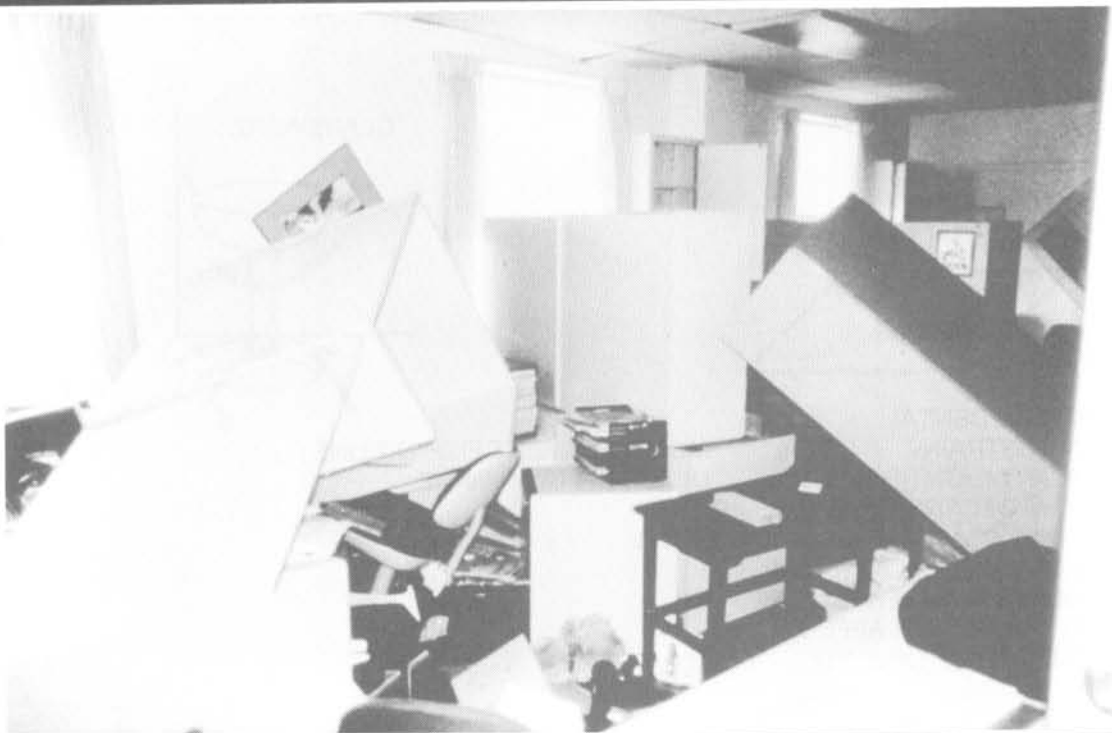
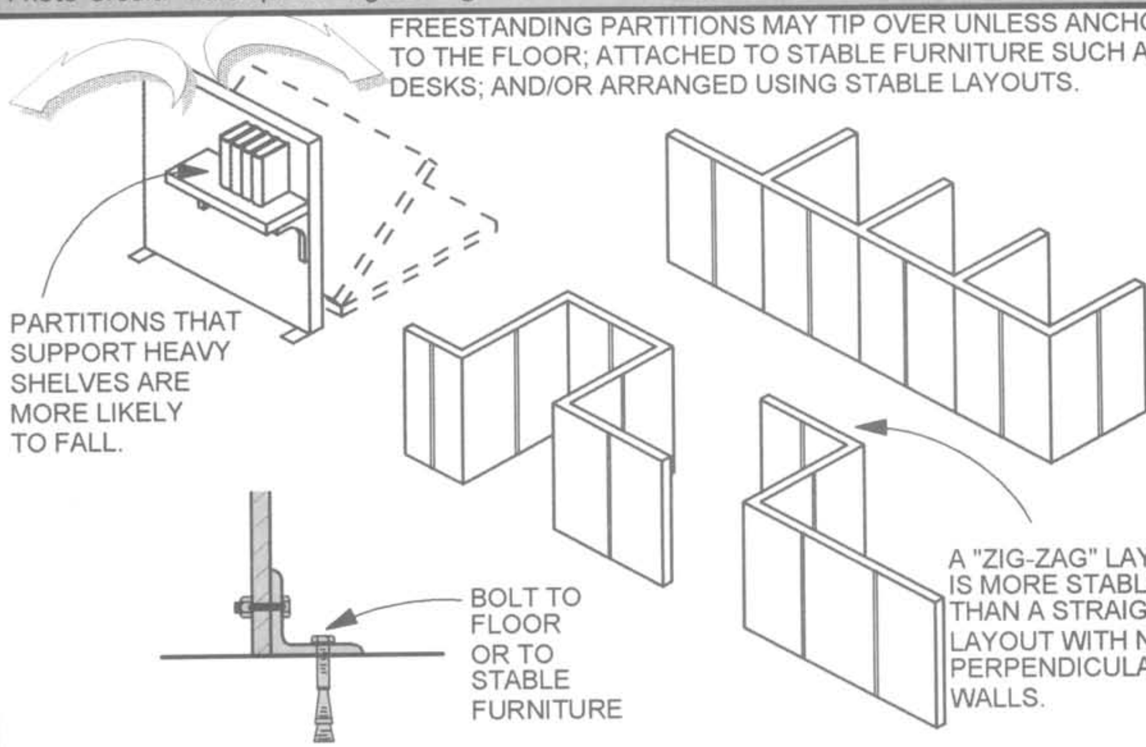
FREESTANDING HALF-HEIGHT PARTITIONS

DO-IT-YOURSELF



Partition damage at Veterans Administration Medical Center in Sepulveda.
Earthquake Damage: 1994, Northridge, California
Photo Credit: Earthquake Engineering Research Institute, James O. Malley



