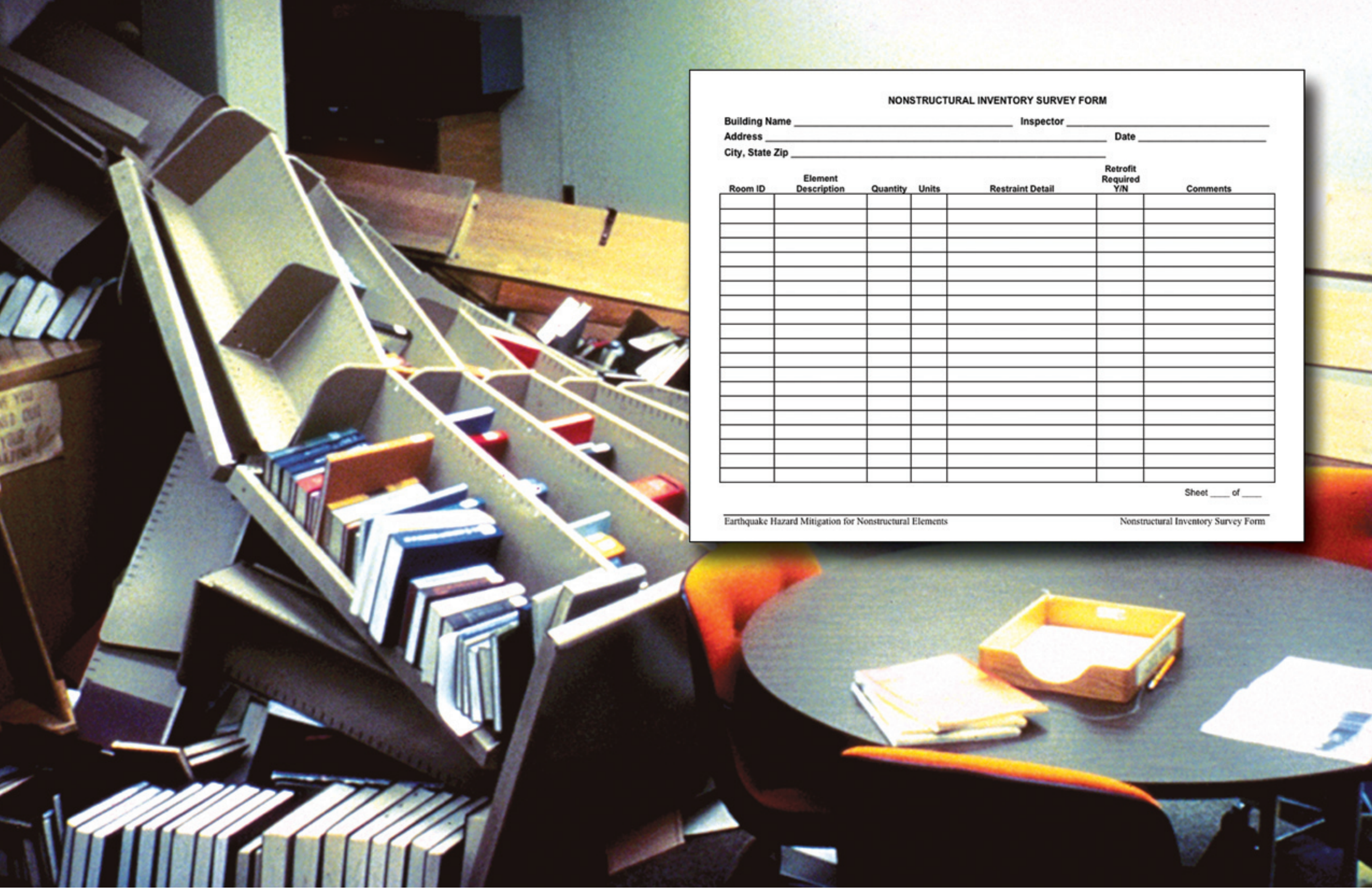

Earthquake Hazard Mitigation for Nonstructural Elements

Field Manual

FEMA 74-FM / September 2005

FEMA

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This field manual was prepared by Wiss, Janney, Elstner Associates, Inc. as a subcontractor to URS Corporation for FEMA under the Hazard Mitigation Technical Assistance Program, Contract EMW-2000-CO-0247.

Chapter 1 - Overview

The primary focus of this guide is to help the reader understand how to conduct a building survey to identify nonstructural items that are vulnerable in an earthquake and most likely to cause personal injury, costly property damage, or loss of function if they are damaged. In addition, this guide contains recommendations on how to implement cost-effective measures that can help to reduce the potential hazards.

Purpose

This guide was developed to fulfill several different objectives and address a wide audience with varying needs. The primary intent is to explain the sources of nonstructural earthquake damage in simple terms and to provide information on effective methods of reducing the potential risks. The recommendations contained in this guide are intended to reduce the potential hazards but cannot completely eliminate them.

Nonstructural Elements

Definitions

Two terms frequently used in the earthquake engineering field should be defined.

Structural

The structural portions of a building are those that resist gravity, earthquake, wind, and other types of loads. These are called structural components and include columns (posts, pillars); beams (girders, joists); braces; floor or roof sheathing, slabs, or decking; load-bearing walls (i.e., walls designed to support the building weight and/or provide lateral resistance); and foundations (mat, spread footings, piles). For buildings planned by design professionals, the structure is typically designed and analyzed in detail by a civil or structural engineer.

Nonstructural

The nonstructural portions of a building include every part of the building and all its contents with the exception of the structure--in other words, everything except the columns, floors, beams, etc. Common nonstructural components include ceilings; windows; office equipment; computers; inventory stored on shelves; file cabinets; heating, ventilating, and air conditioning (HVAC) equipment; electrical equipment; furnishings; lights; etc. Typically, nonstructural items are not analyzed by engineers and may be specified by architects, mechanical engineers (who design HVAC systems and plumbing for larger buildings), electrical engineers, or interior designers; or they may be purchased without the involvement of any design professional by owners or tenants after construction of a building. Figure 1 identifies the structural and nonstructural components of a typical building. Note that most of the structural components of a typical building are concealed from view by nonstructural materials.

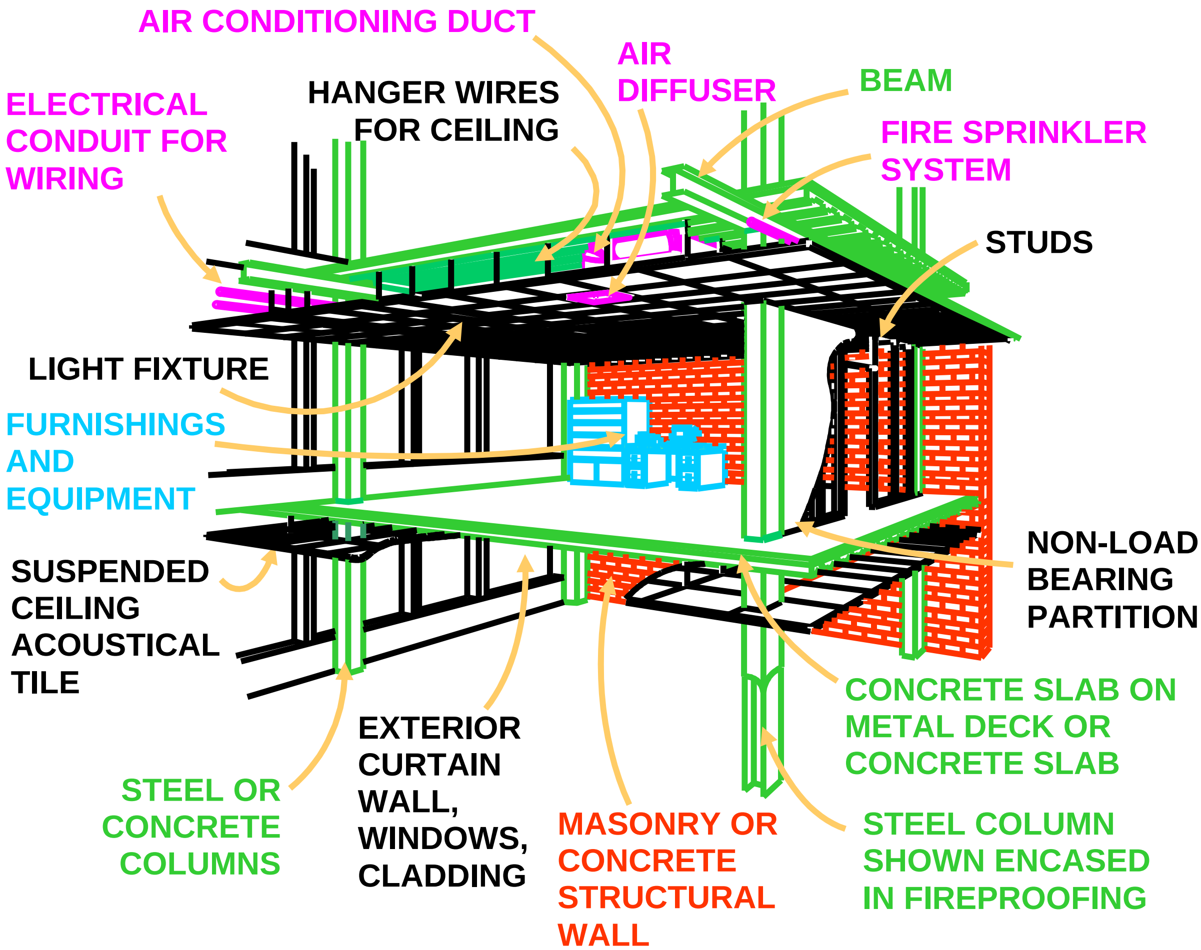

AIR CONDITIONING DUCT
AIR DIFFUSER
BEAM
ELECTRICAL CONDUIT FOR WIRING
HANGER WIRES FOR CEILING
FIRE SPRINKLER SYSTEM
STUDS
LIGHT FIXTURE
FURNISHINGS AND EQUIPMENT
SUSPENDED CEILING ACOUSTICAL TILE
NON-LOAD BEARING PARTITION
CONCRETE SLAB ON METAL DECK OR CONCRETE SLAB
EXTERIOR CURTAIN WALL, WINDOWS, CLADDING
STEEL OR CONCRETE COLUMNS
MASONRY OR CONCRETE STRUCTURAL WALL
STEEL COLUMN SHOWN ENCASED IN FIREPROOFING

Figure 1

Chapter 2 - Behavior of Nonstructural Elements

Types of Nonstructural Elements

The nonstructural components listed in the tables and checklists provided in Chapters 4, 5 and 6 are elements that are most commonly found in commercial, multiple-unit residential, or public buildings such as schools and government buildings. A complex facility such as a hospital, research laboratory, or industrial plant will contain many additional types of specialized equipment that are not addressed in this guide. The common components can be divided into three general categories as follows.

Architectural Elements

These are typically built-in nonstructural components that form part of the building. Examples include partitions and ceilings, windows, doors, lighting, interior or exterior ornamentation, exterior panels, veneer, and parapets.

Building Utility Systems

These are typically built-in nonstructural components that form part of the building. Examples include mechanical and electrical equipment and distribution systems, water, gas, electric, and sewerage piping and conduit, fire suppression systems, elevators or escalators, HVAC systems, and roof-mounted solar panels.

Furniture and Contents

These are nonstructural components belonging to tenants or occupants. Examples include computer and communications equipment; cabinets and shelving for record and supply storage; library stacks; kitchen and laundry facilities; furniture; movable partitions; lockers; and vending machines. Not every conceivable item is included in these lists, so some judgment is needed to identify the critical items in a particular facility. In general, items that are taller, heavier, or important to operations, items that contain hazardous materials, and items that are more expensive should be included before items that are shorter, lighter, nonessential, inexpensive, and do not contain hazardous materials.

Factors Affecting Seismic Behavior

The seismic risk for a particular nonstructural component at a particular facility is governed by a variety of factors, including

- the regional seismicity
- the proximity to an active fault
- the local soil conditions
- the dynamic characteristics of the building structure
- the dynamic characteristics of the nonstructural element and its bracing to the structure
- the location of the nonstructural component within the building
- the function of the facility
- the importance of the particular component to the operation of the facility

Seismic Hazards

The seismic hazard in a given region or geographic location is related both to the severity of ground shaking expected in the area and to the likelihood, or probability, that a given level of shaking will occur. Seismologists review historical earthquake activity, locations and characteristics of mapped faults, and regional geology to estimate the seismic hazard. This information is often depicted on a seismic hazard map.

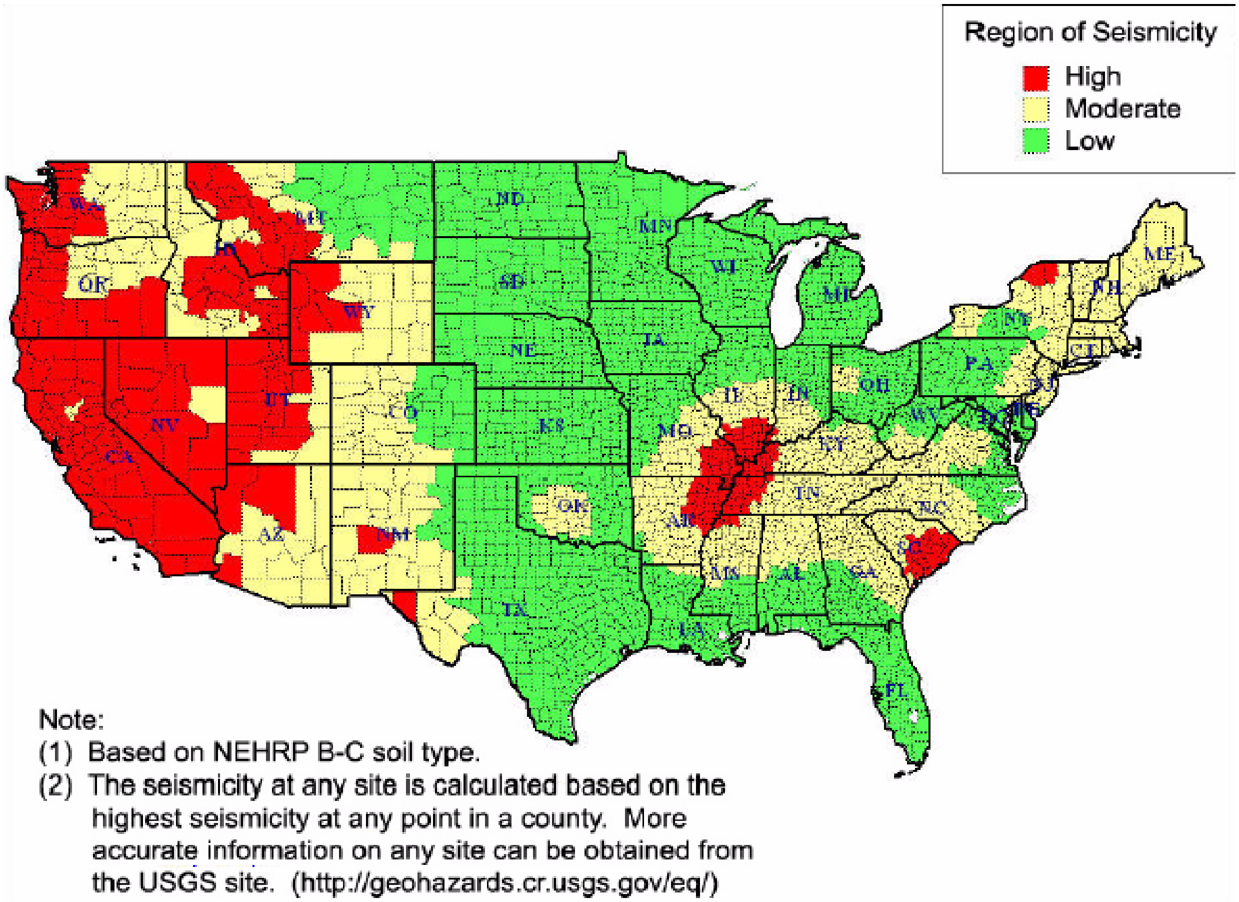


Figure 2

Seismic hazard is often characterized in terms of three levels of shaking intensity: namely light, moderate, and severe. The seismic hazard maps presented in Figure 2 show the geographic areas in the United States with low, moderate, and high probabilities of earthquake ground shaking in the future.

The seismic hazard throughout the country however, is more variable than simple seismic zones. The US Geological Survey (USGS) has published maps with contour lines showing detailed variations in seismicity depending on location. The USGS also maintains a web site that can be used to determine the seismicity of a location based on the zip code. It can be found at http://eqint.cr.usgs.gov/eq/html/zipcode.shtml.

