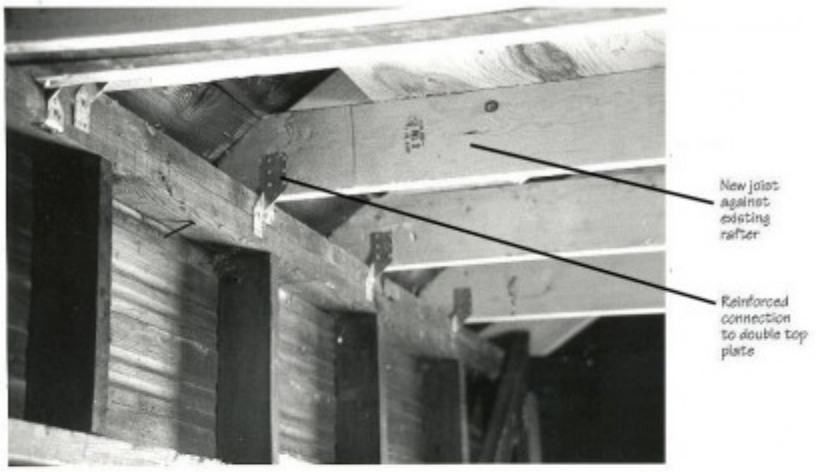
Simpson FJA foundation anchors can secure joists to the foundation. Install following manufacturer's recommendations (typically at every third joist) by anchor bolting to the foundation and bolting or nailing to joists. Cost is about $15 per anchor with expansion bolts.

### Upgrade Existing Foundations

If the existing foundation is deteriorated or inadequate, a new concrete foundation can sometimes be installed on the inside of the existing. Seismic

anchors (e.g., Simpson FTF holdowns, FJA ties, etc.) can be installed with the new concrete. This job will likely require a professional contractor. Cost could easily be $50 per linear foot for a crawlspace foundation, not including floor removal and reinstallation.

## Floors & Ceilings




Reinforced Joist/Top Plate Connection

### Upgrade Connection between Floor Joists and Stud Walls

Simpson L70 reinforcing angles are used to reinforce the connection between floor joists and wall studs. Where joists cross over a top plate of central stud wall, Simpson H4 seismic ties can be used. Cost is about $2 per tie.

### Improve Floor Diaphragm

The horizontal diaphragms (i.e., floors, ceilings and roof) must be strong horizontally to transfer the lateral earthquake forces.

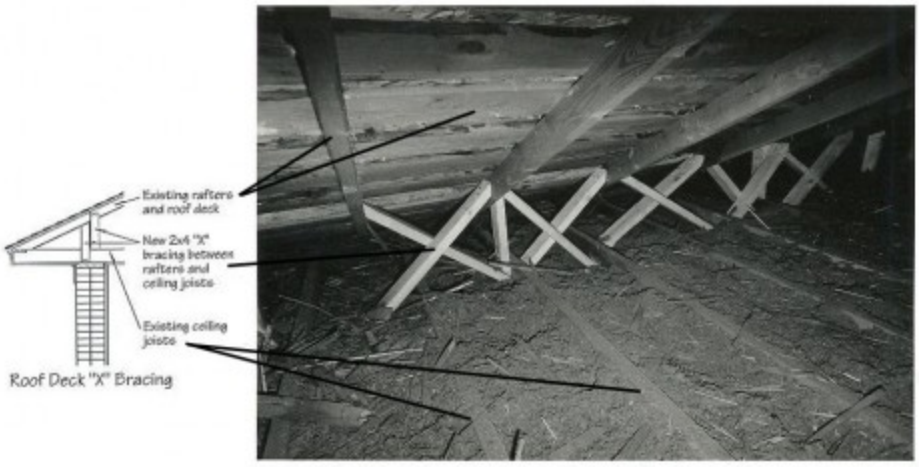
Solid, full-height 2x bridging should be installed between all floor joists at midspan or at 8 feet on center maximum.

If flooring is replaced, install structural plywood and nail similar to shear walls. About $1 per foot of bridging.