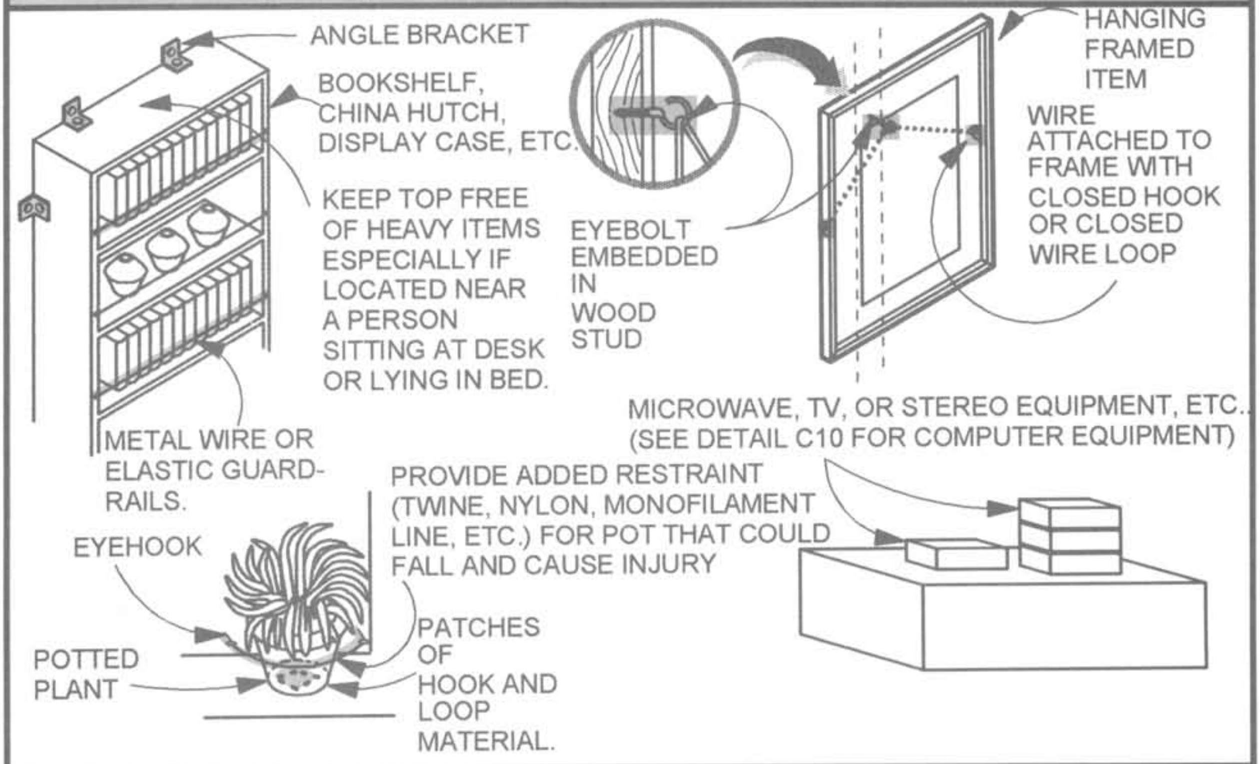
Upgrade Detail C27
Approximate Cost: $10 per lineal foot

C27

MISCELLANEOUS FURNITURE

DO-IT-YOURSELF

Earthquake Damage: 1994, Northridge, California
Photo Credit: Wiss, Janney, Elstner Associates, Inc.



Upgrade Detail C28
Approximate Cost: Varies, approximately $50 per item

C28

INSTALLATION NOTES

For those details where the self-help approach is acceptable, a few words of caution are in order. Many items shown in the upgrade details can be purchased at any hardware store, but it is important to select hardware that is appropriate for the task at hand. A toggle bolt mounted in gypsum board may hold a light picture frame on the wall, but is not appropriate for any of the details shown in this guide. At the other extreme, a 1-inch-diameter bolt is too large for a 2x4 wood stud, since the 1¼-inch-diameter hole you drill for the bolt will essentially eliminate the 1½-inch-wide stud. The following discussion provides general guidelines on hardware selection and installation procedures for the *Do-It-Yourself* details shown in this chapter.

Positive Connections The objective of nonstructural anchorage or restraint details is to provide what engineers refer to as a positive connection between the item and a hard attachment point, such as a solid wall, braced partition, concrete floor, or built-in countertop. Positive connections generally consist of some combination of screws, bolts, cables, chains, straps, steel angles, and other steel hardware. Positive connections do not rely on the frictional resistance produced by the effects of gravity. Neither the frictional resistance between the base of an object and the floor or other support nor such mechanical friction connections as C-clamps or thumbscrew clamps can be considered a positive connection.

The most common nonstructural connection details are for wall attachments, floor or ceiling attachments, countertop attachments for smaller items, and attachments between adjacent items to create a more stable configuration.

Typical Wall Attachment Details Many types of nonstructural items can be anchored, braced, or tethered to an adjacent wall to provide stability in an earthquake. Before installing any anchorage details, however, one should determine whether the wall has adequate structural capacity to support the nonstructural items. The wall element should consist of concrete, masonry, or structural framing members securely attached to the structural framing at both the top and bottom of the wall.

ANCHORAGE TO WOOD OR METAL STUD PARTITION WALLS

Any type of attachment hardware or brace should be attached directly to a structural stud, not to the gypsum board or plaster wall covering. Gypsum board and most other interior wall coverings have little capacity to resist out-of-plane loading, that is, loads perpendicular to the wall. Most likely, a toggle bolt or nail will simply pull out during an earthquake, leaving a hole in the wall.

Typical wood and metal stud walls are constructed with vertical studs located at either 16 inches or 24 inches on centers. Many interior partition walls extend only to the ceiling line and should not be used to anchor heavy nonstructural items unless the top of the partition wall is braced to the structure above. Heavy items anchored to unbraced partitions may bring the partitions down with them if they fall during an earthquake. Partition bracing should consist of diagonal elements of similar size and material as the vertical studs, spaced every few feet, connecting the top of the partition to the structure above. Engineering advice may be needed if the partitions appear questionable.