Earthquake shaking can be represented either as a ground motion with an average return period or a probability of exceedence and the relative seismicity of a site may vary depending on the return period being considered. Building codes in use until about the year 2000 considered an earthquake with an average return period of 475 years, which is also described as having a 10 percent chance of exceedence in 50 years. Newer codes consider the seismicity based on an earthquake with an average return period of 2475 years, which is also described as having a 2 percent chance of exceedence in 50 years. The governing building code should be reviewed prior to a seismic evaluation and retrofit program to determine the appropriate seismicity to consider for each site.

The soil conditions at the site can also influence the seismic hazard. Buildings sited on softer soils may be subjected to greater earthquake shaking. The local soil conditions should be reviewed by a structural or geotechnical engineer to determine the effect of the soil conditions on the building's seismic hazard.

Causes of Nonstructural Damage

Earthquakes shake the ground in all directions. Because of this multi-directional shaking, the structural and nonstructural elements of a building must be specially designed to resist earthquake forces in a variety of directions. Structural and nonstructural elements of a building that are not secured to resist expected earthquake shaking pose a hazard to building occupants. Earthquake ground shaking has three primary effects on nonstructural elements in buildings. These are inertial or shaking effects, distortions imposed on nonstructural components when the building structure sways back and forth, and separation or pounding at the interface between adjacent structures.

Inertial Forces

When a building is shaken during an earthquake, the base of the building moves in unison with the ground, but the entire building and building contents above the base will experience inertial forces. These inertial forces can be explained by using the analogy of a passenger in a moving vehicle. As a passenger, you experience inertial forces whenever the vehicle is rapidly accelerating or braking. If the vehicle is accelerating, you may feel yourself pushed backward against the seat, because the inertial force on your body acts in the direction opposite that of the acceleration. If the vehicle is rapidly braking, you may be thrown forward in your seat. The earthquake inertial forces are greater if the mass is greater (if the building or object within the building weighs more) and if the acceleration of the shaking is greater.

File cabinets, emergency power generating equipment, freestanding bookshelves, office equipment, and items stored on shelves or racks can all be damaged from the effect of inertial forces. When unrestrained items are shaken by an earthquake, inertial forces may cause them to slide, swing, strike other objects, or overturn. Items may slide off shelves and fall to the floor. One common misconception is that large, heavy objects are stable and not as vulnerable to earthquake damage as lighter objects, perhaps because we may have difficulty moving them. Because inertial forces during an earthquake are proportional to the mass or weight of an object, a heavily loaded file cabinet requires much stronger restraints to keep it from sliding or overturning than a light one with the same dimensions.

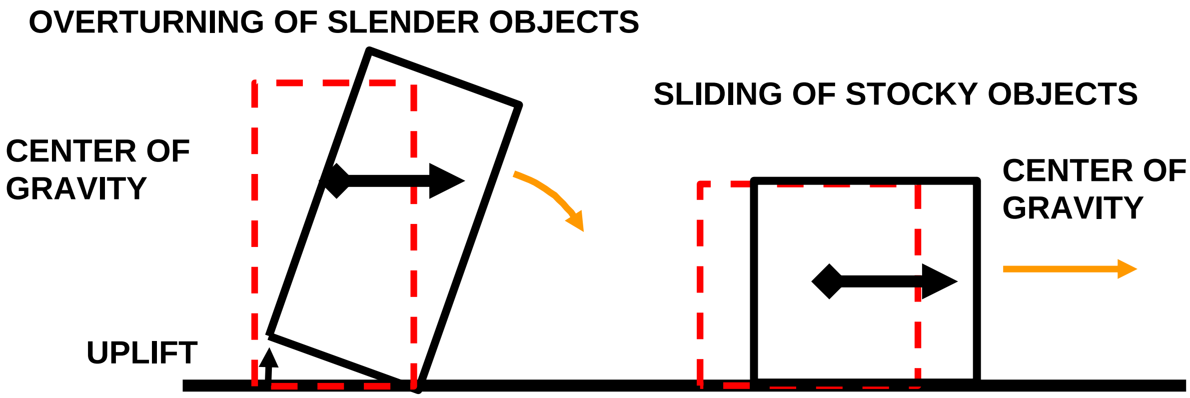


Figure 3

Building Distortion

During an earthquake, building structures distort, or bend, from side to side in response to the earthquake. For example, the top of a tall office tower may displace a few feet in each direction during an earthquake. The displacement over the height of each story, known as the story drift, might range from ¼ inch to several inches, depending on the size of the earthquake and the characteristics of the particular building structure. Windows, partitions, and other items that are tightly locked into the structure are forced to go along for the ride. As the columns or walls distort and become slightly out of square, any tightly confined windows or partitions must also distort the same amount. The more space there is around a pane of glass where it is mounted between stops or molding strips, the more distortion the glazing assembly can accommodate before the glass itself resists the distortion. Brittle materials like glass, plaster or drywall partitions, and masonry infill or veneer cannot tolerate any significant distortion and will crack when the perimeter gaps close and the building structure pushes directly on the brittle elements. Most architectural components, such as glass panes, partitions, and veneer, are damaged because of this type of building distortion, not because they themselves are shaken or damaged by inertial forces.

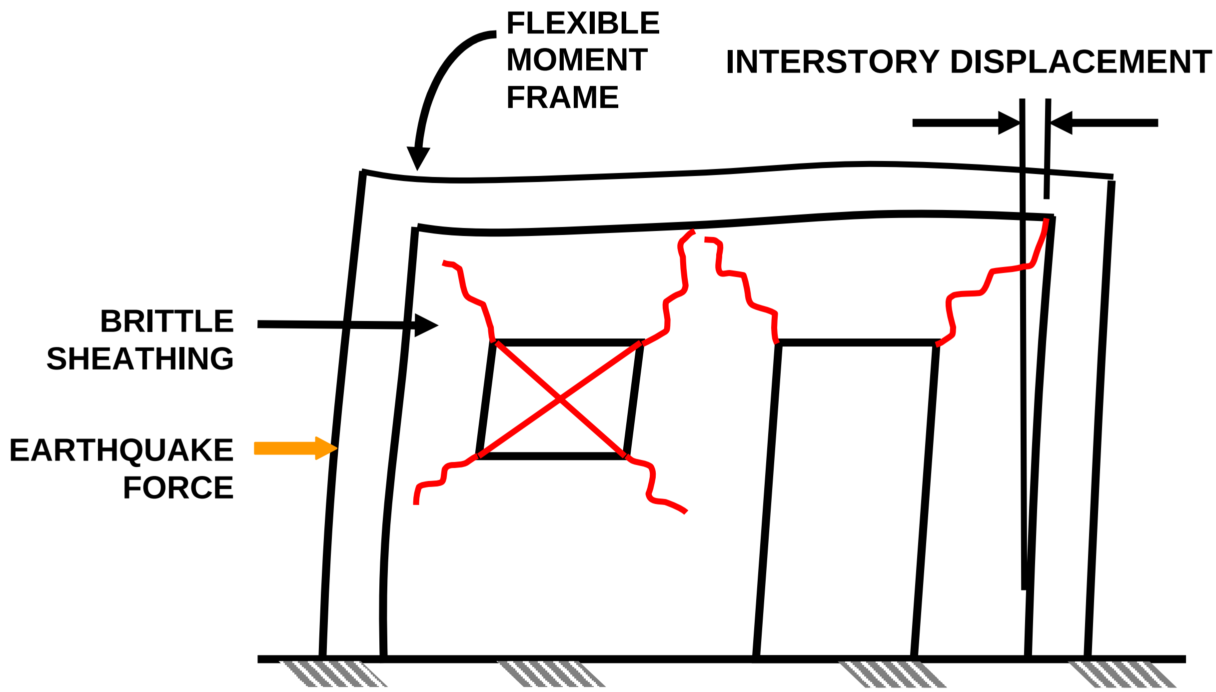


Figure 4

There have also been notable cases of structural-nonstructural interaction in past earthquakes, where rigid nonstructural components have been the cause of structural damage leading to collapse. These cases have generally involved rigid, strong architectural components, such as masonry infill or concrete spandrels that inhibit the movement or distortion of the structural framing and cause premature failure of column or beam elements. While this is a serious concern for structural designers, the focus of this guide is on earthquake damage to nonstructural components.

Building Separations

Another source of nonstructural damage involves pounding between adjacent structures. A separation between two different buildings, often two wings of the same facility, allows the structures to move independently of one another. In order to provide functional continuity between separate wings, building utilities must often extend across these building separations, and architectural finishes must be detailed to terminate on either side. The separation may be only an inch or two in older construction or as much as a foot in some newer buildings, depending on the expected horizontal movement, or seismic drift. Flashing, piping, fire sprinkler lines, HVAC ducts, partitions, and flooring all have to be detailed to accommodate the movement expected at these locations when the two structures move closer together or further apart. Earthquake damage to items crossing these separations is common. If the size of the separation is insufficient, pounding between adjacent structures may result in damage to structural components but more often causes damage to nonstructural components, such as parapets, veneer, or cornices on the facades of older buildings.

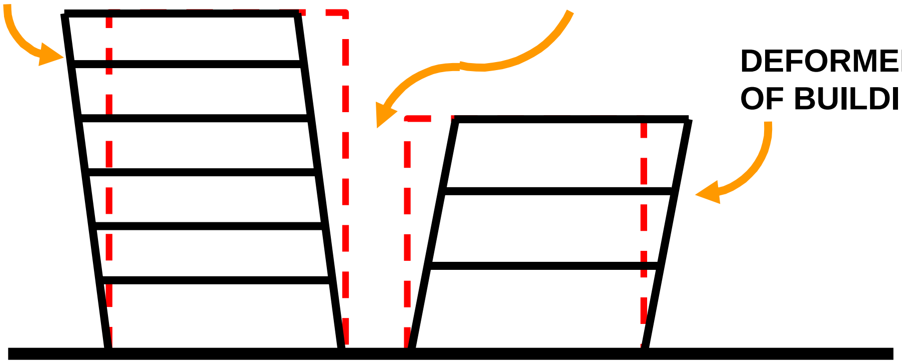


Figure 5

Earthquake Damage Effects

Nonstructural elements are more vulnerable to earthquake damage than is the structural framing of the building. There are several reasons for this, most notably the lack of earthquake design and construction of nonstructural elements. As a result, even light to moderate earthquake shaking can cause damage to nonstructural elements and this damage may result in life safety hazards, loss of function of the nonstructural elements, and monetary loss due to the damage. Cost of repair and disruption due to earthquake damage to nonstructural elements often exceeds the structural repair costs. Typical examples of nonstructural damage include:

Brick chimneys and parapets falling away from the building
Ceiling tiles and light fixtures falling
Exterior glass windows cracking
Spilling contents of shelves
Breakage and leakage of pipes, including sprinkler pipes, gas pipes, water pipes and sewerage
Building utility equipment sliding off of their supports or overturning

Chapter 3 - Nonstructural Inventory Process

Planning

A survey of a facility will identify nonstructural components that may be vulnerable to earthquake damage. As a first step in the inventory process, it may be useful to prepare a plan of action for conducting the survey is prepared. The following describes some of the steps in the process.

Identify areas to be surveyed

The nonstructural inventory program should have a clearly defined scope. The specific buildings and areas of buildings that will be surveyed should be identified prior to beginning the survey. Some buildings or areas of buildings may not be included in a survey if they are scheduled for replacement or remodeling or have been recently remodeled or built and the nonstructural hazards have been addressed. If the survey will be implemented in phases, it may be necessary to identify areas of high priority.

Establish evaluation criteria

The goal of a nonstructural inventory program is to identify the risks associated with existing nonstructural elements. In establishing criteria for evaluation, a number of factors should be considered:

What is the earthquake hazard?
What types of nonstructural seismic risks will be surveyed?
What is the realistic expectation of seismic performance of nonstructural elements?
How detailed should the survey be?
How will a program for risk reduction be implemented?

In considering the realistic performance of nonstructural elements, it is important to define the desired levels of performance. There are six levels or ranges of nonstructural performance that have been described in seismic evaluation guidelines, as shown in the shaded box. These have been presented in order of increasing performance; Not Considered is the lowest performance and Operational is the best performance.

<u>Nonstructural Performance Levels</u>

- Not Considered
- Hazards Reduced
- Life Safety
- Damage Control
- Immediate Occupancy
- Operational

Life Safety performance is selected for most buildings. For Life Safety Performance, nonstructural elements are expected to remain in place and not fall resulting in serious injuries to occupants. Buildings whose functions are critical or important, such as hospitals and fire stations, need their nonstructural elements designed to achieve a higher level of performance. Many of these elements need to be functioning immediately after an earthquake, referred to as Immediate Occupancy Performance, or need to continue functioning even during an earthquake, Operational Performance. For higher performance levels, it is important to not only assure that the nonstructural elements remain in place, but that piping, ductwork, and cabling remain unbroken; equipment is rugged enough to sustain shaking; and utilities continue to function either with municipal services or backup services.

Identify and train personnel

Implementing a program for surveying nonstructural elements requires personnel that can commit the time required and who are familiar with building construction and seismic hazards. Often, this work is accomplished by maintenance personnel who are familiar with the buildings and systems. These people should receive training on the identification of nonstructural seismic hazards prior to implementing a program. A consultant specializing in nonstructural earthquake protection programs may be hired to help train your personnel and develop your survey program.

Prepare survey forms

Record keeping is an essential part of a successful program of nonstructural earthquake risk mitigation. The information obtained from the nonstructural survey should be recorded so that an accurate assessment of the seismic vulnerability can be made and the effort required to implement a mitigation plan is reduced. The essential data from the survey should be recorded in a uniform format.

Figure 6 shows an example of a survey format that can be used to record nonstructural data. Other forms can also be used, as-is or modified, or developed depending on your needs and building occupancy. The important information that should be included is:

- Identification of the building
- The inspector and date of the survey
- A description of the nonstructural element and the quantity
- The location of the nonstructural element in the building
- A description of the existing lateral bracing or anchorage

NONSTRUCTURAL INVENTORY SURVEY FORM

Building Name ______________________ **Inspector** ______________________

Address ______________________ **Date** ______________________

City, State Zip ______________________

Room ID	Element Description	Quantity	Units	Restraint Detail	Retrofit Required Y/N	Comments

Sheet ____ of ____

Figure 6

Notify tenants

Prior to conducting a survey, the tenants of the spaces to be surveyed should be notified that the survey will be conducted. This should be done to avoid unnecessary disruption.

Building Walkthrough

The nonstructural survey generally consists of a walkthrough of the building to identify and record data regarding the nonstructural elements. The typical tools that are needed for the survey are shown in the shaded box. Most of the nonstructural elements can be easily surveyed visually without the need for additional tools.

Identify and Classify Nonstructural Elements

Each room or area of the building should be thoroughly surveyed to identify all the nonstructural elements. Each element should be described by its type and function. It is important to note whether a nonstructural element is critical to building function, such as emergency generators, or pose significantly higher risk of life safety to occupants if damaged, such as pipes containing hazardous materials.

Tools for Nonstructural Survey

- Clipboard
- Inventory form
- Pen or pencil
- Flashlight
- Tape measure
- Camera
- Ladder

Assess the Attachment to the Structure

During the survey, the inspector should carefully examine each nonstructural element to assess how it is anchored or braced to the ground or structural framing to resist lateral forces. Friction due to the weight of an element should not be considered as a reliable means to resist lateral earthquake forces.

Record Information

The data on each nonstructural element should be recorded on the survey form. Care should be taken to fill out the form completely and accurately. Photographs or sketches of the nonstructural elements can be used to document the condition of the bracing and serve as a helpful reminder of the items surveyed.

Identify Patterns and Similarities

When conducting the survey, some types of elements or bracing details may occur repeatedly. The inspector should look for patterns and similarities in the bracing of these elements as well as changes or differences in the pattern. Differences may be due to incorrect installation, changes in structural framing used for bracing, or details of different vendors or age of installation.

Categorize Results

Following the walkthrough, the results of the nonstructural survey should be reviewed and categorized by importance, function, etc. prior to implementing a mitigation program.

Identify Performance Requirements

In the evaluation of the results of the survey, there needs to be an understanding of the performance requirements for various nonstructural components. Not all nonstructural elements need to have the same performance. The seismic performance goal for each nonstructural element should be identified based on its importance and seismic risk.

Determine Need for Engineering Design

Once the survey results have been compiled, the nonstructural elements can be grouped into several categories, such as type of nonstructural element, importance, and presence of existing restraint or anchorage. For those elements that do not appear to have adequate restraint or anchorage, retrofitting may be recommended. Some of the elements requiring restraint or anchorage can have the anchorage designed and installed without the need of an engineer, while other elements will need to have the mitigation designed by an engineer. This manual provides some recommendations for design responsibility for typical nonstructural elements. Those elements that are considered critical and elements in critical facilities may need to be evaluated by an engineer to verify that the existing bracing is adequate. Elements that are not described in this guide may also need to be evaluated by an engineer, particularly if the element is heavy or could cause injury if damaged due to earthquake shaking.