## Roofs

### Create Roof Deck Diaphragm

To improve the roof diaphragm, 5/8″ CDX plywood is nailed to the rafters after all roofing material is removed. (Original planks can remain.) All edges between plywood sheets should be blocked behind with axes between rafters. Nailing is similar to shear wall nailing. New structural deck is about $.50 per square foot not including roofing.




Roof Deck "X" Bracing

**Connect Roof Diaphragm to Load Bearing Walls**

To transfer the lateral loads from the roof to bearing walls, the rafters must be secured to the top plate. Use the appropriate Simpson H hurricane ties if the rafters rest on the top plate. Cost is about $1-3 per foot. If the rafters rest on the extended ends of ceiling joists, 2×4 X-bracing can be installed for approximately 10 to 15 feet on all four sides of the roof for a moderately sized house. Cost for X-bracing would be about $4 per foot. The top plate should also be anchored to the masonry wall (see anchor bolts).

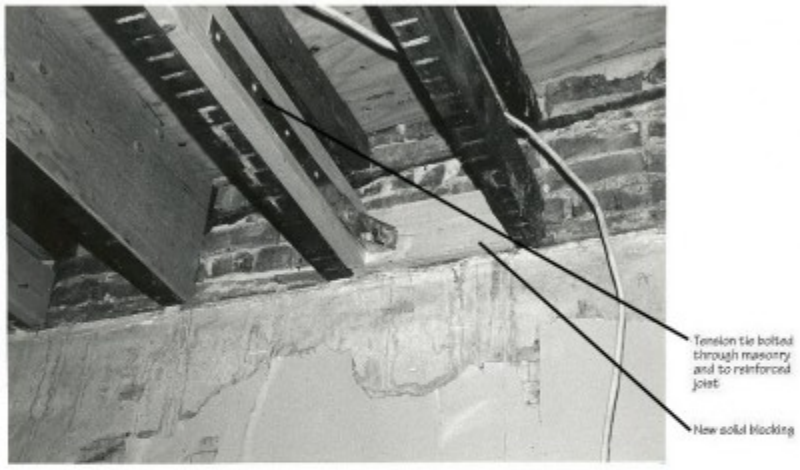
**Reinforce Chimney**

Repoint mortar joints as needed and brace the chimney to the roof. Install a 2″ wide, 14 gauge metal strap tightly around the chimney just below the cap. The strap connector is bolted to a 2″ diameter steel pipe which is connected to the

roof structure with the pipe at an angle less than 45 degrees. The fabricated steel roof connection is braced by bolting through the roof to 2x4s that span at least three rafters.

All exposed metal is primed and painted to match brick color. Cost is about $150. For additional security from falling bricks, particularly where plywood is not used on the-roof deck, 1/2″ CDX plywood is installed on top of ceiling joists in the attic on all sides of the masonry chimney. A more comprehensive chimney bracing/rebuilding solution is detailed in the article “Reinforcing new and old masonry chimneys” (see bibliography). The estimated cost of this solution is upwards of $4,000 with professional bricklaying skills required.

## Walls & Columns




Reinforced Joist/Masonry Wall Connection

### Connect Joists to Masonry Walls

This is one of the most important connections to upgrade. Floor and ceiling joists are secured to masonry walls with the appropriate tension ties (e.g.,

Simpson LlT20) and long 3/4″ bolts placed through the masonry with a substantial bracket/washer (e.g., Simpson RP6 retro plate j on the exterior. When joists are parallel to the wall, new bridging and strap ties (e.g., Simpson MST) are used to securely connect the horizontal diaphragm (floor, ceiling, or roof) and the masonry wall. These ties are placed about 4 feet on center. The large plate washers remain exposed on the exterior.