The structural studs should be located at the start of a project to see that they are within reach of the items to be anchored. In situations where many items must be anchored to a stud wall, it is sometimes advantageous to install a mounting strip first in order to avoid having to relocate items to line them up with studs. Sometimes referred to as seismic molding, a mounting strip is a horizontal member mounted to the wall and anchored to each stud. The strip should be located at or near the top of the items to be anchored. Furniture or cabinets may then be anchored directly to the mounting strip without regard to the stud locations. A mounting strip may be constructed of a structural-grade wood 2x4 or 2x6 or a continuous steel channel or angle.

Recommended Hardware:

- Attach steel angle directly to wood studs using a minimum ¼-inch-diameter by 3-inch lag bolt. Embed the bolt at least 2 inches into the wood stud.
- Attach steel angle to metal studs using #12 sheet-metal screws long enough to penetrate the flange material. Use two screws per connection, located 3 inches apart vertically.
- Attachments to sheet-metal shelving or cabinets may be made by using a minimum ¼-inch-diameter machine bolt. Where possible, attach the bolt through two layers of material, for example where the top and side or back and side pieces overlap. Otherwise, use an oversized 2-inch-diameter by 3/32-inch-thick fender washer with the nut on the inside of the cabinet to provide additional strength.
- For seismic molding, use #14 flat-head wood screws with countersunk heads, with at least 2 inches embedded into the wood stud behind the wall covering. Locate screws along the centerline of the 2x4 or 2x6, and anchor the strip to each stud with maximum spacing of 24 inches on centers. For attachments to the molding strip, do not screw or bolt anything within 1 inch of each edge of a wood member.
- Small quick-release safety hooks (carabiners) and nylon cord or straps are often available at sporting-goods stores that carry mountain-climbing equipment. These items may be useful for tethering small office equipment.

Not Recommended:

- Toggle bolts mounted in gypsum board or plaster are not recommended for any of the details presented here.
- Nails have little capacity in tension or withdrawal, i.e., when you pull directly on the head of the nail. Thus, nails are not recommended for any of these details either.

ANCHORAGE TO CONCRETE OR MASONRY WALLS

Connections to existing concrete or grouted masonry walls should be made with concrete anchor bolts. Many types of anchors are available from various vendors, including expansion anchors, sleeve anchors, and epoxy anchors. Since the installation procedures and capacities for these anchors vary widely, it is important to check the local building code or vendor literature for the *allowable load* capacity and install the anchors in accordance with the manufacturer's recommendations. Holes into concrete or masonry walls should be drilled with care to avoid cutting any reinforcing steel (rebar). A magnetic device can be used to locate the steel prior to drilling. If rebar is encountered while drilling, stop, and relocate the hole; *do not cut through the rebar.*

The capacity of an anchor bolt in concrete is governed by the strength of the concrete, the bolt diameter, the depth of embedment of the bolt into the concrete, the spacing between adjacent bolts, and the distance to the edge of the concrete. In order to develop the full capacity of a concrete anchor, the spacing should be at least 12 diameters, with a minimum edge distance of 6 diameters. The minimum embedment length is typically 8 bolt diameters. The bolt will have a greatly reduced capacity if it is too near an edge or too close to an adjacent bolt or if it has insufficient embedment into the concrete.

The most common anchor bolts are wedge anchors, where part of the shank expands to press against the sides of the hole as the nut is tightened. Other types of anchors include sleeve anchors and epoxy anchors. Sleeve anchors consist of a threaded sleeve installed directly into the concrete, flush with the concrete surface, and a bolt that is screwed into the sleeve. Sleeve anchors may be advantageous in situations where items may be moved frequently. The bolt may be removed, leaving the sleeve flush with the wall (or floor) and without leaving a protruding bolt. Epoxy anchors are inserted into slightly oversized holes with epoxy or polyester resin so that the adhesive will hold the bolt in place. Extreme care is required to ensure that the epoxy components are mixed in the proper proportions within the hole; otherwise the bolt will never reach the manufacturer's rated capacity. Quality control is critical for these bolts, and they are not recommended unless the installation is performed by experienced personnel.

Recommended Hardware and Procedures:

- Do not cut reinforcing steel or electrical conduit in concrete or masonry walls. Locate the steel or conduit with a magnetic device prior to drilling.
- Follow manufacturer's recommendations for installation. Remove dust from the hole prior to inserting the anchor bolt by using a hand-held vacuum cleaner; or blow the dust out with a bellows or a bulb.
- For anchorage to reinforced concrete walls, expansion anchors are the most common and easiest to install. Typical sizes for wall anchorage of nonstructural items might be a 3/8-inch-diameter A307 bolt with 3-inch minimum embedment (allowable seismic loads 1450 pounds shear and 650 pounds tension) or a ½-inch-diameter A307 bolt with 4-inch minimum embedment, 5-inch edge distance, and 6-inch spacing (allowable loads 2000 pounds shear and 1850 pounds tension) [12].
- To check the installation procedures and quality of workmanship, test a sample of installed bolts with a proof load.
- Use galvanized or preferably stainless steel bolts and other hardware in locations where they will be exposed to moisture or weathering.
- Corrosion-resistant chains, eyebolts, and quick-release safety hooks can often be found at marine supply stores. These fasteners may be needed to provide wall anchorage for gas cylinders or other items stored outside or in a damp location.
- For anchors in walls constructed of concrete masonry units, the expansion anchors should be installed only in grouted cells, i.e. locations where the cavity in the masonry unit is filled with grout and reinforcing steel. In order to achieve adequate embedment into the grout, longer bolts may have to be used in concrete masonry unit walls than in concrete walls. Unreinforced masonry walls, particularly cantilever partition walls, may not have adequate strength to anchor heavy nonstructural items. For light loads, up to 100 pounds or so, masonry toggle bolts can be used in ungrouted cells.
- For unreinforced brick walls, engineering assistance is recommended. Published capacities for expansion anchors typically apply to concrete, not to brick. Anchorage to the floor may be a preferable solution in a brick building.