The nonstructural items in the survey can then be classified as either:

Restraint appears to be adequate
Restraint inadequate and can be retrofit without an engineer
Restraint inadequate and mitigation should be designed by an engineer

Compare Benefit/Cost Ratio

For the nonstructural elements that are categorized as requiring bracing or anchorage, preliminary retrofit schemes can be prepared using the examples in this field manual and other available documents. Costs for the retrofits can be estimated. The cost for simple retrofit designs can be estimated based on knowledge of construction costs and an estimate of the time that may be required to install the retrofit. Nonstructural elements that require complex or specialized retrofit design or construction may need to be estimated by a contractor or engineer experienced with the elements.

For each nonstructural element being considered for mitigation, the benefit can be estimated in terms of repair cost or reduced disruption if damaged by an earthquake. The monetary benefit for bracing of some nonstructural elements may be easy to estimate based on expected cost to repair or replace. For other elements, the consequence of damage may be more difficult to quantify, because they may cause personal injury, result in fires or flooding, or damage financial or medical records or inventory.

The estimated cost of retrofit can then be compared to the estimated benefit of the retrofit. For some elements, the benefit of retrofitting may obviously outweigh the costs. However, for some elements, the cost of retrofitting may be large compared to the benefit. The benefit versus cost comparison can be used to assess whether retrofitting is reasonable and can be used for prioritizing retrofits. For those items that could pose a significant life safety risk in the event of an earthquake, mitigation should be implemented to reduce the life safety hazard, without regard to the benefit/cost ratio.

Prioritize

After deciding that retrofitting of some nonstructural elements are needed to achieve the desired earthquake performance for the building, it may be necessary to prioritize the retrofitting. Prioritization could be done for a number of reasons:

- Budget constraints limit the amount of money that can be allocated
- Safety considerations suggest that those elements that pose the greatest risk to safety be retrofitted first
- Future construction presents opportunities for retrofitting in certain areas
- To achieve the best benefit: cost

Implement Retrofit Program

There are a number of different methods that can be used to implement the desired mitigation of nonstructural elements depending on the type of elements, the complexity of the required mitigation, and the availability of personnel. The implementation of the mitigation consists of design and execution.

Design Methods

The three methods that can be used for designing mitigation for nonstructural elements are described below. Next to each design method is a **graphic symbol** to indicate whether that type of design method can be implemented without an engineer.

Non-Engineered design relies on mitigation details that do not require engineering design to

determine the requirements. Some examples of types of nonstructural mitigation that can be designed without an engineer are:

— Restraints for tenant-supplied equipment
— Restraints for cabinet doors and drawers
— Restraints for the contents of shelves

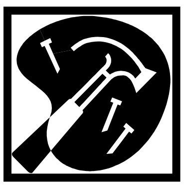
For these types of elements, typical methods of restraint are usually sufficient to provide adequate mitigation. The earthquake forces on these elements are generally small compared to the strength of the restraint methods that are usually recommended. However, there are limitations to the use of non-engineered mitigation:

This method should only be used for elements that are relatively lightweight

Non-engineered restraints should not be used for elements that are considered critical, such as emergency power systems, or for large inventories of hazardous materials

Non-engineered restraints should not be used in critical facilities, such as hospitals

Prescriptive Design relies on standard methods that have been developed for use in mitigating



specific types of nonstructural elements. For each of these types of elements, standard restraint details have been developed and can be implemented without the need for an engineer. Reference guidelines for nonstructural seismic restraints, such as FEMA 74, include details for these types of elements.

Examples of elements that can be mitigated by prescriptive methods are:

Water heaters, up to 100 gallons capacity

Suspended acoustic ceilings, up to 4 pounds per square foot in weight

While the underlying design of the prescriptive methods has been reviewed by experienced engineers, use of these procedures relies on the ability of the person specifying and implementing these procedures to verify that the procedures are appropriate for the situation.

Engineering Design, as the name implies, requires design by an engineer. All other types of

nonstructural elements, the mitigation should be designed by an engineer experienced in seismic design of nonstructural elements. The engineer will use building codes and guidelines to determine the requirements for supporting, considering the earthquake forces, the structural capacities of the restraint and structural framing. For critical facilities, it is important that mitigation details for all of the nonstructural elements be designed, or at least reviewed by an engineer to verify the appropriateness.

The engineer will need certain information to be able to design the mitigation:

Access to the nonstructural elements to assess the condition and be able to determine the mitigation options

Access to structural and architectural drawings for the building and vendor information for the elements to be able to accurately assess the weight, strength, and stiffness of the nonstructural elements and the structural elements to which they will be mitigated

A description of the intended performance goals for each of the elements to be mitigated

Notification of any constraints that may affect the design, such as locations that may affect operations of the facility

Implementation

The final step in the process is to implement the seismic retrofit of the nonstructural elements. The retrofit can be accomplished by either the maintenance staff of the building, a contractor, or by a combination of the two. Whoever implements the retrofit should be aware of the limitations and restrictions that may be imposed by the occupants.

The contractor or maintenance staff should also take care to follow the specified drawings and construction details. When conflicts arise due to existing conditions, the contractor or maintenance staff should request assistance or clarification from an engineer or other responsible party to verify that the intent of the retrofit is not compromised.

Other considerations in the implementation process are described below:

- **Prepare Timelines and Goals** if the project is being phased over time. This provides incentives and encouragement to complete the project in a reasonable period of time.
- **Look for Opportunities for Incremental Retrofits** where opportunities to retrofit certain areas or types of nonstructural elements. Future construction or remodeling may allow for retrofitting certain areas of a building. Replacement of building utilities may also provide an opportunity to retrofit the equipment and distribution systems associated with the building utilities.
- **Coordinate the Work with the Occupants** to avoid unnecessary disruption. The occupants of an area may also be able to provide information on retrofit opportunities.
- **The Interaction Between the Building and the Nonstructural Components** needs to be considered. The nonstructural components and their bracing should not interfere with the movement of the building during an earthquake.

Chapter 4 - Architectural Nonstructural Elements

Characteristics of Architectural Elements

Architectural elements are typically built-in elements that form part of the building. Most architectural elements are not intended to be load-bearing structural elements, but are usually attached to the structural framing. Typically architectural elements are visible to occupants. Often they are non-permanent (i.e. they can be moved or removed). Examples of nonpermanent architectural elements are partitions and ceilings, which are often moved or relocated to meet the needs of the tenants. Architectural elements can pose a safety hazard to occupants and the public if the element falls or becomes dislodged during an earthquake.

Architectural elements are often designed by architect. However, sometimes they can be designed by a specialty engineer, manufacturer, or structural engineer. For example, exterior façade panels are often designed by a manufacturer or an engineer that specializes in façade panel design.

Categories of Architectural Elements

The following are categories and types of architectural elements that are present in most buildings.

- Partitions
- Ceilings and Soffits
  - Suspended Acoustic
  - Concealed Spline
  - Gypsum Board
  - Lath and Plaster
- Computer access floors
- Windows and Glazing
- Permanent Ornamentation and Appendages
- Cladding
  - Brick or Stone Veneer
  - Glazing
  - Precast Walls
  - Infill Walls

Architectural Element Restraint Checklist and Examples

The following eight pages describe some typical architectural elements of a building. For each of the elements, there are a series of questions regarding the seismic anchorage. These questions are not intended to definitively assess the adequacy of the anchorage of the elements. The intention is to identify key areas of vulnerability that should be checked during a seismic survey.

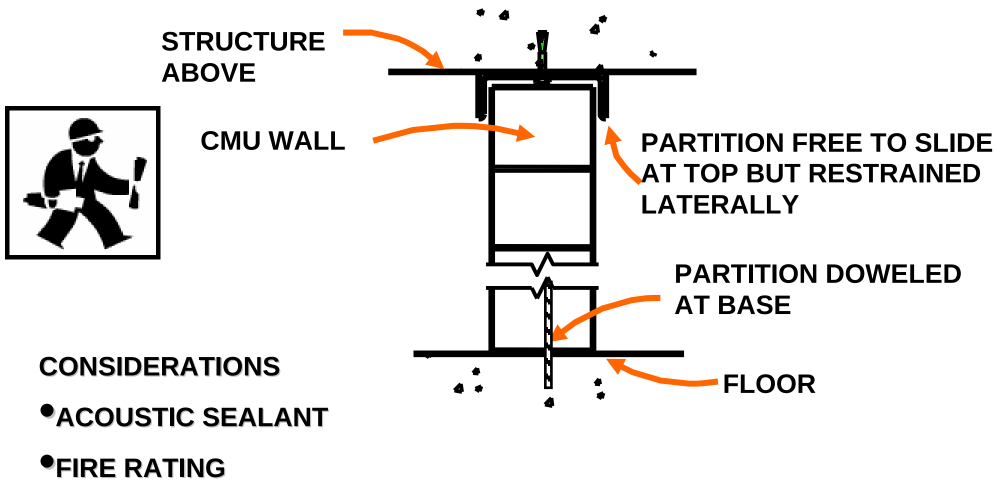
For several types of architectural elements, drawings have been provided to show typical retrofit measures that can be used to mitigate the seismic risk. These drawings are not intended to apply to all conditions, but are intended to provide an example of a type of retrofit that may be used. Next to each of the drawings is a graphic symbol to indicate whether the mitigation for this type of element should be designed by an engineer as described in the previous chapter. The mitigation methods shown depict generic details using standard hardware. Many manufacturers have developed products that can also be used in lieu of the generic details.

Partitions

These may include elements of many different materials and construction types:

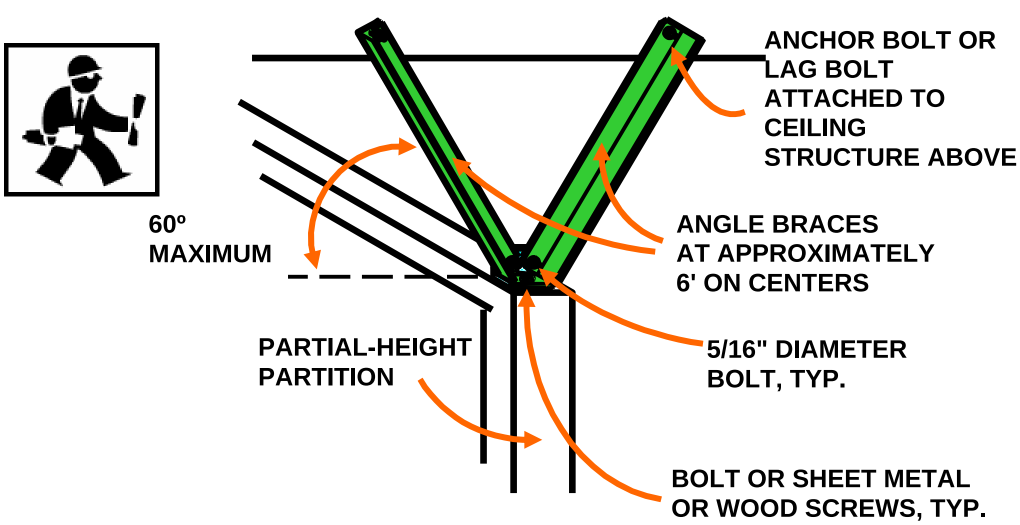
Permanent block wall partitions (concrete masonry unit, brick, hollow clay tile)

- ☐ Are block wall partitions reinforced? (Most brick or hollow clay tile walls in pre-1933 California buildings are unreinforced. In other geographic regions, unreinforced masonry elements may be found even in current construction.)
- ☐ Are the block wall partitions restrained at the top and bottom to resist out-of-plane forces?
- ☐ Are concrete masonry unit (CMU) partitions detailed to allow sliding at the top?



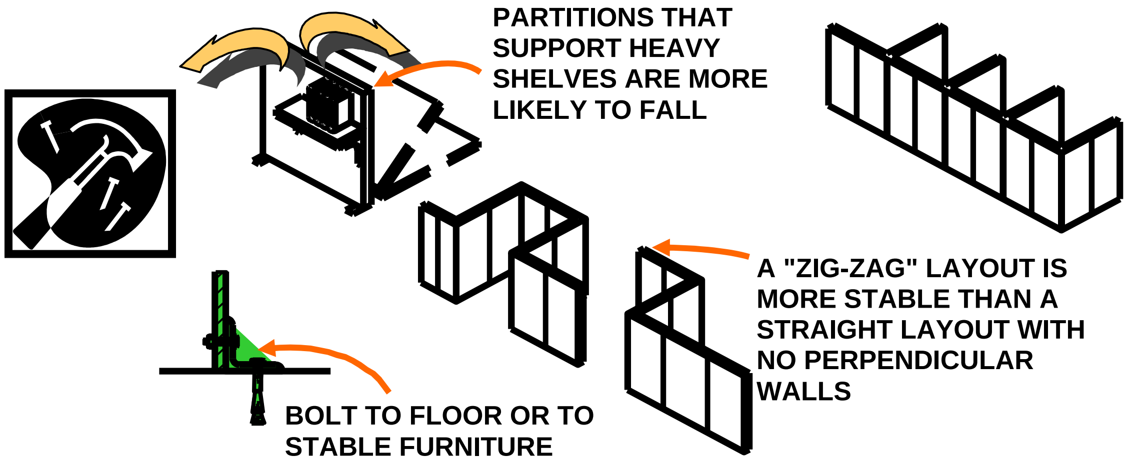
Partial-- and full--height stud wall partitions

- ☐ Are partial-height partitions attached to the structure above the ceiling line?
- ☐ If partitions function as lateral support for tall shelving or cabinets, are these partitions rigidly attached to the structure above the ceiling line?



Partial-height Prefabricated Partitions (Less than 6 feet tall)

- ☐ Are partial-height partitions attached to each other?
- ☐ Are partial-height partitions anchored to the floor?
- ☐ If tall shelving or cabinets are located next to the partitions, can these items be moved or independently anchored to the floor or structure?

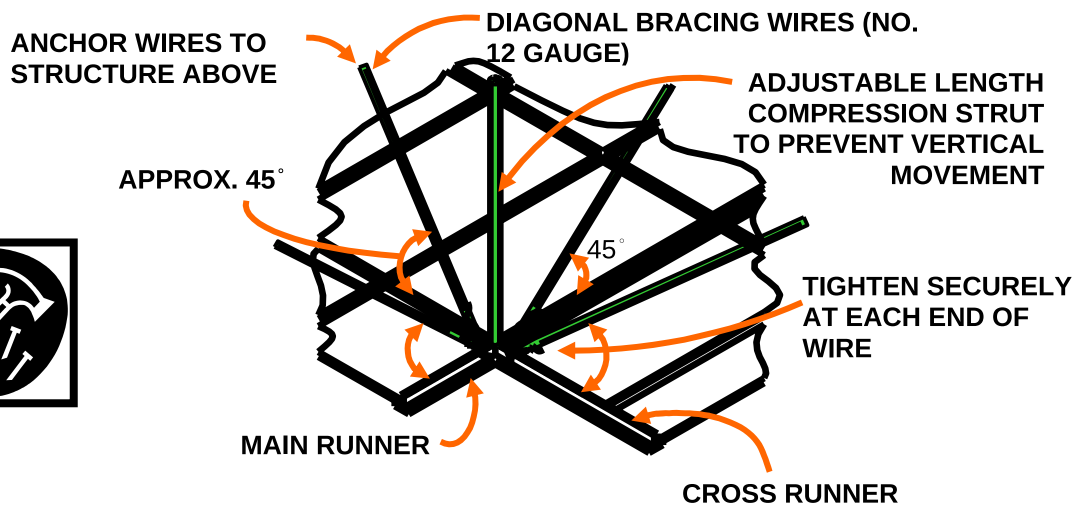


Ceilings and Soffits

These may include elements of many different materials and construction types:

Ceilings (acoustic tile, gypsumboard, plaster)

- ☐ Does the suspended ceiling have adequate diagonal bracing wires and compression struts?
- ☐ Are decorative ceiling panels and/or latticework securely attached?
- ☐ For plaster ceilings, is the wire mesh or wood lath securely attached to the structural framing above?
- ☐ Are partitions and lighting restrained independently and do not rely on the ceiling to provide lateral support?