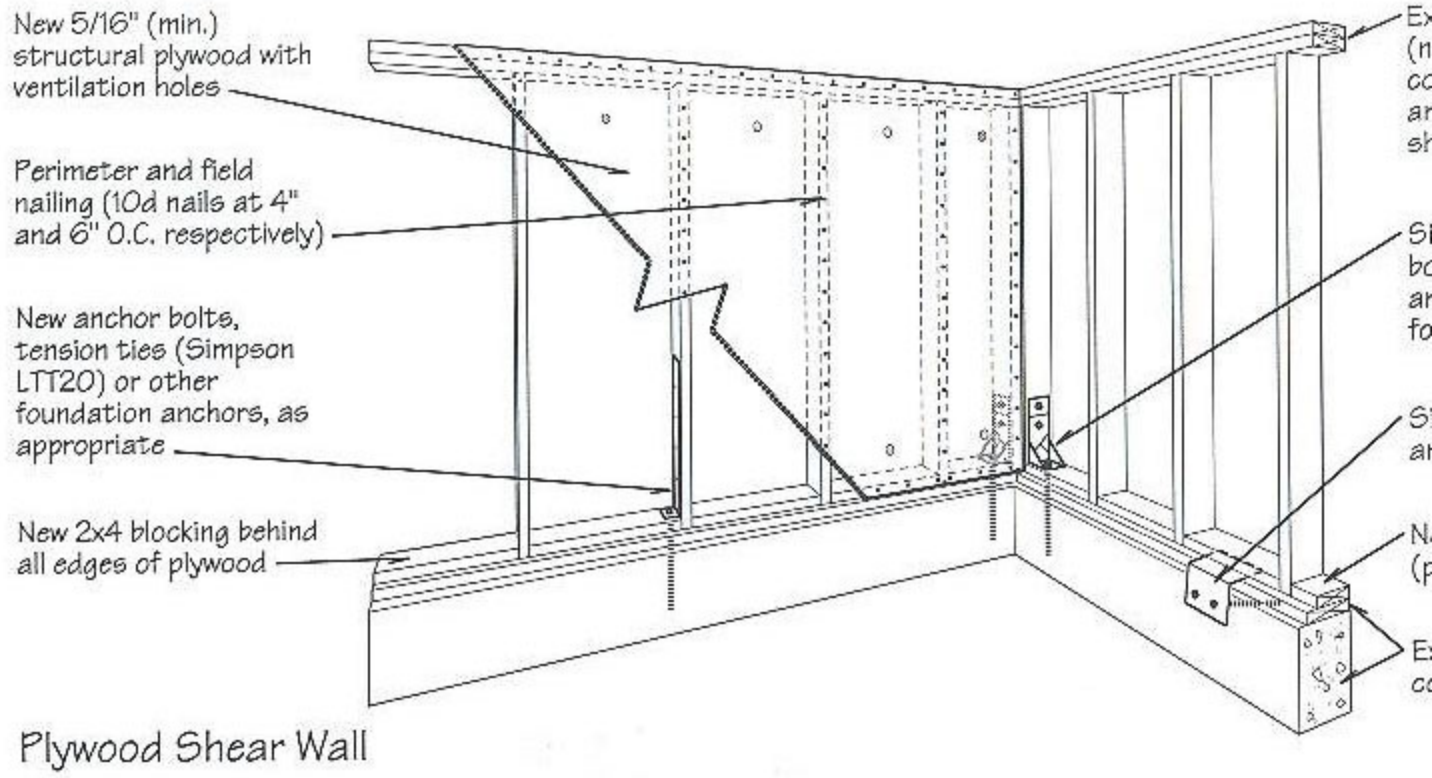
To minimize impact to the historic integrity, design the plates well (e.g., diamonds, "S."), position carefully, and paint appropriately. Access to the joists must be gained on the interior, removing portions of either the floor or ceiling. This connection is also adaptable to masonry parapets and gables, tying the masonry wall to the roof structure. Material cost is about $20-30 per tie.

**Anchor Masonry Wall with Internal Anchors**

When rowlock or header bricks are absent, the outer wythe of brick (the exposed layer) can be secured to the inner wythe by using an epoxy anchoring system (e.g., Dur-O-Pair anchors). Design and installation by professionals is recommended. Cost depends on the extent of repair, ease of access, strength of historic masonry, etc.

**Create Shear Walls**

Shear walls can strengthen "cripple" walls or a "soft" story. The new shear walls should be positioned at right angles to each other and be distributed evenly about the center of the building. Installation includes securing top and bottom of stud wall to the house structure (Simpson L90 reinforcing angles, FA anchors, A23 angles, HD5A holdowns, etc. as appropriate) and covering the entire wall with structural plywood (5/16″ minimum). All edges of the plywood must be blocked and the plywood is nailed heavily (about every six inches) around the perimeter and in the '"field" (along studs behind each sheet). Use 16d nails rather than staples or screws. (See the video *Home Safe Home* for a clear explanation and demonstration of shear wall and anchor bolt installation.) Cost to upgrade a cripple wall is about $12 per square foot.