Not Recommended:

- Adhesive or epoxy anchors are not recommended unless installed by experienced personnel. Proper quality control is critical for this type of anchor bolt.
- Inserts made of lead or plastic placed in holes drilled in concrete or masonry and used with lag screws have very limited capacity and are not recommended.

Typical Floor and Ceiling Attachment Details For heavy items, anchorage to a concrete floor slab is often preferable to wall anchorage because it avoids the additional seismic load to the wall. Ceiling attachment details are required for many types of piping, ducts, light fixtures, and overhead fans or heaters. The type of detail used in each situation will depend on the structural materials of the floor and ceiling framing.

ANCHORAGE TO WOOD FRAMING

Because wood flooring typically does not have adequate strength to resist large concentrated forces, floor or ceiling anchorage hardware should be attached directly to the floor or ceiling beams or joists.

Recommended Hardware and Procedures:

- Locate the floor or ceiling joists prior to beginning work. If wood beams or joists are not situated within a convenient distance, wood blocking may be used to provide additional anchor locations. Install blocking perpendicular to the joists, using, as a minimum, a member of the same size as the joists. Anchor the blocking with framing clips to the joists at each end. Do not toenail the blocking.
- Wood screws or lag bolts should be used for simple anchorage connections for lighter items. A ¼-inch-diameter by 3-inch lag bolt will be adequate for many types of connections.
- For anchorage of heavier items to the roof or floor, add blocking beneath the anchor location, run A307 bolts through the blocking, and tighten them on the underside with nuts and washers.

Not Recommended:

- Do not anchor items directly to wood or plywood floor or roof sheathing, as these materials typically do not have adequate capacity to resist significant out-of-plane loads.
- Nails are not recommended for nonstructural anchorage details.

ANCHORAGE TO STEEL FRAMING

Caution should be used in anchoring nonstructural items to structural steel framing. Engineering expertise may be needed to determine whether holes can be drilled through structural steel framing without compromising the integrity of the structural members.

There are several types of connection details that do not require holes through the steel framing.

Recommended Hardware:

- Vendor catalogues of hardware that can be used to provide both vertical and lateral support for piping often include fittings specifically designed for steel framing. While C-clamps are not recommended, there are a variety of other devices that clamp mechanically around the flange of a steel beam or are designed to fit between column flanges. These devices are typically load-rated by the vendors and come in a variety of sizes. Besides bracing piping, this type of hardware might be used for bracing or anchoring items like lights or ceiling fans.

ANCHORAGE TO CONCRETE FLOOR OR ROOF SLABS

Concrete expansion anchors are the most common type of hardware used to anchor items to a concrete slab on grade or a structural floor slab. For heavy loads or concrete slabs less than 4-inches thick, it may be preferable to use through-bolts, i.e., machine bolts that go through the concrete slab and are fastened with nuts and steel plate washers on the underside of the slab.

Recommended Hardware and Procedures:

- Refer to discussion of expansion anchors under concrete wall anchorage details.
- *Do not cut reinforcing steel in concrete slabs or beams.* Locate the reinforcing steel and electrical conduit with a magnetic device prior to drilling holes in concrete slabs.
- For anchorage to a concrete foundation pad, slab on grade, or suspended floor, check the drawings for the thickness of the concrete, or drill a small pilot hole first. While short expansion bolts may be adequate to prevent sliding of low equipment, longer bolts with greater embedment are generally needed to prevent the combination of sliding and overturning forces for items that are taller than they are wide.

• Typical hardware for floor anchorage of lighter nonstructural items might be with a ½-inch-diameter A307 bolt with 4-inch minimum embedment and 6-inch spacing (allowable loads 1500 pounds shear and 1400 pounds tension). For heavy items, larger bolts are needed. For example, a 1-inch-diameter A307 bolt with 7-inch minimum embedment and 12-inch spacing (allowable loads 3750 pounds shear and 2850 pounds tension) [12]. Engineering assistance is recommended for very heavy items.
• If equipment is resting on leveling bolts or must be level for proper operation, vertically slotted connections may be needed to allow for adjustment.

Not Recommended:
• A ¼-inch-diameter expansion anchor has an allowable capacity for seismic loading of 650 pounds shear and 250 pounds tension [12]. (Note that the capacities cited above are for pure shear or pure tension. Combinations of shear and tension must be considered simultaneously, resulting in reduced capacity. For example, if you pull on the bolt with 200 pounds of tension, it will have the capacity to resist only approximately 300 pounds of shear.) These bolts are generally too small for most equipment or for fully loaded file cabinets, unless a number of bolts are used in combination.

Typical Shelf or Countertop Attachment Details If important or essential contents are to be secured, the shelf or mounting surface should be secured prior to anchoring nonstructural items. While standard desks and office tables are unlikely to overturn, they may slide during an earthquake. Desktop computers and printers can be anchored to the desk by means of hook-and-loop tape or various types of security devices designed to prevent theft.

Recommended Hardware and Procedures:
• Unanchored desks or tables may slide and pull on the electrical cords of office equipment if the items are anchored to the tabletop. Electrical cords should have adequate slack to allow for movement of unanchored desks or tables.
• Loose shelves should be secured to their wall or shelf brackets. Wood shelves that rest on wall-mounted brackets may be secured to the brackets with ½-inch-long wood screws.
• Many types of vendor-supplied anchorage and security devices are available for computer equipment. These may also be adapted for other types of countertop equipment, such as medical or laboratory equipment. Heavy-duty hook-and-loop tape with adhesive backing may be purchased at most hardware and fabric stores and can readily be cut into patches or strips.
• Desktop computer equipment usually consists of several independent components. If items are stacked, make sure each component is anchored to the one beneath it and that the bottommost item is anchored to the desk. For tall configurations of items that do not have to be moved frequently, it may be more advantageous to tie an assembly of components together with nylon strap and then anchor the base to the desktop.
• For light and nonessential items on shelves or countertops, a 1- to 2-inch lip secured to the edge of the counter or shelf may be adequate to prevent miscellaneous items from falling off. In this case, individual items need not be anchored.