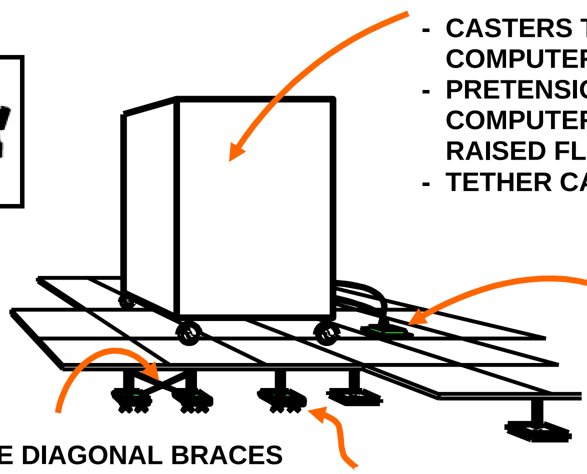
PROVIDE 4-WAY DIAGONAL BRACING AND COMPRESSION STRUT APPROXIMATELY EVERY 12 FT. EACH WAY.

Soffits (stucco, gypsumboard, plaster)

- ☐ Are decorative finishes and/or latticework on beam soffits or beneath exterior eves securely attached, particularly over exits?
- ☐ For stucco soffits, is the wire mesh or wood lath securely attached to the structural framing above?

Computer access floors

- ☐ Are computer access floors braced with diagonal steel members, or is it verified that the vertical pedestals are a seismically qualified model, installed in accordance with the manufacturer's recommendations?
- ☐ Do cable openings in the access floor have edge guards to prevent equipment legs from sliding into the openings?



Windows and Glazing

Glazing

- ☐ Is it known whether the glazing was designed by an architect/engineer to accommodate lateral movement?
- ☐ Do large windows, especially storefront windows, have safety glass?

Note: The term safety glass means tempered, laminated, or wired glass; glass covered with shatter-resistant film; or plastic panels.

Overhead glazing or skylights

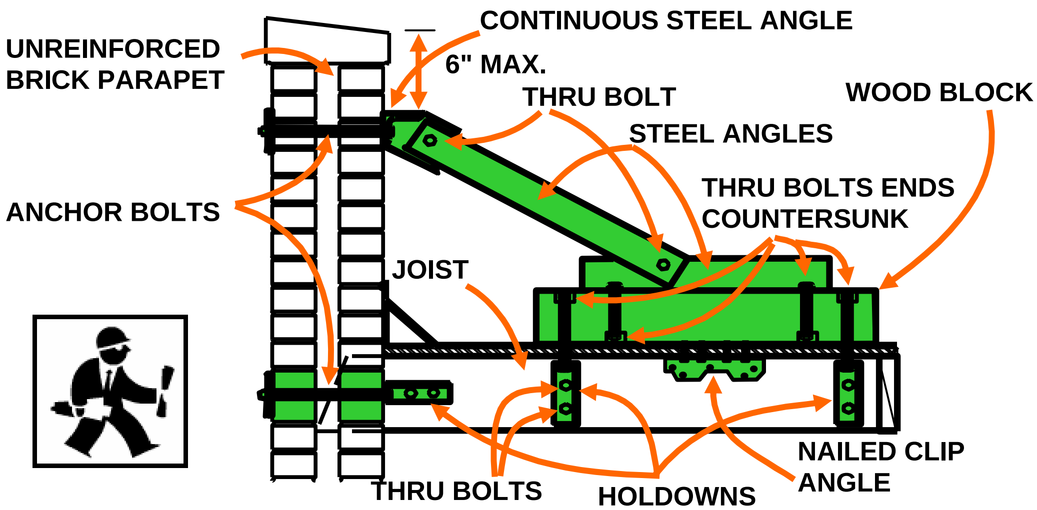
- ☐ Are transoms (glass panes over doors) made of safety glass?
- ☐ Are skylights made of safety glass or covered with shatter-resistant film?
- ☐ Are large panes made of safety glass, or is it known whether the glazing assembly was designed by an architect/engineer to accommodate the expected seismic distortion of the surrounding structure?

Interior glass or glass block partitions

- ☐ Are the glazed partitions laterally supported by the structure?

Parapets, cornices, veneer or other decoration

- ☐ Are parapets or cornices reinforced and adequately supported laterally?
- ☐ Do other decorative elements have positive anchorage to the building?
- ☐ Does the veneer have positive anchorage to the building?



☐

Exterior lighting

- ☐ Are exterior light fixtures properly supported or securely attached to the structure?

Tall sculptures (over about 5 feet)

- ☐ Are heavy or sharply pointed sculptures anchored to prevent overturning during an earthquake?
- ☐ Do hanging sculptures have a safety cable to prevent them from swinging excessively or falling?

Hanging appendages

- ☐ Are hanging appendages braced or secured with a safety cable?

Clay roof tiles

- ☐ Are clay roof tiles secured to the roof with one nail-and-wire connection per tile?

Freestanding walls or fences (concrete, CMU, brick, or stone)

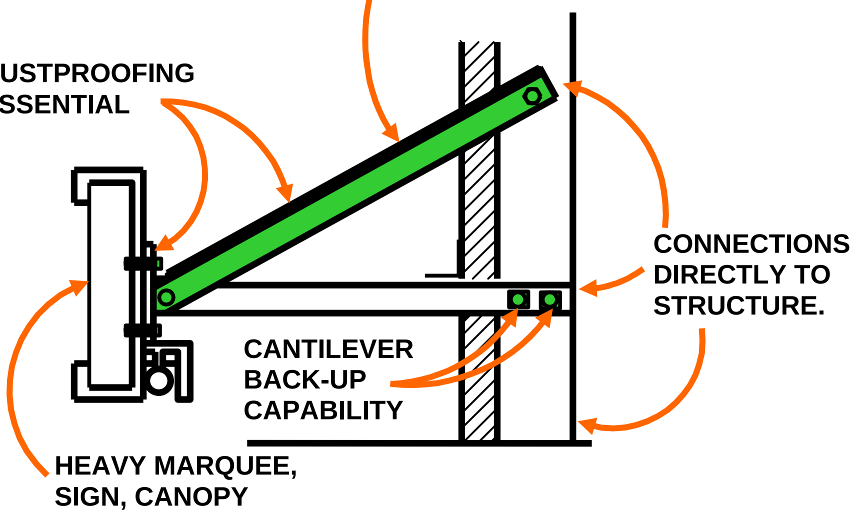
- ☐ Is it known whether freestanding walls or fences were designed by an architect/engineer to resist lateral forces?
- ☐ Are CMU walls adequately reinforced with vertical bars set in grout-filled cells and horizontal bars embedded in the mortar joints?
- ☐ Is it known whether CMU walls or fences were built with adequate foundations to prevent them from tipping over in an earthquake?

Flagpoles

- ☐ Are flagpoles securely attached to the structure?

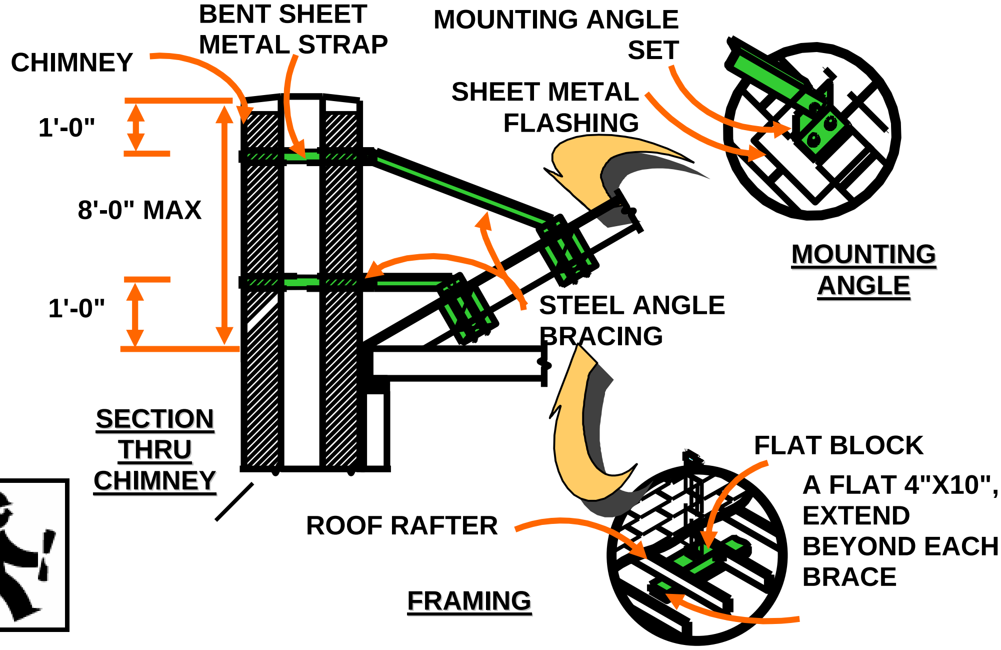
Heavy signs or exterior billboards

- ☐ Are exterior signs or billboards adequately supported laterally and anchored?
- ☐ Are interior signs securely attached with positive connections?



Small stacks or residential chimneys

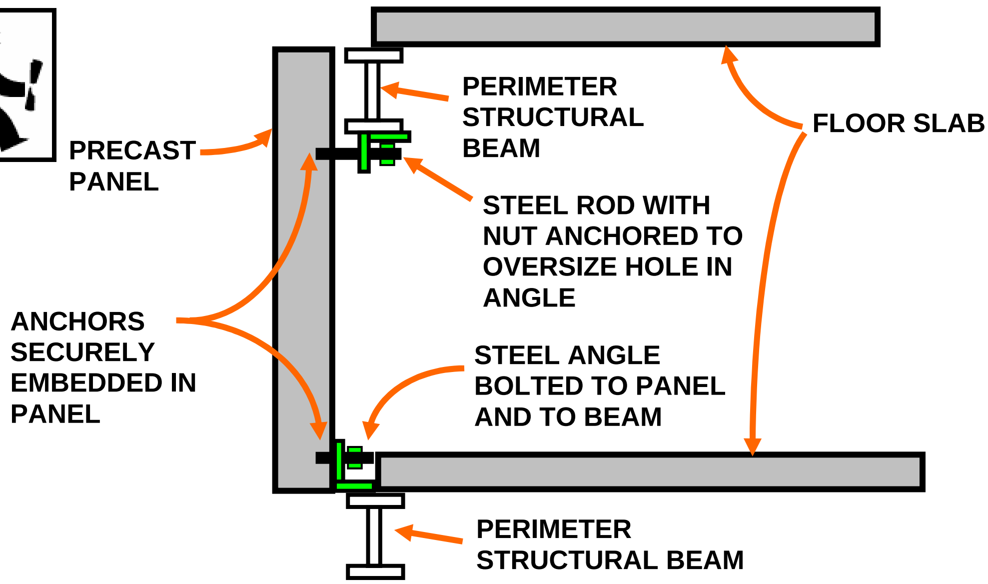
- ☐ Is the brick chimney restrained with braces to the roof near the top of the chimney?
- ☐ Is the brick chimney anchored near the roof line?
- ☐ Are stacks anchored to the supports or foundation by means of anchor bolts of adequate length and double nuts?



Cladding and Veneer

Prefabricated Cladding Panels

- ☐ Are prefabricated cladding panels detailed to allow relative movement between the panel and the structure?
- ☐ Are prefabricated panels supported for vertical loads with at least two connections per panel?
- ☐ Are prefabricated panels supported for out-of-plane loads with at least four connections per panel?



Masonry Veneer

- ☐ Is the masonry veneer supported by shelf angles or other elements at each floor?
- ☐ Is the masonry veneer connected to a structural back-up wall at adequate spacing?

Chapter 5 - Building Utility Nonstructural Elements

Characteristics of Building Utility Systems Elements

Building utility systems include a wide variety of elements including mechanical systems, electrical systems, plumbing, and communications. These elements can be either single elements, such as a tank or distributed systems, such as sprinkler piping. Usually these elements are attached to the structural framing and are often heavy elements. Typically the building utility systems are hidden from public view. As a result, they may not present an immediate hazard to the public due to falling, but failure of these systems in an earthquake will affect the functioning of the building.

The building utility systems element could have been designed by a mechanical or electrical engineer or mechanical or electrical contractor. Some elements, such as elevators, are designed by specialty engineers for the manufacturer.

Categories

The following are categories and types of building utility nonstructural elements that may be present in most buildings.

- Emergency power-generating equipment
- Electrical equipment and distribution
- Fire detection and suppression equipment
- Fuel tanks and distribution
- Heating, ventilation, air conditioning (HVAC) equipment and distribution systems
- Plumbing system (water, sewerage)
- Gas piping
- Mechanical appendages
- Lighting
- Communications equipment
- Elevators and escalators

Building Utility Elements Restraint Checklist and Examples

The following fifteen pages describe some typical building utility system elements of a building. For each of the elements, there are a series of questions regarding the seismic anchorage. These questions are not intended to definitively assess the adequacy of the anchorage of the elements. The intention is to identify key areas of vulnerability that should be checked during a seismic survey.

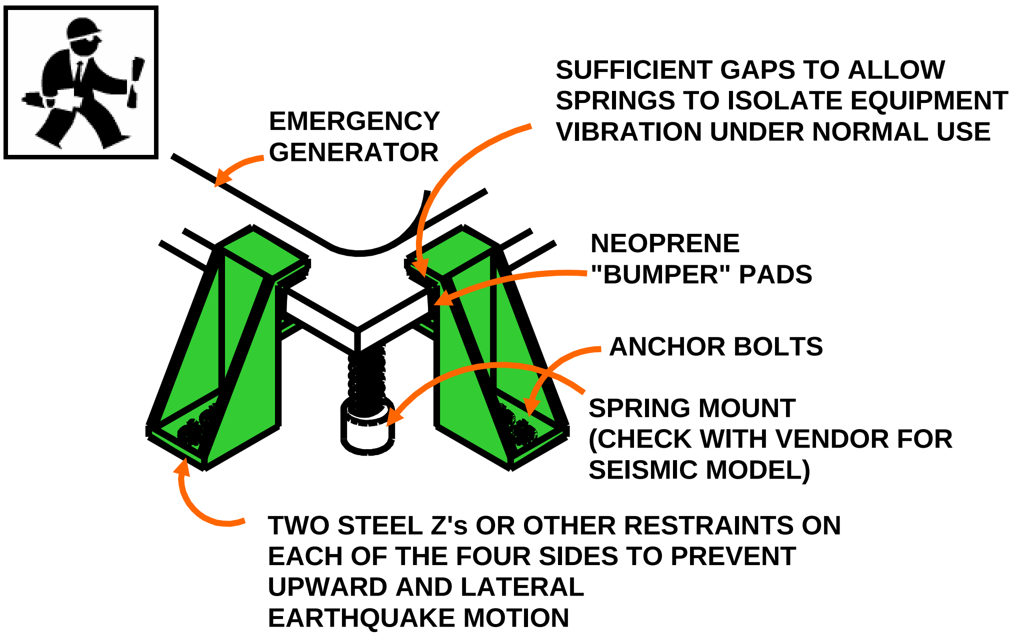
For several types of building utility system elements, drawings have been provided to show typical retrofit measures that can be used to mitigate the seismic risk. These drawings are not intended to apply to all conditions, but are intended to provide an example of a type of retrofit that may be used. Next to each of the drawings is a graphic symbol to indicate whether the mitigation for this type of element should be designed by an engineer as described in the previous chapter. The mitigation methods shown depict generic details using standard hardware. Many manufacturers produce earthquake retrofit products that can also be used in lieu of the generic details.

Emergency Power-Generating Equipment

Emergency power-generating equipment generally consists of the following components:

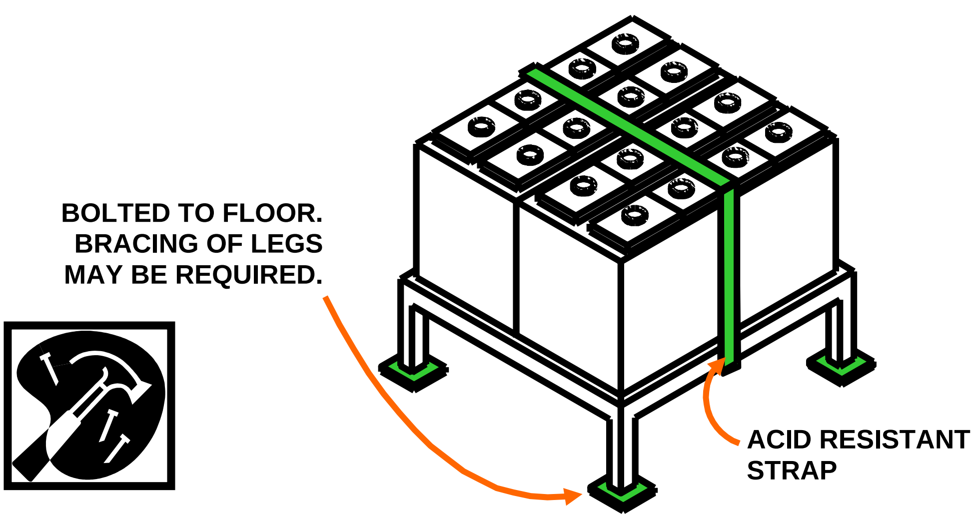
Generator

- ☐ Is the emergency generator adequately anchored, especially if mounted on motor vibration isolation springs?