**Install Holdown Brackets**
Holdowns (e.g., Simpson HD5A) are installed at each end of each shear wall. The wood stud is first "doubled" by nailing a second stud to the existing stud and the holdown is bolted through both studs and anchor bolted to the foundation. Cost is $20-25 per bracket.

**Strengthen Connection between Beams and Columns**

To reinforce a beam/column connection (typically in the basement), install Simpson AC postcaps, T or L strap ties, or A angles as appropriate. Use two ties or angles per connection if accessible and offset to allow for proper nailing or bolting. Cost is about $10 per connection.

**Secure Column to Floor Slab**
The connection between wood columns and concrete foundation can be improved by installing two Simpson A23 angles at the base of each column, securing the column to the slab. Again, about $10 per connection.

### Secure or Reinforce Porch Columns

Hollow wooden porch columns can be strengthened by supporting the porch roof, and opening or removing the existing column. A 4×4 wood column is then installed with a Simpson AB adjustable post base (a good foundation is needed) and A23 angles at the top. (The metal base and angles will keep the column from falling during an earthquake.) Carefully remove railings and decorative elements only if needed, otherwise, protect in place. Reinstall all original elements. Porch columns can also be secured in place without opening or rebuilding by attaching the column at both top and bottom with metal clips, bolts, or screws. Use curly weather-resistant materials. If the column is "punching through" the wood porch deck, disassembly and reinforcing rebuilding is needed. Cost varies with difficulty and condition.

### Historic Interiors & Non-Structural Items

Secure the water heater with rigid supports, strapped to the tank and bolted to the wall structure or use approved platform restraints, and install a flexible gas line. Contact the gas utility for details. Other gas appliances may also need flexible supply lines. Consider similar potential fire danger from freestanding wood burning stoves. Post-earthquake fires often destroy as many buildings as the earthquake itself.

Add latches to all cupboards to prevent opening and spilling of contents. Concealed or reproduction latches are available. Child safety latches may also work.

Hanging objects (e.g., pictures, mirrors, lights) can be restrained with strong nylon fishing line.

Tall cabinets, mirrors, hutches, etc. should be bolted or secured with strong brackets to wall studs.

Objects resting on tables, shelves or other items (e.g., china dishes, framed photos, vases, statues, computer monitors, VCRs) can be secured by placing them in cabinets with doors that latch closed, installing a guardrail along the shelf, or by securing the object with pressure sensitive hook-and-loop fasteners (Velcro), wire, fishing line, or other mechanical fasteners. (See the articles in Sunset Magazine for detailed information.)

## Summary

Many of the retrofit procedures described here are inexpensive. A minor investment now in upgrading your historic house can help prevent major, costly repairs after an earthquake or perhaps save the building from complete

destruction. While historic buildings are constructed of old, sometimes archaic materials, effective seismic retrofit is mostly a matter of improving the strength of connections as well as securing and anchoring building elements, objects, etc. to reduce hazards. It is important to remember that in both old and new construction, there is no such thing as “earthquake-proof.” Only repair and upgrade efforts now can reduce the seismic risk to your historic house and improve your personal safety in the next big earthquake.

### Disclaimer

The work described in this brochure follows recognized building and seismic retrofit practices, but has not been engineered as complete solutions for the seismic upgrading of any particular property. The agencies and individuals involved in the preparation of this brochure assume no responsibility or liability for any damage or claim that may arise from any action or occurrence based on or resulting from these seismic retrofit techniques. Always seek professional advice for complicated situations. The use of proprietary names is not an endorsement of the product. Typically, equivalent products or materials are offered by several manufacturers.

## Documentation & Insurance

Photograph the entire house for insurance purposes and to guide repairs or reconstruction. Store a second set of photos or the negatives off site (e.g., safety deposit box, insurance company file, or at work). In addition to overall views, remember to include details of chimneys, gables, porches, doors windows; and on the interior, decorative plaster, stenciling, woodwork, leaded glass, and antiques.