Purchasing In some instances, it is easier to install nonstructural anchorage details for newly purchased equipment than for existing equipment. Many items are available off the shelf or can be special-ordered with seismic detailing. Some file cabinets come with predrilled holes for floor anchorage and strong latches on the drawers. Battery racks, industrial storage racks, and computer access floors can be ordered that meet seismic requirements specified in the building code. It is always useful to inquire about the availability of seismic details when purchasing new equipment.

Patching, Painting, and Corrosion Protection Most of the details shown here assume that the nonstructural item is situated in a dry, interior location. In these locations, some cosmetic patching and painting may be desirable, primarily for aesthetic reasons.

For basements, roofs, or other exterior locations, it is important to provide adequate protection from weathering and corrosion. If attachment details perforate a roof membrane, appropriate sealants or localized repair will be needed to avoid roof leakage. If expansion anchors or other steel hardware will be exposed to moist conditions or weathering, either stainless steel or galvanized hardware should be selected to avoid corrosion and deterioration. Many types of paints and coatings are available that will help to retard corrosion. Exterior earthquake protection devices may need periodic maintenance to avoid deterioration.

In cases where a chain, latch, or tether is installed and users must remove and replace some hardware whenever they need to use the item, it may be helpful to select a bright or distinctive paint color as a reminder that the chain or hook needs to be refastened.

Safety Precautions As with any type of construction work, there are safety precautions that must be followed while installing nonstructural attachment details. Employers and tradesmen must comply with numerous local, state, and federal safety regulations and follow guidelines established for specific trades or industries. The following is not comprehensive but is a brief list of safety precautions that merit emphasis in connection with the nonstructural attachment details shown here.

Recommended Procedures:

- The people doing the installation work should have adequate training and supervision. Office workers or volunteers may not have the necessary background.
- Electrical hazards are present around any equipment supplied with electrical power. It may be necessary to disconnect the power before starting work. Transformers are especially hazardous. Transformers, switchgear, and other electrical cabinets should be handled or opened only by qualified personnel.
- The installation of most nonstructural restraint details involves the use of power tools. Personnel should use safety goggles and other protection recommended by tool manufacturers, and all workplace safety standards should be followed.
- Many heavy pieces of furniture or equipment may have to be moved temporarily in order to install seismic restraint details. Unless proper lifting techniques are utilized, back injuries or other injuries may result [19].

5 DEVELOPING EARTHQUAKE PROTECTION PROGRAMS

The preceding sections of this guide have provided information. The question is how to apply this information effectively. How should protective techniques be implemented? The answer depends on the nature of the physical conditions in the facility and the characteristics of the organization. The following suggestions can be considered by the reader in the context of his or her own situation.

SELF-HELP VS. USE OF CONSULTANTS

Self-help implementation of a program can be adequate where the potential hazard is small or the in-house familiarity with engineering or construction is greater than average. For larger facilities, engineering or architectural engineering consultants may be employed to survey the seismic vulnerability and design specific upgrade details. In some cases, after an initial survey is conducted and a report prepared by an expert, the remainder of the implementation can be handled in-house without further assistance.

One of the larger nonstructural earthquake hazard evaluation and upgrade programs is that of the U.S. Department of Veterans Affairs (VA) for its hospitals. The typical procedure followed by the VA has been to hire consultant experts to assess the seismic risk at the site, to review the facility and list specific nonstructural items that are vulnerable to future earthquakes, and to provide estimated upgrade costs and group the items by priority. Once the consultants have established the program outline, the VA maintenance staff at each hospital has been given many of the implementation tasks. As mentioned in the introduction, there are limits to the self-help diagnosis and prescription approach; especially if larger buildings or more serious safety hazards, property risks, or critical functional requirements are involved, the use of consultants may be advisable.

Types of Consultants Various types of consultants are available, each of which may have a different type of expertise. The choice of a particular consultant will depend on the nature and complexity of a particular facility. Many of the consultant designations below correspond both to a specialized field of study or practice and to a category of state license. Not all practicing design professionals are licensed. If building permits are required for the anticipated work, it may be important to ascertain that the consultant has an appropriate license for the state where the facility is located.

- **Earthquake Engineer** This is a commonly used term, but no state has such a license category, and earthquake engineers are not listed in the Yellow Pages. An earthquake engineer is a structural or civil engineer (see below) experienced in earthquake design and analysis.

- **Structural Engineer** A structural engineer is a civil engineer (see below) who has gone on to obtain an additional license based on work experience and examinations specifically on topics relating to structural engineering. Not all states issue a separate license for structural engineers. California is an example of a state where schools, hospitals, and some high-rise structures must be designed by licensed structural engineers. Structural engineers are more likely to be familiar with building construction than many civil engineers, who specialize in other areas. Some structural engineers have had extensive experience in designing nonstructural anchorages and protective measures, often involving hospitals because of their stricter building code requirements. Structural engineers are listed in the Yellow Pages under "Engineers, structural."

• **Civil Engineer** A civil engineer may be licensed by the state. Some civil engineers specialize in structural engineering. Other civil engineers specialize in fields such as airport and harbor design, utility systems, or soils engineering, which do not involve the structural design and analysis of buildings.

• **Mechanical Engineer** A mechanical engineer may have a state license based on education, experience, and examinations. Some mechanical engineers practice aspects of their discipline completely unrelated to buildings (such as the design of power plants, automotive engines, or machinery). Mechanical engineers who specialize in the design of HVAC systems, or "mechanical" systems, for buildings are often familiar with these types of nonstructural items, but they typically rely on structural engineering consultants for the design of earthquake bracing for mechanical equipment.