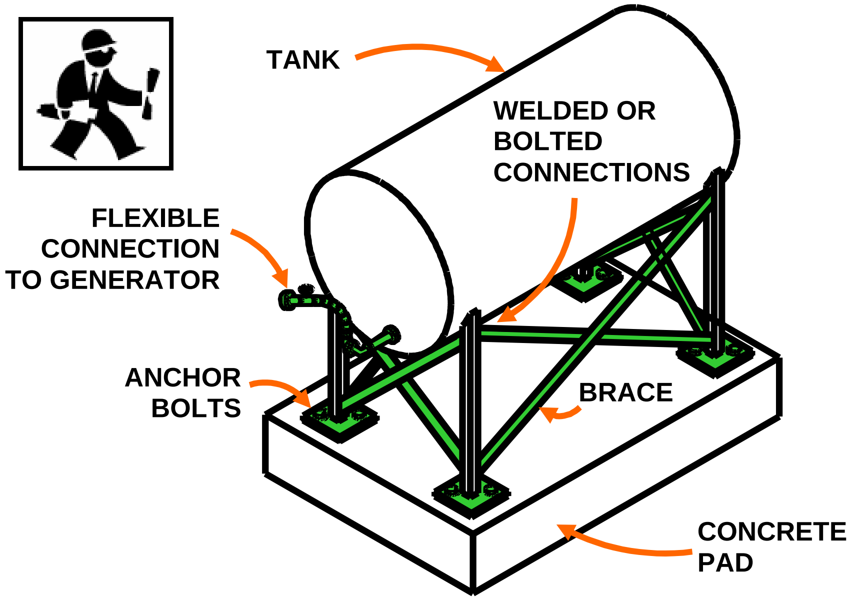
Batteries, battery rack

- ☐ Are the batteries securely attached to the battery rack?
- ☐ Is the battery rack cross-braced in both directions?
- ☐ Does the battery rack have anchor bolts secured to a concrete foundation pad?
- ☐ Is the foundation large enough to keep the rack from sliding or tipping?



Diesel fuel tank

- ☐ Is the tank securely attached to the supports?
- ☐ Are the tank supports laterally supported in both directions?
- ☐ Are the supports attached with anchor bolts to concrete walls or foundation pad?



- ☐ Is the foundation large enough to keep the tank from tipping over or sliding?
- ☐ Is the wall strong enough to support the tank?

Fuel line, cooling water lines, exhaust flues

- ☐ Are these lines attached with flexible connections that are able to accommodate relative movement at junctions to spring-mounted equipment, at building entry and exit points, and at expansion joints within the building?

Electrical Equipment and Distribution

The emergency power system includes both power-generating equipment and the electrical distribution system:

Transformers

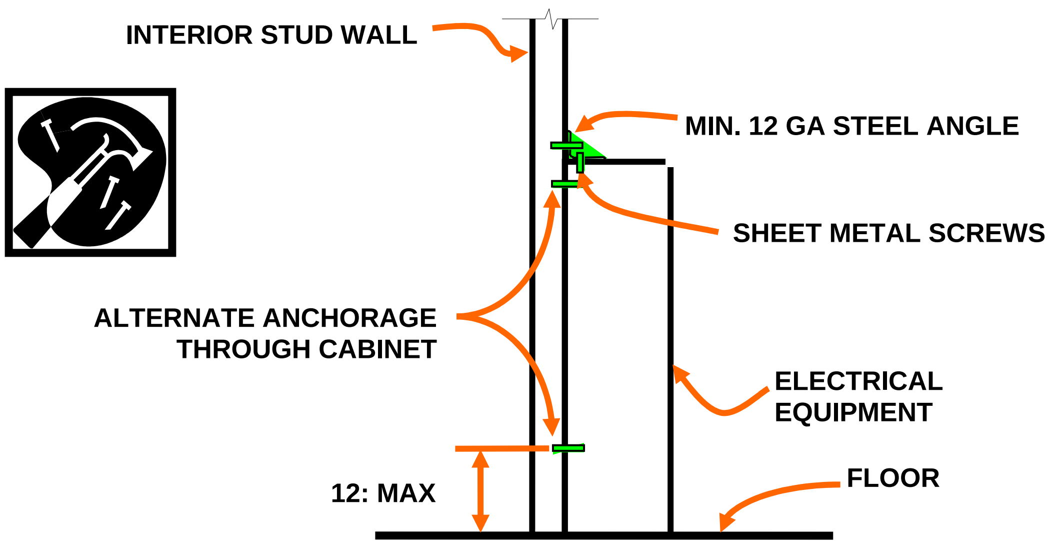
- ☐ Are transformers properly anchored to the floor or wall?

Motor Control Center (MCC)

- ☐ Are the motor control centers properly anchored to the floor or laterally supported by the wall?
- ☐ Does the wall have adequate strength to restrain the motor control center?

Electrical switchgear

- ☐ Is the switchgear properly anchored to the floor or supported by wall?
- ☐ Does the wall have adequate strength to restrain the switchgrear?



Electrical bus ducts and primary cable system

- ☐ Are electrical cables or conduit able to distort at the connections with the equipment or where they cross seismic joints between buildings?
- ☐ Are the bus ducts or cable conduits laterally braced?

Caution: Only qualified personnel should open access panels on electrical equipment.

Fire Detection and Suppression System

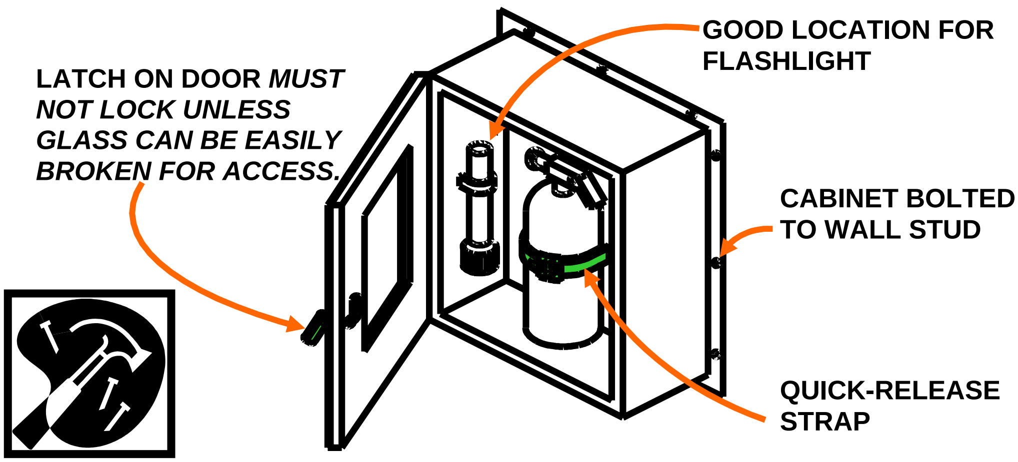
The fire detection and suppression system may include any or all of the following components:

Smoke detectors, fire alarm system, control system for automatic fire doors

- ☐ Are fire and smoke detectors properly mounted?
- ☐ Is the control equipment for the fire alarm system and automatic fire doors securely anchored?

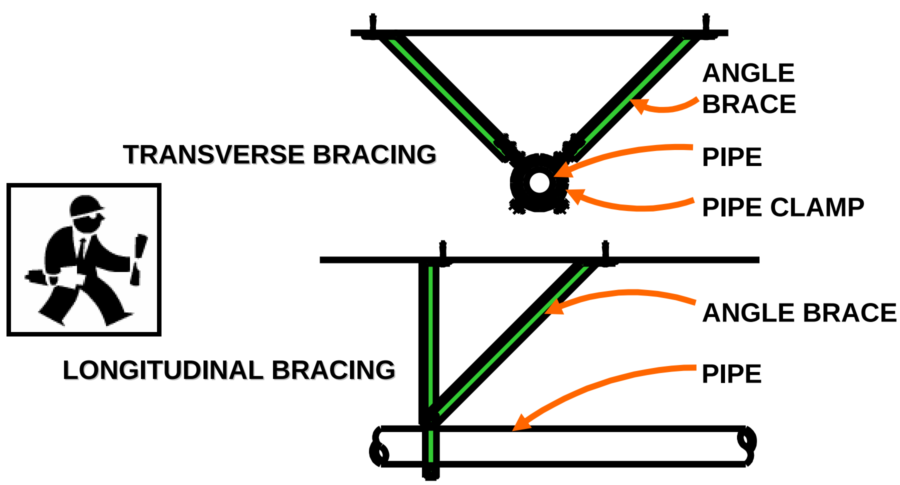
Fire extinguisher or fire hose cabinets

- ☐ Are the fire extinguisher cabinets and/or hose cabinets securely mounted?
- ☐ Are the fire extinguishers secured with quick-release straps?



Fire sprinklers and distribution lines

- ☐ Are the fire sprinkler piping components laterally restrained in each direction?
- ☐ Is the ceiling restrained so the ceilings won't break the sprinkler heads?
- ☐ Are the distribution lines able to accommodate movement where they cross between buildings?



Fire water pump

- ☐ Is the fire water pump anchored, or is it mounted on vibration isolation springs with additional seismic restraints?

Emergency water tank or reservoir

- ☐ Is the water tank or reservoir securely attached to its supports?
- ☐ Are the tank supports braced in both directions?
- ☐ Are the supports or braces properly anchored to the foundation?

Smoke control systems

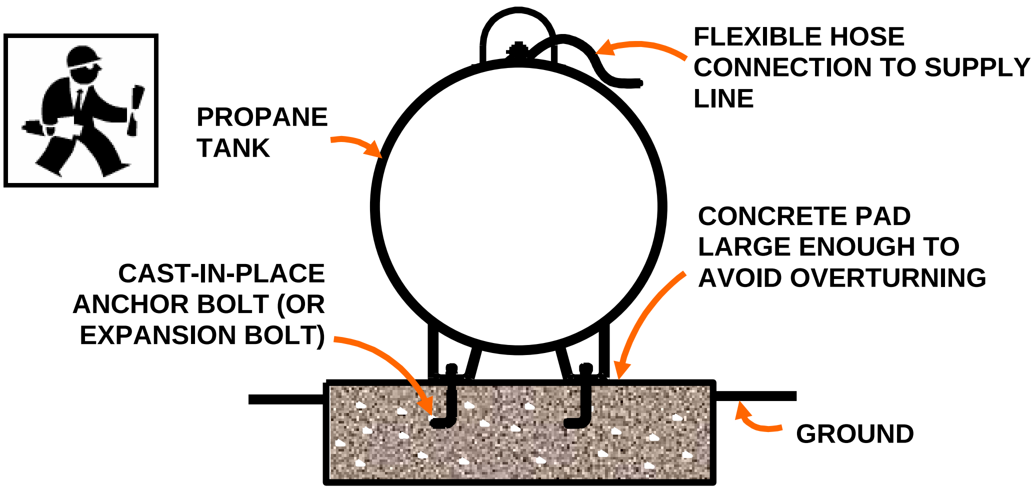
- ☐ Are the fans properly supported and/or anchored?
- ☐ Are fan control centers securely anchored?

Fuel Tanks and Distribution

Propane tanks may be used for backup power, heating, or cooking. These systems include:

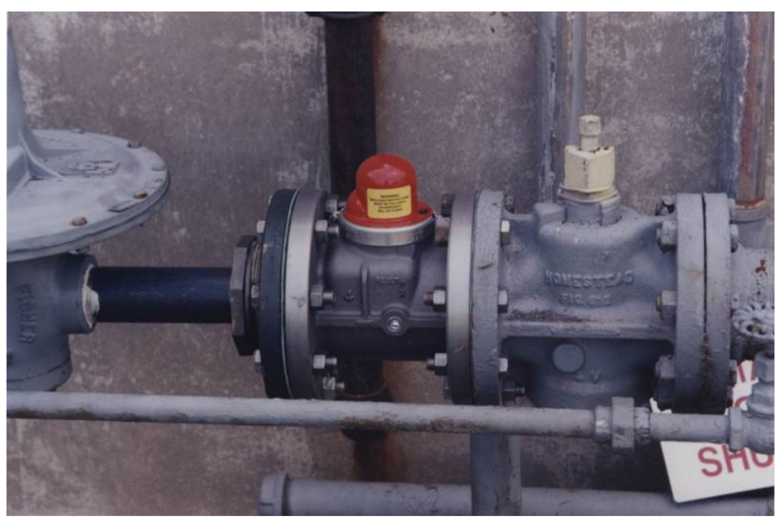
Propane tank

- ☐ Is the tank securely anchored to the supports?
- ☐ Are the tanks laterally supported in both directions?
- ☐ Are the supports anchored to a concrete foundation pad?
- ☐ Is the foundation large enough to keep the tank from sliding or tipping over?



Shut-off valve

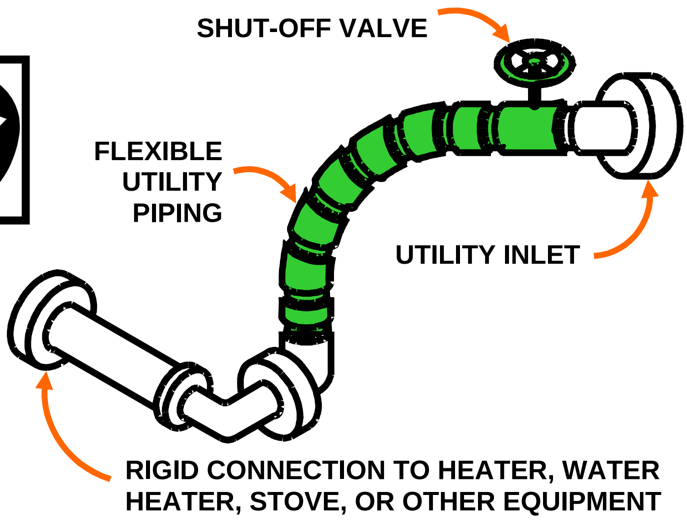
- ☐ Does the system have an automatic, earthquake-triggered shut-off valve?
- ☐ If the shut-off is manual, is a wrench stored within easy reach?



Caution: Only qualified personnel should make modifications to gas piping.

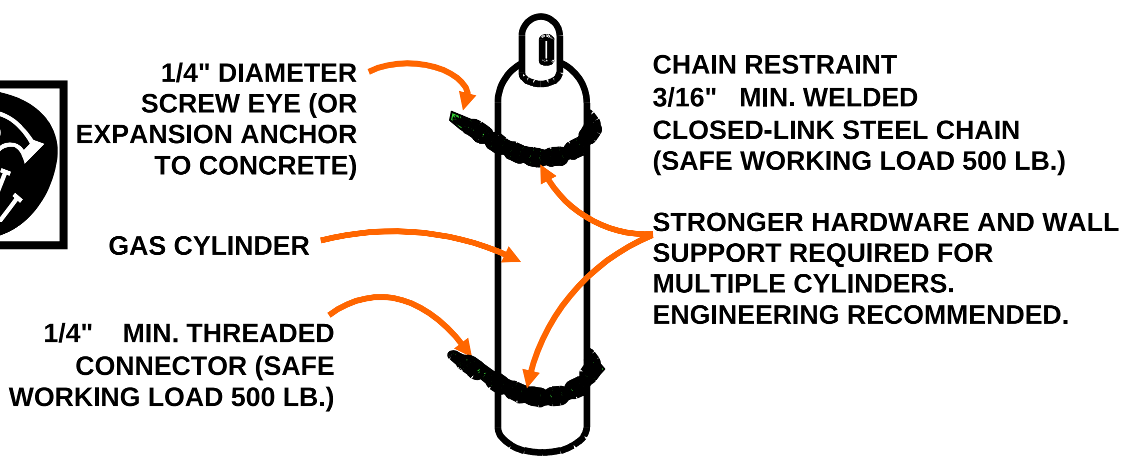
Gas or fuel supply pipe

- ☐ Are the supply pipes laterally restrained at reasonable intervals in each direction?
- ☐ Are the restraints securely attached to the structure?
- ☐ Do the pipes have flexible connections at the tank that are able to accommodate relative movement?



Compressed Gas Cylinders

- ☐ Are all gas cylinders tightly secured with a chain near the top and bottom or otherwise restrained from movement in each direction?
- ☐ Are the chains or restraints securely anchored to a wall or counter with screws or bolts rather than clamps?