In addition to regular homeowner’s insurance, consider either earthquake or catastrophic insurance. For a brick home (either “solid” brick or more modem brick veneer), earthquake insurance currently costs about $8 per $1000 of coverage in Utah. For a frame house, rates are about $1.70 per $1000 of coverage. Owners of masonry homes can waive the coverage for brick and insure as a frame house, but damage to the brick will not be covered.

Another possibility is the Homeowners Catastrophe Insurance Trust available through Trustco, Inc. LICIT covers both flood and earthquake damage and costs about $2.90 per $1000 of coverage. Earthquake insurance typically has a major deductible of 3-5% of total loss. Because of archaic building materials and technology, insurance companies will generally charge high premiums for full replacement coverage on historic houses. Evaluate your needs with your insurance agent.

### After the Earthquake

- Inspect utilities for damage or leakage. Shut off the main gas valve only if you smell or hear escaping gas, or if there is significant structural damage to the building. Only gas company personnel should turn it back on after checking for damage.
- Retrieve 72 hour emergency kit, supplies, and tools — you may need to secure and leave the house.
- Check the structural condition of the house, protecting yourself from broken glass, dust, etc. Inspect all areas, comparing existing conditions with photos to assess damage, crack formation, or deformed structural members or connections.
- Shore up the house if needed to prevent damage from aftershocks (see front cover).
- Cover damaged areas in the roof and any broken windows to prevent further damage from rain or snow.
- If an inspector determines the house is unsafe, do not occupy the building. Red "tagging" typically means the building should not be occupied, rather than demolished, but many people misinterpret this. Get a second opinion from a professional engineer or architect experienced with historic buildings. If the severely damaged building is unoccupied and does not pose an immediate threat to people or other structures, a comprehensive structural evaluation may find ways of securing and repairing the building, and preventing its demolition.
- Prioritize needed repairs and research repair methods that won't damage the integrity of the historic house.
- If needed, obtain the services of qualified engineers, architects, and contractors who are experienced with historic buildings.

## Bibliography & Other Resources

Most are available for public use at the Utah Division of State History – 300 S. Rio Grande Street, Salt Lake City, UT 84101, 801/533-3563, Barbara Murphy

*Site & Building Investigation*


- "The Crack Detective," *The Old House Journal*, May-August 1981. OHJ is a monthly magazine covering all aspects of old house investigation, repair, and preservation.
- "Surface Fault Rupture and Liquefaction Potential Special Study Areas" (natural hazards map), Salt Lake County Planning Division (468-2061), 1989.


*Emergency Preparedness*

- "Earthquakes — What you should know when living in Utah." Utah Division of Comprehensive Emergency Management (5383400), 1992.
- QUAKE — Securing your House, Possessions, Family and Neighborhood. "Sunset Magazine," Oct-Nov 1990.
- *Surviving the Big One*. Comprehensive video on personal earthquake preparation. Available for checkout from Salt Lake County Planning Division.

*Historic Preservation & Non-Structural Aspects*

- "Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide." FEMA Report 74. 1985.
- National Park Service publications, including Preservation Briefs, Tech Notes, and the "Secretary of the Interior's Standards for Rehabilitation." These resources present a variety of sensitive repair solutions for historic features and materials.

*Seismic Retrofit Techniques*

- *Controlling Disaster: Earthquake-Hazard Reduction for Historic Buildings*. Information Series National Trust for Historic Preservation, 1785 Massachusetts Avenue, N.W., Washington, D.C. 20036. 1992
- *Connectors for Earthquake-Resistant Structures*. Simpson StrongTie Company, Inc., San Leandro, CA, 1991.
- *Earthquake Safe*. David Helfant, Builders Booksources, Berkeley, CA, 1989.
- *Home Safe Home*. 30 minute video produced to teach the homeowner basic earthquake principles and how to install anchor bolts, seismic connectors and shear walls. A copy is available for checkout through the Utah Division of State History (801/533-3500).
- *Homebuilder's Guide for Earthquake Design*. Applied Technology Council, Berkeley, CA, 1980.
  Introduction to Earthquake Retrofitting. Charles Smith-Kim and Cindy Furukawa, The Owner Builder Center, Berkeley, CA, 1991.
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