• **Architect** An architect may also have a state license based on education, work experience, and examinations. Since architects must be knowledgeable about many aspects of building design and construction, generally only a small part of their education, work experience, and examinations is devoted to structural engineering. Even architects licensed in California generally do not perform seismic computations or make structural detailing decisions but instead rely on in-house or consultant structural engineers. For new construction, the engineer usually works as a subconsultant to the architect, rather than directly for the owner. Architects, not engineers, are generally responsible for the design of windows, partitions, ceilings, and many other nonstructural items. It is important, therefore, for the architect to be made aware of the client's concerns regarding protection from nonstructural earthquake damage, since the architect will design and provide specifications for most of the nonstructural components.

• **Interior Designer** An interior designer or space planner would not be expected to have any particular background in earthquake engineering, though in some cases this designer will be intimately involved with the specification of file cabinets, furniture, finish materials, and so on. Designs by interior designers can be reviewed by a structural engineer to ensure appropriate detailing for earthquake hazards.

• **Specialty Contractor** Contractors in various specialties, as well as general contractors, may be licensed by the state. Contractors can implement upgrade schemes designed by others or may be able to help devise the upgrade technique if no formal engineering is required. For example, contractors experienced in the installation of new suspended ceilings in accordance with current earthquake code provisions may be capable of installing seismic upgrade details for older, unbraced ceilings. Individuals skilled in the building trades can bring special talents to bear if they are made aware of seismic problems and solutions. At one large research and development facility, for example, all the light fixtures have been thoroughly upgraded for earthquakes over a few years, thanks mostly to the efforts of one electrician.

IMPLEMENTATION STRATEGIES

There are a number of options to consider in implementing a program to reduce the vulnerability of nonstructural components. Some of these are discussed below.

Integration with Maintenance Programs One of the easier means of gradually implementing earthquake protection in an existing building is to train maintenance personnel to identify and properly correct nonstructural hazards that they may discover as they survey the building for other purposes or to correct problems identified by an outside consultant engineer. The disadvantages of this approach are that protection is increased only gradually and the potential cost savings from doing several related projects at the same time may be lost. Note (under the heading Sustaining Protection, below) that a maintenance program can also be used for upkeep of protective measures.

Remodeling If there are other reasons for remodeling, there may be an opportunity to increase the protection of several nonstructural components at the same time, especially ceilings, partitions, windows, air conditioning ducts, or other built-in features. A word of caution: in some cases, remodeling efforts have reduced rather than increased the level of earthquake protection through the accidental modification of components that originally received some seismic protection as a result of the input of a structural engineer or architect. If an architect, interior designer, or contractor is handling the remodeling, the possibility of incorporating additional earthquake protection into the space should be discussed, and a structural engineer's expertise should be employed where indicated.

Purchasing A guideline with a list of nonstructural items could be created to indicate special purchasing considerations. For example, file cabinets should have strong latches and wall or floor attachments, bookcases should have bracing and floor or wall attachments. Increasingly, vendors are marketing items with "seismic-resistant" details such as predrilled holes for anchorage. The effective use of these guidelines requires coordination between the purchasing and facilities functions.

Incremental Upgrading In some cases, it may be possible to upgrade different areas within a building at different times or to select one or more types of nonstructural components throughout a building and upgrade them at the same time. Some projects can be completed in a weekend, making it possible to upgrade equipment or other items without interrupting the normal work flow. Companies with annual shutdown periods may find it wise to upgrade the highest-priority items during each annual shutdown. Work that interrupts the use of a space, such as setting up ladders or scaffolding to work on the ceiling or ceiling-located items, could be restricted to limited areas in a facility at a given time, minimizing the overall disruption.

An all-at-once implementation process, similar to that used in new construction, can be used in existing facilities either when the extent of the work required is small or when the work is extensive but the resulting disruption is tolerable. A favorable time for this approach is when a building is temporarily vacant.

New Construction For new construction, it is possible to anchor, brace, or restrain all the critical nonstructural items at the same time according to a unified design. As noted earlier, it is more efficient and less costly to install anchorage details during construction than to upgrade existing buildings.

For large organizations, the development and adoption of nonstructural guidelines to be used by designers or contractors, as discussed in Chapter 7, could be considered. For small companies or organizations, a letter or conversation with the architect could be used to bring up the matter of designing earthquake resistance into nonstructural items. Providing the architect or other designer with a copy of this guide might be advisable.

Sustaining Protection Some nonstructural protection devices, such as anchorage hardware for exterior objects, may deteriorate with time if not protected from rust. Over time, interior fastenings and restraints may be removed as people move equipment or other items and fail to reinstall the protection devices. Chains used to restrain gas cylinders or elastic shock cords on bookshelves are effective only when they are in use. It is sometimes more problematic to maintain the human aspects than hardware aspects of nonstructural protection. As noted above, remodeling projects can sometimes result in the elimination of protective features if there are no seismic guidelines. Training is required to ensure that gas cylinders, storage rack contents, office equipment, chemicals, and so on, are properly stored.

Maintenance personnel may be the people most likely to periodically survey the building to ascertain whether earthquake protection measures are still effectively protecting mechanical equipment such as emergency generators, water heaters, special equipment, and so on. Supervisors can be made responsible for an annual review of their work spaces. If there is a separate facilities or physical plant office in an organization, that may be a logical place for the responsibility for sustaining protection to reside. Organizations with safety departments have successfully assigned the role of overseeing nonstructural earthquake protection to this functional area.

An earthquake hazard mitigation program should conform to the nature of the organization. In the case of the University of California, Santa Barbara, the implementation and maintenance of a campuswide program to address nonstructural earthquake hazards was initiated by a one-page policy memo from the chancellor. Each department head was made responsible for implementation of the policy, and the campus Office of Environmental Health and Safety was given the job of advising departments on implementation, making surveys, and evaluating the program's overall effectiveness [13, 14].