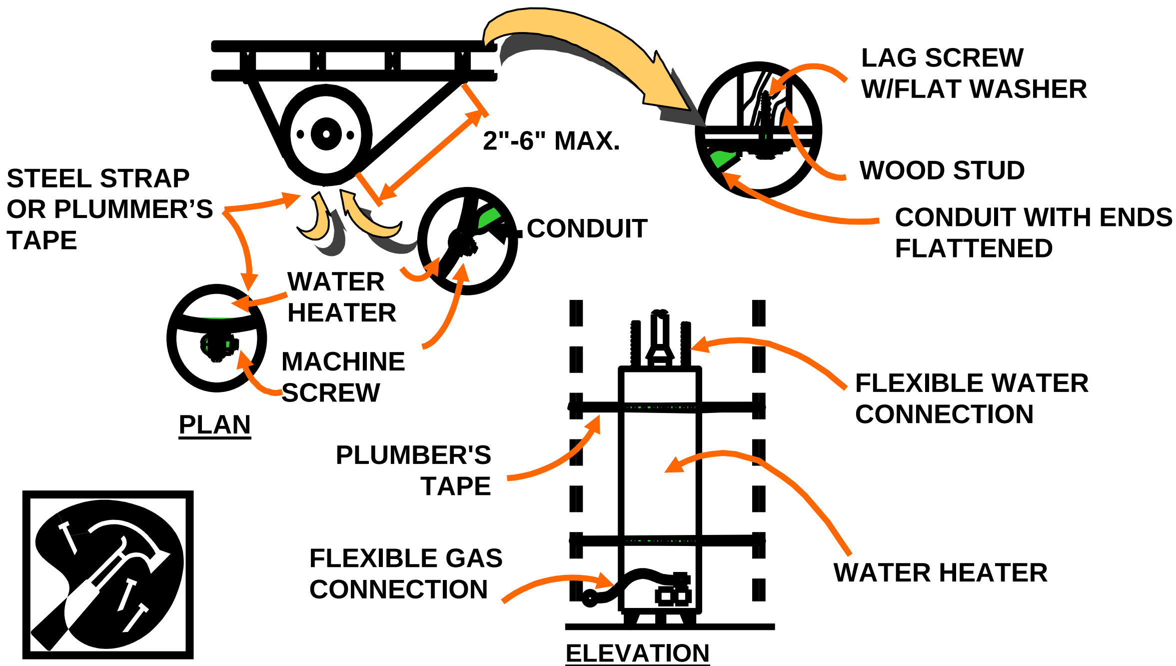


Plumbing System

The plumbing system may include:

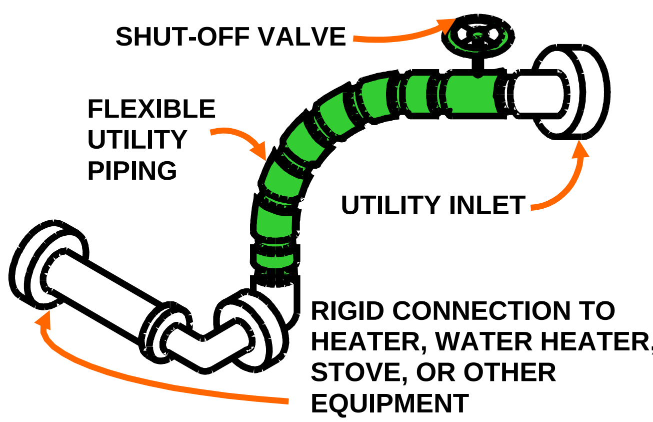
Residential water heater

- ☐ Are the water heaters securely anchored to the floor or wall?
- ☐ Does the gas line or electrical conduit have a flexible connection to the water heater that is able to accommodate movement?
- ☐ Does the water heater meet the limitations for use of prescriptive restraints:
  Capacity < 100 gallons
  Structural wall within 12 inches?
- ☐ Does the wall have adequate strength to restrain the water heater?



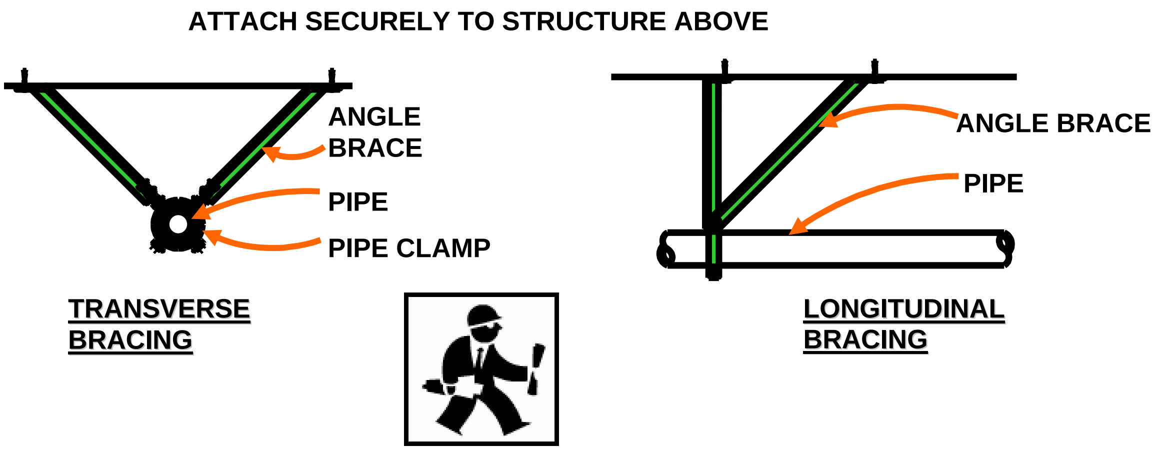
Commercial gas-fired water heater or boiler

- ☐ Are the large commercial water heaters or boilers securely anchored to the floor or wall?
- ☐ Are housekeeping pads under boilers anchored to the floor slab?
- ☐ Does the gas line have a flexible connection to the water heater or boiler that is able to accommodate movement?



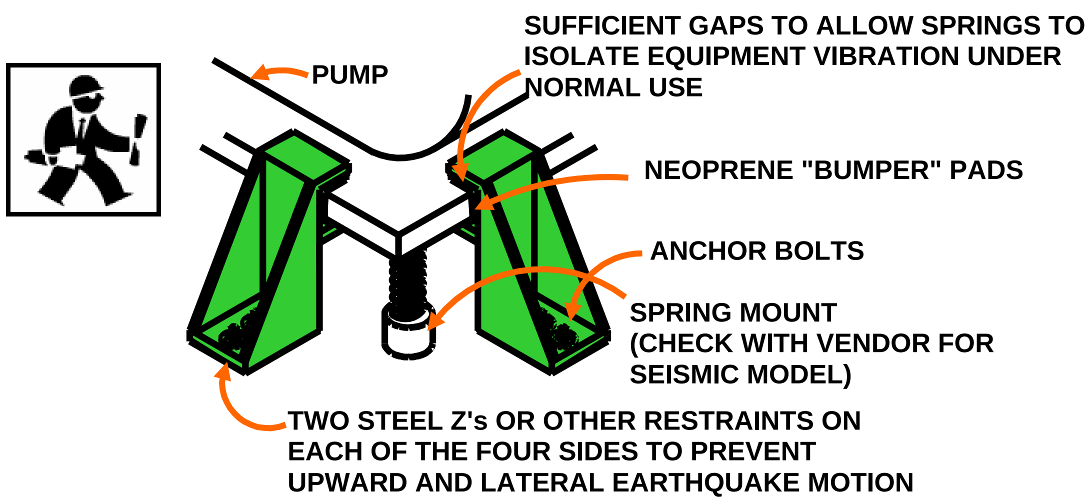
Hot and cold water pipes, hot water return, wastewater pipes

- ☐ Are the pipes laterally restrained at reasonable intervals in each direction?
- ☐ Are the restraints securely attached to the structure?
- ☐ Do the pipes have flexible connections to boilers or tanks that are able to accommodate movement?
- ☐ Are the distribution lines able to accommodate movement where they cross seismic joints between buildings?
- ☐ Are pipe penetrations through structural walls or framing members large enough to allow for some seismic movement?
- ☐ Are the pipes free of asbestos insulation that could be damaged by movement in an earthquake?
- ☐ Will asbestos abatement be required before any retrofit work?
- ☐ Are risers (vertical runs of piping) laterally restrained at each floor level?



Distribution pumps

- ☐ Are the distribution pumps anchored, or are they mounted on vibration isolation springs with additional seismic lateral restraints?



Solar panels

- ☐ Are the solar panels securely anchored to the roof?
- ☐ Is the piping laterally restrained?

Heating, Ventilating, and Air Conditioning (HVAC) System

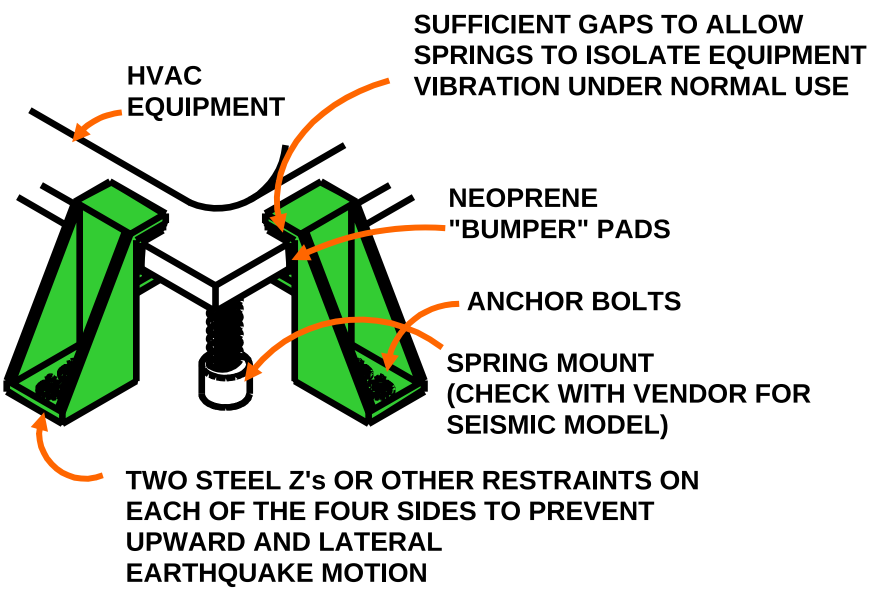
The HVAC system may include any or all of the following components, depending on the size of the facility:

Boilers and furnaces

- ☐ Are boilers and furnaces securely anchored with adequately sized bolts?
- ☐ Are furnaces, and furnace or boiler bases, constructed without using unreinforced masonry?

Chillers

- ☐ Are chillers securely anchored, or are they mounted on vibration isolation springs with added seismic restraints?



Heat pumps or heat exchangers

- ☐ Are pumps or heat exchangers anchored, or are they mounted on vibration isolation springs with added seismic restraints?

Fans, blowers, filters

- ☐ Are fans, blowers, and filters securely anchored, or are they mounted on vibration isolation springs with added seismic restraints?

Air compressors

- ☐ Are air compressors anchored, or are they mounted on vibration isolation springs with added seismic restraints?

Roof-mounted HVAC units

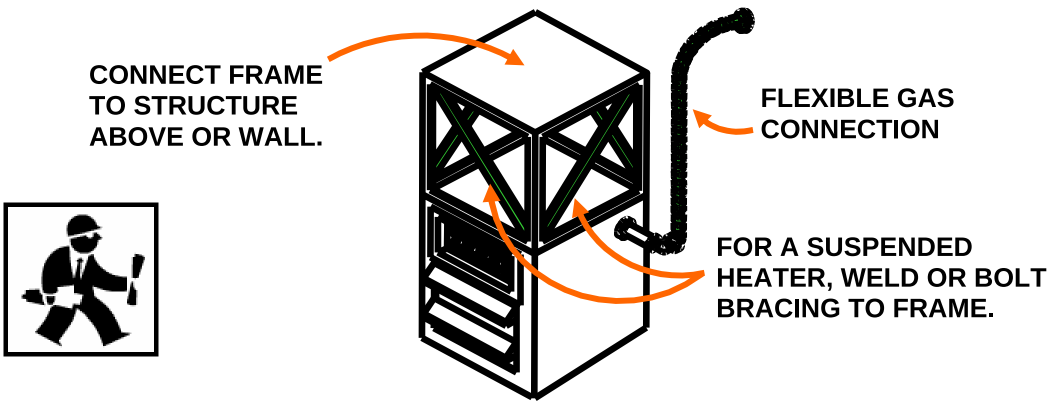
- ☐ Are the HVAC units securely anchored, or are they mounted on vibration-limiting springs with added seismic restraints?
- ☐ Are the curbs supporting the spring isolators securely attached to the structural roof framing?

Wall-mounted room air conditioning units

☐ Are the air conditioning units securely mounted to the wall or shelf?

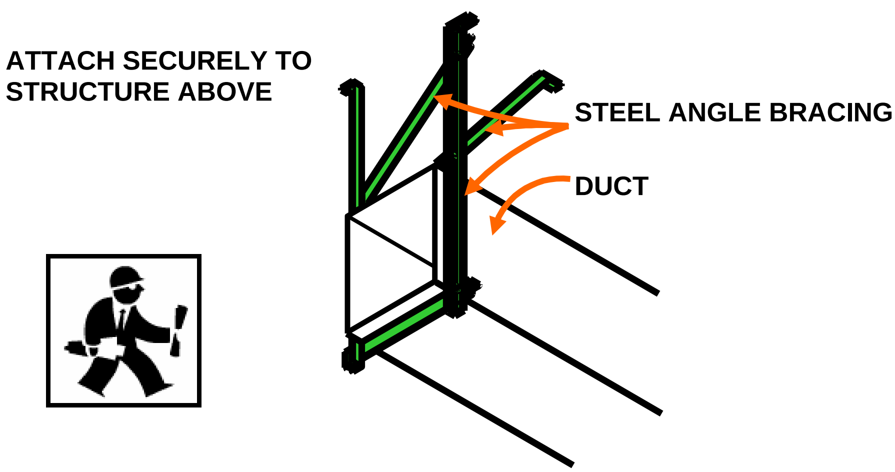
Suspended room heaters

☐ Are the suspended room heaters, especially gas-fired ones, laterally supported?
☐ Are gas-fired heaters fitted with flexible gas connections?



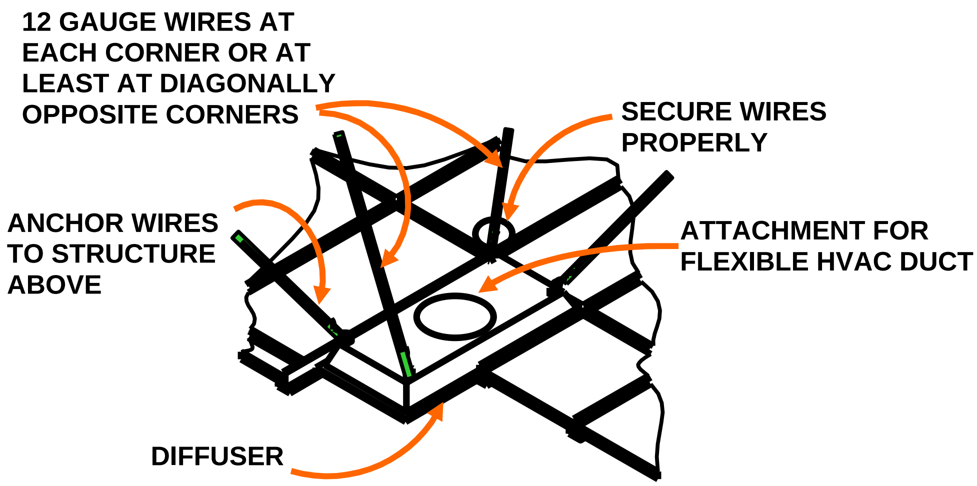
Distribution ducts

☐ Are the rectangular distribution ducts larger than 6 sq ft in cross sectional area laterally supported in each direction?
☐ Are circular ducts larger than 28 inches diameter laterally supported in each direction?
☐ Are the supports and hangers securely attached to the structure?
☐ Are the distribution ducts able to accommodate movement at locations where they cross separations between buildings?



Diffusers

- ☐ Are the air distribution grills or diffusers anchored to adequately supported sheet-metal ducts or to the ceiling grid or wall?
- ☐ Do the diffusers have positive restraint, independent of the ceiling grid, such as at least two hanger wires per diffuser?