EVALUATION

How good is a nonstructural earthquake protection program? Is it worth the cost? What is the best way to evaluate its strong points and deficiencies?

There are two basic techniques to employ in accomplishing this task. The first is to ask, How well has the program met its stated objectives? Have the costs been within the budget? Have the tasks been completed on schedule? Is the scope of the effort as broad as was originally intended, or have some items been neglected that were targeted for upgrades? Have employee training exercises or other features of the response plan all been implemented? How well have the measures been implemented? Have the upgrade details been correctly installed? Is the training taken seriously?

The second basic evaluation technique is to ask, If the earthquake happened today, how much better off would we be than if we had never developed a nonstructural protection program? This can be done in a rough cost-benefit format by estimating the total cost of the program, including estimated staff time. A fairly crude method, described below, can be used to estimate the potential benefit due to property loss savings.

The risk ratings in Appendix C are presented in terms of a low, moderate, or high potential for property loss. If we consider only direct property loss to the item itself, then these ratings might be approximately equivalent to a loss equal to a percentage of the replacement cost of each item, as follows:

Low	0%-20%	(10% average)
Moderate	20%-50%	(35% average)
High	50%-100%	(75% average)

For areas that expect only light- or moderate-intensity shaking in an earthquake, it can be assumed that direct property losses following the implementation of the upgrade will be negligible. In areas that expect severe shaking, it can be assumed that property losses for upgraded items will be low, with an average loss of 10%, as indicated above. The benefit, then, is the difference between the expected losses without the program and the expected losses with the program in place.

When using this method, it is important to remember that it covers only direct losses to the item; i.e., the maximum property loss is limited to the replacement cost for each specific item. As stated earlier, property losses due to broken water or fire sprinkler pipes might be well in excess of the cost to repair or replace the piping.

In many cases, the value of not experiencing outages and not sustaining injuries will be very significant, and property loss savings cannot be the sole measure of the benefit. Cost-benefit computations such as those described above should be used only as a guide, not as automatic decision-making devices, since the upgrade costs, damage costs, and potential savings can be estimated only very approximately.

6 EMERGENCY PLANNING GUIDELINES

What types of nonstructural damage should be addressed in an earthquake response plan? How should training and exercises be conducted to take the prospect of nonstructural damage into account?

IMPLICATIONS OF NONSTRUCTURAL DAMAGE FOR EMERGENCY PLANNING

The first step is to develop a valid picture of the probable postearthquake state of the facility. The nonstructural survey and vulnerability analysis will indicate what types of items are present and provide an approximate assessment of their earthquake resistance. The better this survey and analysis are, the more likely it is that the envisaged postearthquake conditions will actually materialize. Less expert assessments will be more likely to either overestimate or underestimate damage. Even with the most thorough of analyses, however, there is still great uncertainty in the process of estimating earthquake performance.

One approach to this uncertainty is to assume the worst. This conservative approach is not warranted and is prohibitively expensive for purposes of allocating construction money to upgrade items, but in the initial stage of the emergency response planning process, it may be inexpensive to at least briefly consider the impact of severe damage to each nonstructural item on the list. What would be the emergency planning implications if each particular nonstructural item were to be severely damaged?

For example, what would be the consequences if an emergency power generator were to be damaged or if its support services were to be rendered inoperative. This will provide the worst-case scenario.

A particular generator may be anchored to the concrete slab with adequate bolts; it may have an independent fuel supply; the batteries may be restrained; and the cooling water system, if any, may be braced or anchored. The owner or operator may test the generator monthly and may be confident that it will work after an earthquake. However, out of 100 very well protected generators such as the one described above, at least a few would probably fail to run after a large earthquake. The probable outcome is that the generator will work properly, but there is still an outside chance that it won't. In the 1994 Northridge earthquake, a number of facilities, including more than one major hospital that was designed and constructed under the State of California's Hospital Seismic Safety Act, had temporary emergency power outages.

If there are inexpensive backup measures that can be included in the plan or in the training program or exercises, then this may be a form of inexpensive insurance. Such inexpensive measures might include occasionally including in an earthquake scenario the complete absence of electricity (by switching off all electricity except where it would be dangerous to occupants or deleterious to equipment); testing battery-powered exit lights; buying a supply of flashlights and batteries; maintaining a list of local suppliers of rental generators; and exploring whether recreational vehicle generators could supply power to run some essential functions and, if so, including the idea as a backup tactic in the earthquake plan (employees could be quickly queried to see whether some RVs might be available for use by the company or organization).

After the worst-case outcome has been considered with regard to each nonstructural item, it will then be necessary to consider the probable-case scenario. Because emergency planning resources are limited, extensive effort cannot be devoted to every conceivable problem. Once a facility survey has been completed, the estimated vulnerabilities indicated on the nonstructural inventory form can be used as a guide.

Human Response As protection against almost all types of nonstructural damage, the common advice to take cover beneath a desk or table is generally valid. While the photos of earthquake damage presented in this guide may appear frightening, a careful look will show that if an occupant had been in the vicinity of the damage but kneeling under a desk or table, serious injury would have been unlikely. Taking refuge in a doorway is not recommended, since lintel beams over doorways provide little protection from falling debris, which can occur in and near doorways, particularly in exterior walls of buildings. Taking refuge under a desk or table is a simple measure to undertake, but this advice requires some training and exercises if the technique is to work. Some people may have an immediate impulse to try to run outdoors if the shaking is severe or lasts for more than a few seconds. Many adults will feel embarrassed about crawling under a table. The quarterly earthquake drills for school students, now required by law in both public and private schools in California, appear to be very successful in getting students to take cover quickly and follow instructions during earthquakes. Similar drills, if only annual, are necessary if adult office workers, salespeople, or government employees are to be expected to respond quickly and protect themselves when the need arises.