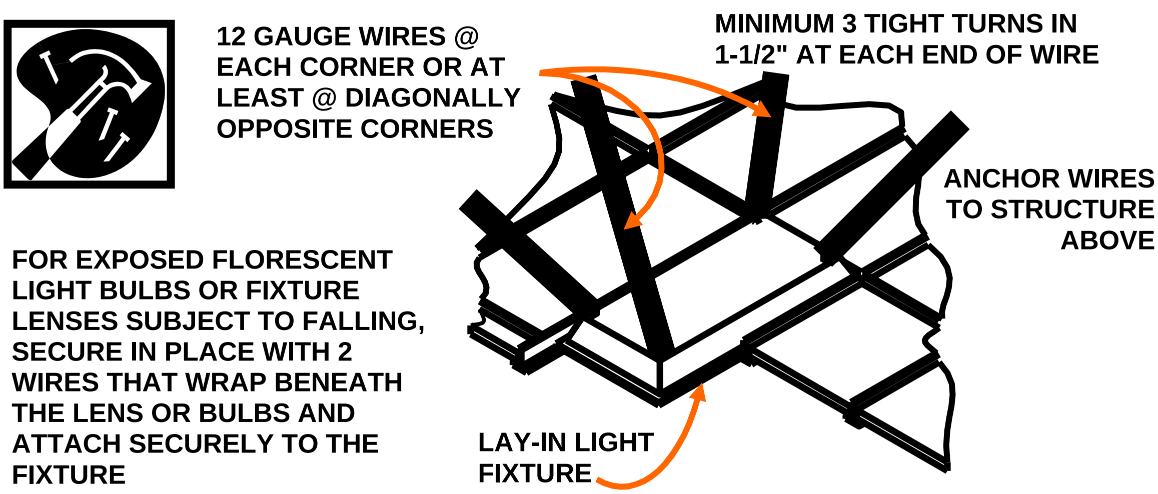


Lighting

This category may include the following:

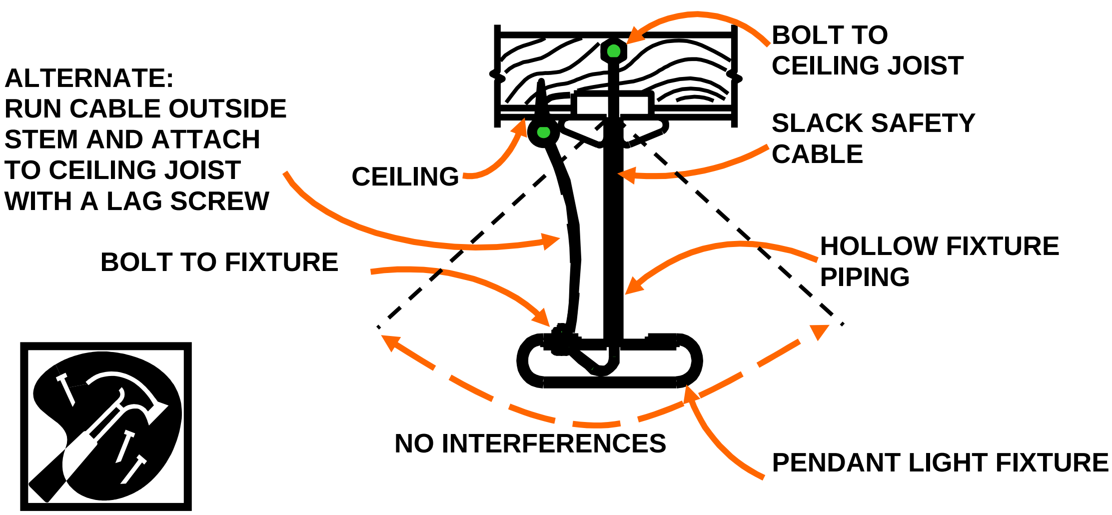
<u>Suspended overhead lighting, fixed or track lighting</u>

- ☐ Do the lay-in fluorescent light fixtures have positive support, independent of the ceiling grid, such as at least two diagonally opposite hanger wires per light fixture?
- ☐ Do chandeliers or other hanging fixtures have safety cables to prevent them from falling or impacting each other or a window?
- ☐ Are lens covers attached or supplied with safety devices?



<u>Fixed overhead, pendant, or track lighting</u>

- ☐ Do pendant or stem light fixtures have safety cables so they will not fall if the fixture sways and breaks the stem connection, or are they braced to prevent swaying?
- ☐ Are spot lights or track lights securely attached to resist seismic shaking?



<u>Emergency lighting and exit lights</u>

- ☐ Are emergency lights and exit lights mounted to protect them from falling off shelf supports?

Communications Equipment

Communications and emergency communications systems may include:

Radio and short short-wave radio equipment

- ☐ Is radio equipment restrained to keep it from sliding off shelving or tabletops?

Telephone, cellular phone, and fax equipment

- ☐ Is important equipment restrained to keep it from sliding off shelving or tabletops?
- ☐ Are telephones placed on desktops or counters far enough from the edge that they will not slide and fall off?

Public address system

- ☐ Is the public address system restrained to prevent the equipment from sliding and falling off the shelving?

Suspended speakers in conference room or auditorium

- ☐ Are sound system speakers in elevated locations anchored to the structure or hung with safety cables?

Microwave equipment (antennae, receiver, transmitter, etc.)

- ☐ Is the microwave communications equipment securely supported and/or anchored?

Computer networks, data storage

- ☐ Is computer information vital to operations backed up and stored off-site?
- ☐ Is critical computer equipment securely anchored to supports?
- ☐ Is sensitive computer or communications equipment located out of range of fire sprinkler heads or joints in the sprinkler pipes where they are less prone to water damage if the sprinkler lines break?

Overhead-mounted television sets or surveillance cameras

- ☐ Are overhead-mounted television sets or surveillance cameras securely anchored to support shelves or brackets that are in turn adequately connected to the wall or ceiling?

Elevators and Escalators

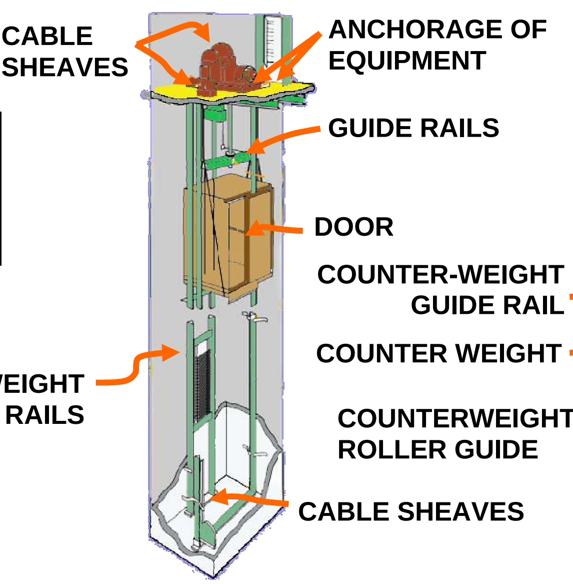
The transport equipment generally includes:

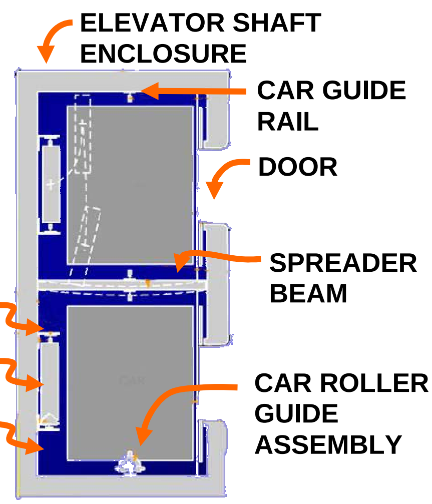
Elevator cab

- ☐ Is the elevator cab properly attached to the guide rails?
- ☐ Is the elevator equipped with a seismic switch?

Cables, counterweights, and guide rails (for cable--traction systems)

- ☐ Are the cables installed in such a way that they are protected against misalignment during an earthquake?
- ☐ Are the counterweights properly attached to the guide rails?
- ☐ Are the guide rails securely attached to the building?





Elevator motor and motor control cabinets

- ☐ Are the motor and motor control cabinets properly anchored?

Elevator cab and hydraulic elevator equipment (hydraulic systems)

- ☐ Are the components of the hydraulic system properly anchored?

Escalator

- ☐ Is the escalator control equipment securely anchored?

People mover

- ☐ Is the control equipment for the people mover properly anchored?

Caution: The moving parts or components of these systems need to be evaluated by qualified personnel. Inappropriate seismic restraints may compromise the safe operation of these systems.

Chapter 6 - Furniture and Contents

Characteristics of Furniture and Contents

Other nonstructural elements that are present in a building are furniture and contents. This classification can include any non-permanent elements in a building. Often furniture and contents are tenant-supplied elements that are not permanently attached to the structural framing. Furniture and contents can include a wide variety of elements within a building, from bookshelves and the books on the shelves to computer equipment.

Most furniture and contents elements are installed in a building with little or no consideration of seismic restraint.

Categories of Furniture and Contents

The following are typical categories and types of furniture and contents elements that are present in most typical buildings.

Office and computer equipment
Storage of records and supplies
Kitchen and laundry equipment
Hazardous materials (Hazmat)
Furniture and interior decoration

Some buildings may contain additional elements that are specialized for the use and occupancy of the building, such as medical equipment in hospitals. These specialized elements may have characteristics similar to typical furniture, but some elements may require specialized considerations.

COMMON FAILURES
CAUSING HAZ MAT RELEASES

- Building structural failures
- Dislodged asbestos
- Underground pipeline breaks
- Short connector pipe breaks
- Buckling of vertical cylindrical tanks
- Overturning of elevated tanks
- Sloshing from open-topped tanks
- Falling containers
- Equipment sliding or overturning

Furniture and Contents Examples

The following six pages described some typical furniture and contents of a building. For each of the elements, there are a series of questions regarding the seismic anchorage. These questions are not intended to definitively assess the adequacy of the anchorage of the elements. The intention is to identify key areas of vulnerability that should be checked during a seismic survey.

For several types of furniture and contents, drawings have been provided to show typical retrofit measures that can be used to mitigate the seismic hazard. These drawings are not intended to apply to all conditions, but are intended to provide an example of a type of retrofit that may be used. Next to each of the drawings is a graphic symbol to indicate whether the mitigation for this type of element should be designed by an engineer as described in the previous chapter. The mitigation methods shown depict generic details using standard hardware. Many manufacturers have developed products that can also be used in lieu of the generic details.

Office and Computer Equipment

This category may include a broad range of equipment, such as:

Large computer equipment, tape drives

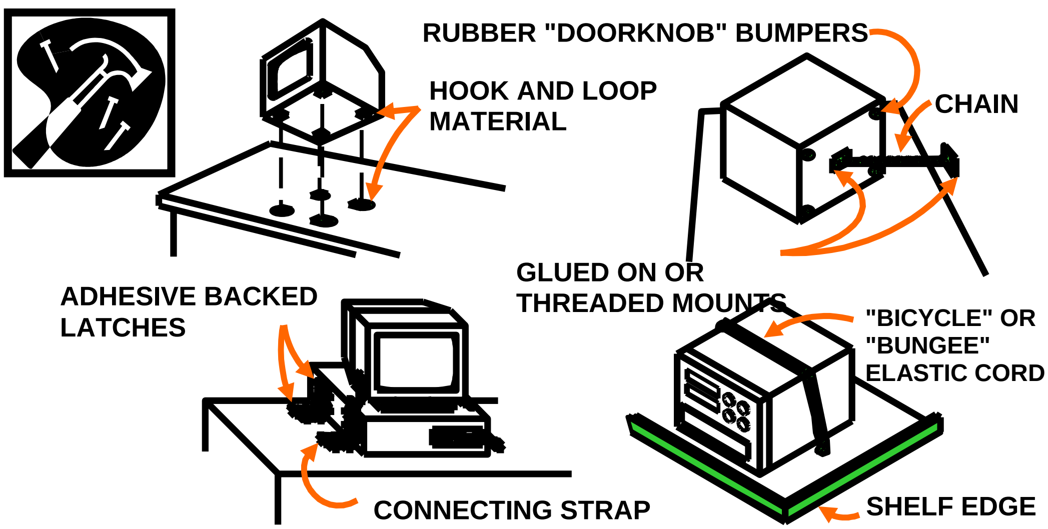
- ☐ Are computers, tape racks, and associated equipment that are about twice as tall as wide, anchored, tethered, and/or laterally supported?
- ☐ Is heavy computer equipment anchored to the structural floor slab and braced independently of the computer access floors?

Computer cabling

- ☐ Is computer cabling long enough to accommodate lateral movement within the building?

Desktop computer equipment or printers

- ☐ Are computer monitors anchored to desktops or computers?
- ☐ Are desktop computers and printers mounted with positive restraint, resting on high-friction rubber pads, or located far enough from the edges of desks and tables to prevent them from sliding and falling in an earthquake?

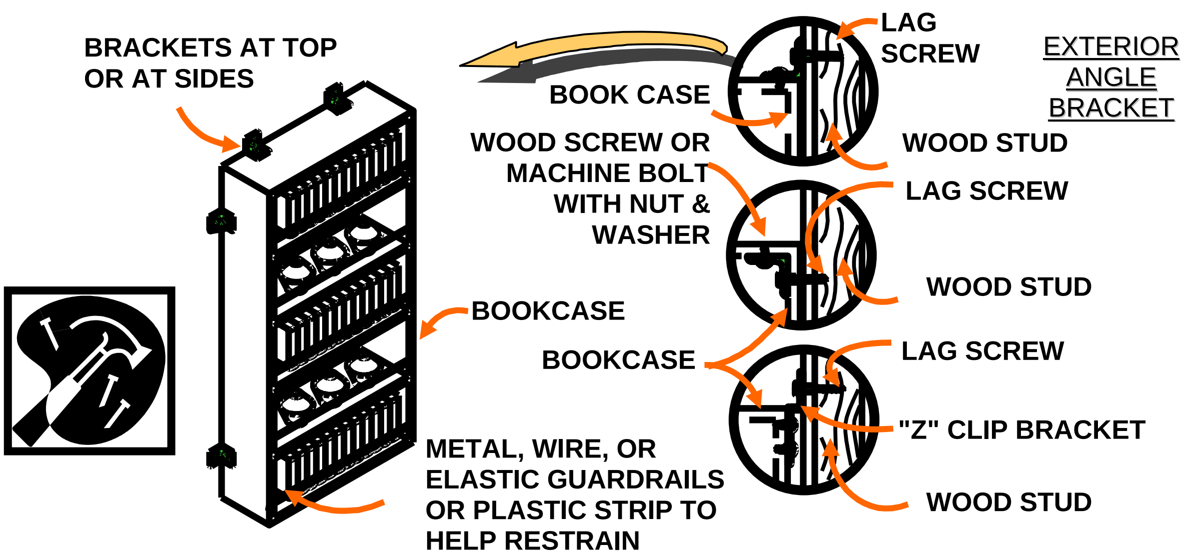


Storage of Records and Supplies

Storage for files, accounting records, and emergency supplies may include:

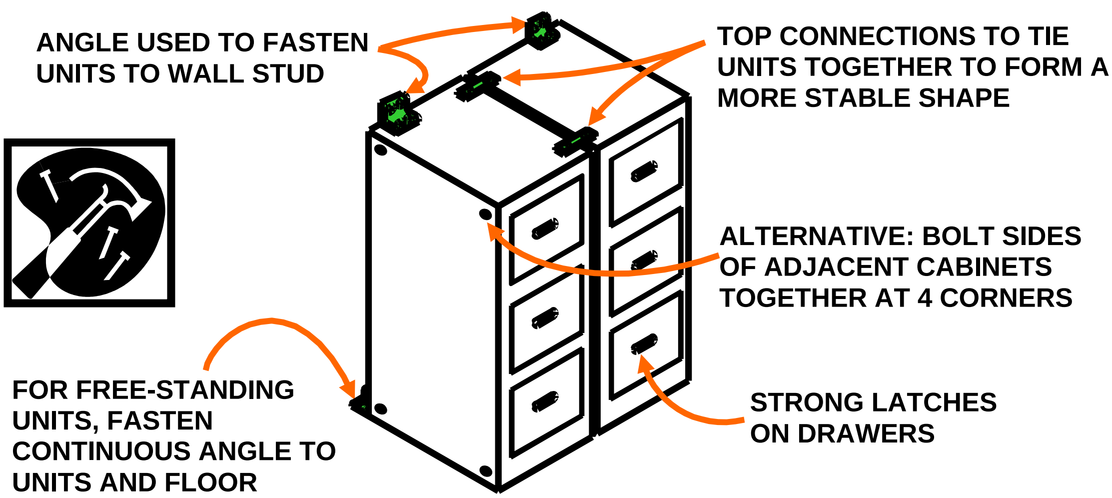
<u>Bookshelves and library stacks 5 feet or taller</u>

- ☐ Are bookshelves properly anchored with brackets to a solid wall or studs, or anchored to the floor?
- ☐ Are bookshelves fitted with edge restraints or elastic cords to keep books from falling?
- ☐ Are large and heavy books located on the lowest shelves?
- ☐ Are rare books given extra protection to prevent falling and water damage?



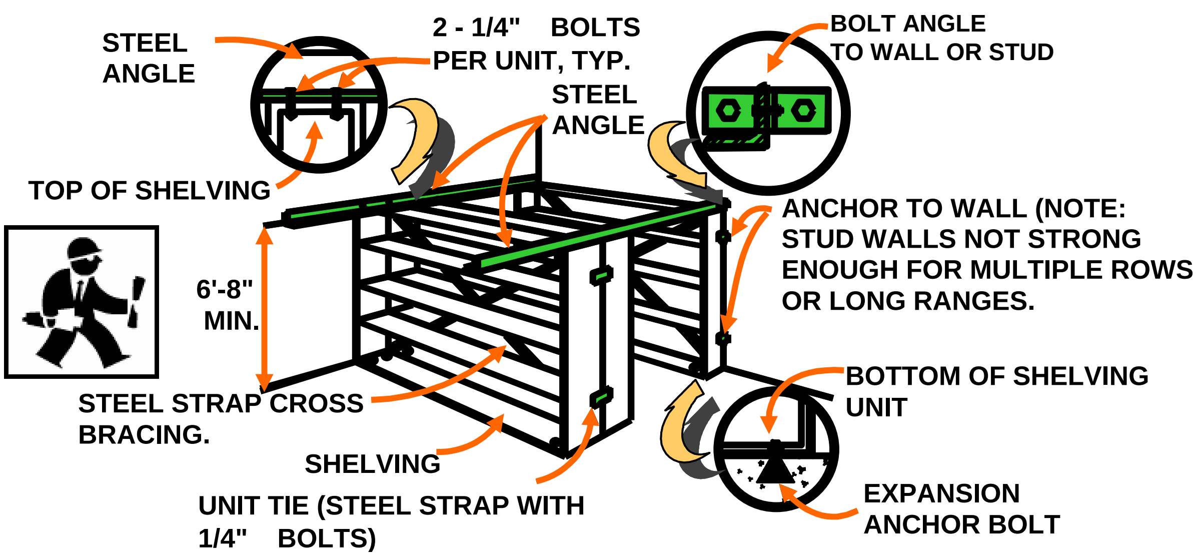
<u>Tall vertical or lateral file cabinets</u>

- ☐ Do the file cabinet drawers or doors latch securely?
- ☐ Are tall file cabinets anchored with wall brackets to a solid wall or studs, anchored to the floor, or bolted to one or more adjacent cabinets to form a more stable configuration, i.e., a larger "footprint"?
- ☐ Are unanchored cabinets located so that they will not fall or slide and block an exit?



Tall storage racks or shelving

- ☐ Are tall storage racks or shelves securely anchored to the floor or walls?
- ☐ If walls are used for lateral support, has the capacity of the walls been checked for adequacy to restrain the shelving?
- ☐ Are heavily loaded racks or shelves supported in both directions?
- ☐ For racks significantly taller than wide, are large anchor bolts used to anchor each leg to a concrete slab?
- ☐ Are breakable items secured to the shelves or racks, or are they stored in stable units (e.g., are they shelved in the original packing boxes, or are small items shrink-wrapped together)?

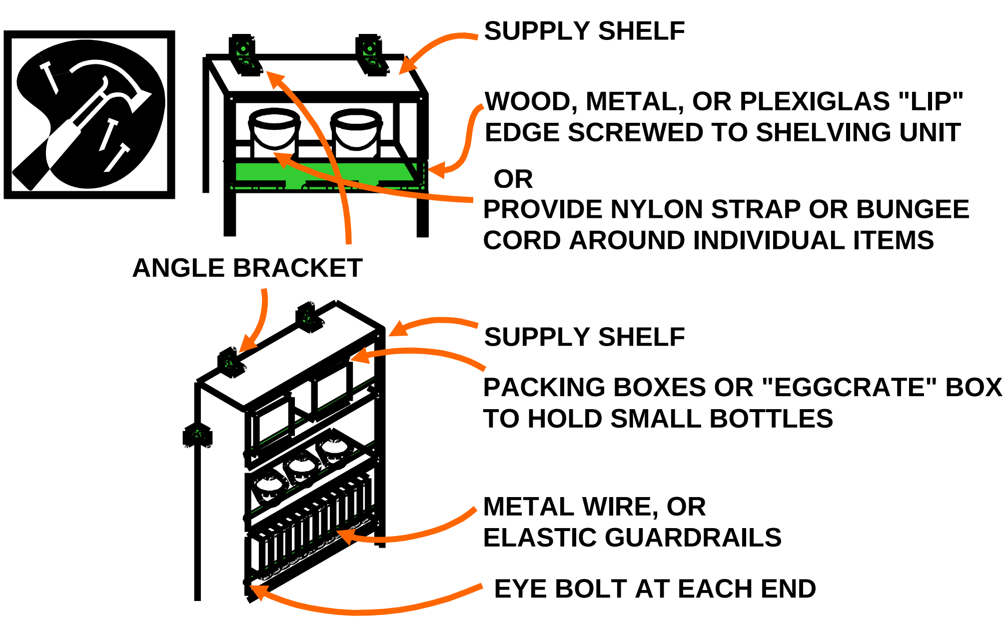


Emergency supply cabinet (water, medicine, food, etc.)

- ☐ Is the cabinet in an accessible location that is not likely to be heavily damaged?
- ☐ Is the cabinet properly supported and anchored, and are the cabinet doors securely latched?

Especially valuable and fragile merchandise

- ☐ Are valuable or fragile items protected against tipping or falling off shelving or pedestals?



Kitchen and Laundry Equipment

These facilities may include any or all of the following items: gas and/or electric stoves and ovens, built-in or countertop microwave ovens, garbage compactors, dishwashers, refrigerators and freezers, clothes washers and dryers, ironing and pressing equipment.

Large kitchen or laundry equipment

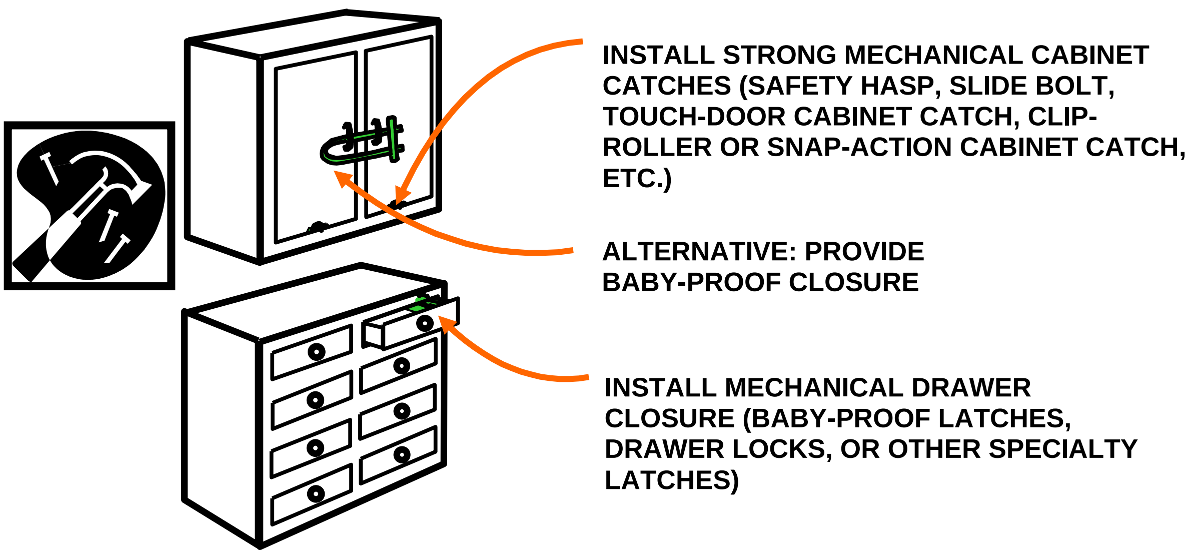
☐ Are all of the items securely anchored to the floor, wall, or countertop with adequate capacity?

Gas and/or electric hook hook-up

☐ Are the gas or electric hook-up lines able to accommodate movements at the equipment interface and where they cross between buildings?

Drawer and cabinet latches (kitchen, laboratory, office, etc.)

☐ Are the drawers and cabinet doors latched securely, e.g., with special latches or baby-proof hardware that will not fly open in an earthquake?



Hazardous Materials

Hazardous materials may include:

Chemical, laboratory, or medical supplies

- ☐ Are chemical supplies secured with shelf lips several inches high, or are they stored in "egg crate" containers in drawers, so that the containers will not overturn or fall and spill?
- ☐ Are chemicals stored in accordance with manufacturers' recommendations?
- ☐ Are incompatible chemicals stored at an appropriate distance from one another so that they will not mix if the containers are broken?
- ☐ Are the chemicals in each cabinet catalogued properly and marked clearly?
- ☐ Are Material Safety Data Sheets (MSDSs) stored in a location separate from the chemicals?

Cabinets for hazardous materials

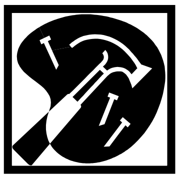
- ☐ Are cabinets for hazardous materials securely attached to the floor or to a sturdy wall?

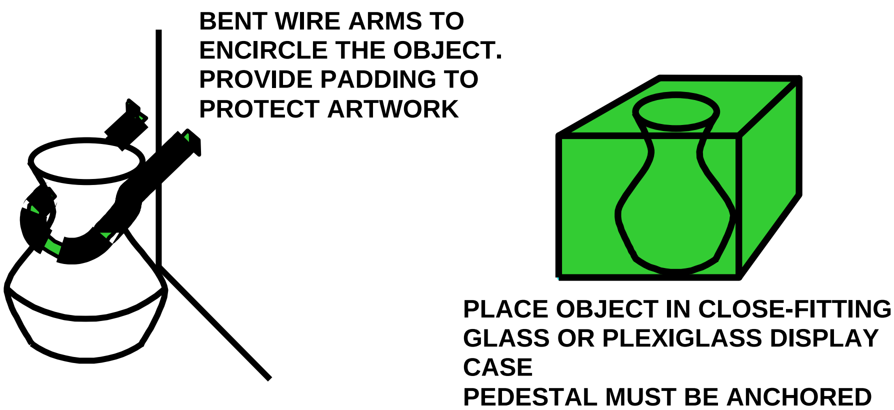
Asbestos

- ☐ Has asbestos insulation been removed, or has it been encapsulated to reduce the possibility of damage in an earthquake?
- ☐ Will asbestos abatement be required prior to installing retrofit details?

Especially valuable and fragile artwork or decorative vases

☐ Are valuable or fragile items protected against tipping over and/or falling off shelves or pedestals?





Potted plants or indoor landscaping

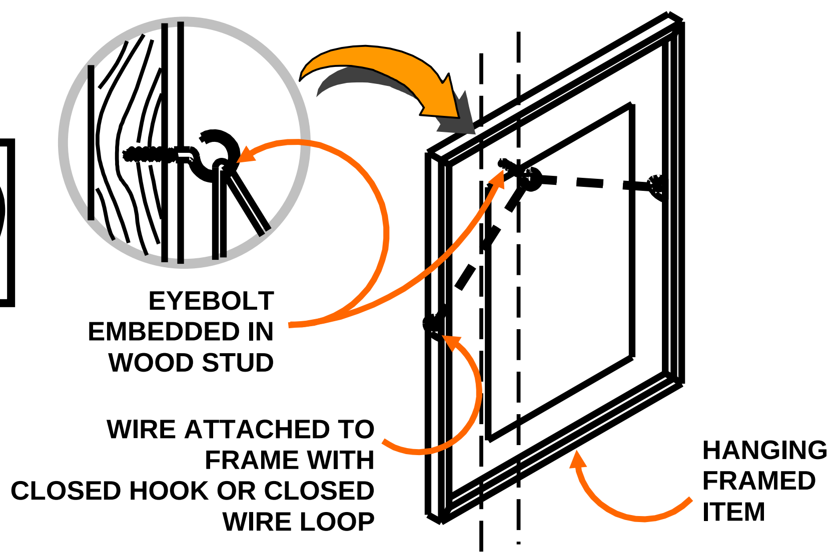
☐ Are heavy potted plants on file cabinets or tall shelves restrained to prevent falling?

☐ Are heavy hanging plants secured to prevent falling or impact with windows?

Miscellaneous furnishings

☐ Are unanchored furnishings located where they cannot slide or overturn to block corridors or doors?

☐ Are heavy wall pictures and other wall hangings well anchored to the studs or structural framing?



Lockers, vending machines

☐ Are personal or storage lockers and vending machines anchored and laterally supported, or are they clear of exits?

Chapter 7 - Special Considerations

Disruption to Occupants and Operations

The mitigation project should consider the potential disruption to the building occupants. This applies to both the disruption caused by installing the restraints and the disruption of the mitigation components to ongoing operations after each is installed.

Permanence

The bracing for some nonstructural items can be permanently installed. However, other nonstructural items need to have mitigation designed so that the nonstructural items can be moved easily during normal operations. It can be more difficult to design a restraint system that allows for removing and reapplying the restraints. It is also very difficult to verify that nonstructural restraints that can be removed will be reinstalled. Occupants often forget to replace restraints or tethers or choose to leave them unattached to avoid delays and disruption. Periodic checks of removable restraints should be performed to verify that the restraints are still effective.

Redundancy

For some critical nonstructural items, it may not be sufficient to rely on a single type of mitigation. Providing additional supports or a back-up restraint may be necessary to assure a low probability of failure during an earthquake.

Building Interaction

The interaction between the building and the nonstructural component needs to be considered. The nonstructural elements and their bracing should not interfere with the movement of the building during an earthquake. Items, such as partitions and exterior walls, may unintentionally resist earthquake forces if they are not designed to allow building movement in each direction. Nonstructural elements that are attached to two or more structural elements, such as columns, walls, or ceilings, can potentially cause unintentional restraint of the structural framing. It may be advisable to consult with an engineer to determine the expected amount of structural movement so the nonstructural mitigation can be designed to accommodate this movement.

Building Performance

The expected performance of the building during an earthquake should be considered. Nonstructural components in buildings that may not be adequately designed to resist earthquake forces can be mitigated, but this mitigation may not be effective if the building is significantly damaged during an earthquake.

Anchorage to Structural Framing

When anchoring nonstructural elements, the structural framing must have sufficient strength to resist the forces due to the nonstructural elements. For nonstructural items that weigh more than 100 pounds, it is recommended that an engineer be consulted to determine whether the structural framing can support the forces of the nonstructural element. Building codes typically require engineering calculations for anchorage or support of items weighing more than 400 pounds.

There are various methods that can be used to anchor nonstructural elements to the structural framing. The general types of anchorage are discussed below.

Structural Framing Material	Types of Anchorage	Considerations
Steel	Welding	Welding should be done by qualified welders in compliance with applicable codes and standards. For older structures it may be necessary to check the existing steel for weldability.
	Bolts and screws	Bolts should be installed in drilled holes. Self-tapping screws should be installed according to manufacturers' recommendations.
	Clamps	Clamps should only be used to restrain lightweight items.
Concrete or Masonry	Cast-in-place anchors	Cast-in-place anchors can only be installed when new concrete elements are placed.
	Epoxy anchors	Holes for epoxy anchors need to be thoroughly cleaned.
	Expansion anchors	Expansion anchors need to be tightened to verify that the wedges are properly set. Expansion anchors should not be used for overhead applications or for vibrating equipment.
Wood	Bolts	Bolts should be installed into drilled round holes.
	Lag screws	Lag screws should be installed into holes that are predrilled in the wood to reduce the possibility of splitting the wood. Lag screws should not be forced into the wood using a hammer. Nails should not be used for anchorage.

Limitations

The many nonstructural elements in a building and our imperfect understanding of both regional earthquake hazards and their impacts on buildings make the elimination of **all** damage to nonstructural building elements an unrealistic and expensive goal.

Some of the nonstructural elements described in this Field Manual require specialized expertise to identify the specific earthquake hazard and to develop appropriate nonstructural protection measures. This expertise may not be available among building facilities personnel. Many of these elements are included in the Field Manual as a means of increasing awareness of risks they present and the types of outside services that may be needed to reduce the risks.

Information in this Field Manual is based on current earthquake retrofit practice and standards for existing buildings. Practice and standards change as new information is available. Buildings and their elements cannot be made "earthquake proof" due to the many variables causing earthquake damage. The strengthening methods in this Field Manual can help make facilities more resistant to earthquake damage and improve the safety of building occupants.

Implementation of nonstructural protection measures must be completed before the ground begins to shake. These measures, which reduce the severity of loss through increasing the resistance of nonstructural elements, are called mitigation measures. The earthquake is a test of the success of the implemented mitigation measures to resist damage.

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