In settings where there are no desks or tables, occupants should get down beside the next best thing. In an auditorium or public assembly setting, kneeling down between the seats is the best advice. It may be possible to move away from obvious hazards, such as items on tall industrial storage racks, and to put oneself in a safer position at the other side of a room, but in a very severe earthquake it may be impossible to stand up or walk.

EARTHQUAKE PLANS

The following points relating to nonstructural damage should be addressed in an earthquake plan.

Pre-Earthquake Tasks The document can describe the identification and upgrading of nonstructural items and the procedures for routinely checking to see that protective measures are still effective. If emergency training for employees is anticipated, then that should be written into the plan also.

Earthquake Emergency Response Tasks What tasks must be accomplished immediately after an earthquake? The tasks can be made contingent upon the severity of the earthquake and the amount of damage that is immediately seen to have occurred. If the structure of the building is obviously damaged--if there are sizable cracks in concrete walls, floors, or columns; if the building is leaning out of plumb; or if any portion of it has pulled apart or collapsed--then evacuation of the building will obviously be in order. This is not the time for a thorough survey of nonstructural damage. If there is no apparent structural damage, a survey of the mechanical equipment, elevators, and so on, could be listed as the appropriate response. Hazardous material storage areas should be quickly checked for spills.

Responsibilities For each task, someone must be assigned responsibility. If no responsibility is assigned in the plan, it is likely that no one will carry out the task. Because the earthquake may happen at any time and will have roughly a 75% chance of happening outside normal work hours, backup positions for responsibilities should be listed. To minimize the obsolescence of the plan, it is preferable to list positions rather than individuals' names, but in any event, someone must have responsibility for the plan itself and for keeping it current. Figure 9 provides a blank form for use in collecting information that may be helpful in formulating an earthquake plan.

TRAINING

How should you establish an earthquake training program? Ironically, the best advice may be to avoid establishing a separate earthquake training program and, instead, to integrate earthquake training tasks into other ongoing training programs. Because of the infrequency of earthquakes, even the best earthquake training program may slowly lose its effectiveness or completely die out. In addition, an earthquake training program that requires its own separate funding will probably have a relatively low priority in the overall ranking of training concerns. But it may be possible to find ways of slightly expanding existing training programs --at small cost--to deal with the problems unique to earthquakes.

Fire safety is typically the most common of hazards on which hazard training is based. In the process of instructing employees about extinguishers, alarms, notification procedures, safe storage methods, exiting, and other fire-related topics, it may be possible to incorporate an earthquake safety training unit at the same time. It is essential to have procedures for controlling leaks from fire sprinklers and other pipe lines. Security staffs should be trained in the process of responding to earthquakes at the same time they are familiarized with other emergency plans for theft, fire, or other hazards. Maintenance personnel must be trained in certain upkeep and operational aspects of the HVAC system, elevators, plumbing, lights, sprinkler system, and so on, and many of these items are precisely the components of a building that will require attention in an earthquake hazard reduction or response plan. Workplace safety training sessions are ideal forums for dealing with earthquake safety.

To minimize the number of earthquake training requirements, consider the unique aspects of earthquake problems that are not already covered by preparations for other hazards. For example, the fact that the phones may not work is one of the key ways in which earthquake response differs from that for fire or other hazards. If an emergency plan addresses building evacuation, it should identify gathering points that at a safe distance from falling hazards adjacent to other buildings. Individual emergency plans may contemplate a telephone outage, an electrical outage, the need to evacuate the building, traffic disruption, injury, pipe leakage, or window breakage, but it is unlikely that the response plan for any other hazard will consider that all these events may occur simultaneously. At a minimum, having an earthquake backup plan for reporting injuries or fires in the event that the telephones are inoperable is one essential feature to include.

The nearest fire station should be located and indicated on a street map so that aid can be quickly summoned in person if the phones are out. Even if emergency medical services are not provided by the fire department, the radio equipment available at fire stations will allow for communication with other agencies.

In addition to adding earthquake training to other ongoing training programs, it may be reasonable to occasionally devote brief training sessions exclusively to earthquake preparedness. An annual training schedule can easily be coordinated with an annual exercise schedule, as discussed below.

EXERCISES

The vulnerability estimates summarized on the nonstructural inventory form can be used to compile a list of nonstructural damage situations for inclusion in an earthquake scenario to be used for an exercise.

The list of nonstructural damage events may grow lengthy and may include contingencies that would be very costly and disruptive to simulate. For example, full-scale evacuations of high-rise buildings without the use of the elevators are rarely conducted; rather, one or two floors are evacuated periodically. Turning the electricity off will accurately simulate an earthquake-caused power outage and the attendant problems of visibility in windowless office areas, lack of air conditioning, and so on, but this may be too disruptive, or in some cases unsafe, to do throughout an entire office building. In a large company or government office, one department, one wing, or one work area of the building could be included in a more realistic simulation of effects while employees in the remainder of the facility are allowed to function normally or simply participate in a brief "take cover" exercise.

Employees with specialized earthquake response tasks--such as the maintenance personnel who check for water or gas leaks, supervisors who are responsible for checking on the well-being of employees in their areas, and safety or security officers responsible for communications within the building or with outside emergency services--should have more frequent training and exercises. A brief annual exercise, such as having people take cover beneath desks and reminding them not to use elevators after earthquakes, is probably adequate for most employees, whereas more frequent brief drills may he warranted for employees with specialized tasks. An important test of preparedness for nonstructural damage is to check to see whether the responsible personnel can quickly identify which valves to shut in order to control water pipe leakage in any part of the facility.

PERSONAL EMERGENCY KITS

Each employee should be encouraged to have their own Personal Emergency Kit containing a supply of necessary medical prescriptions, a flashlight, portable battery powered radio, a water bottle or soft drink, and an energy bar or some snack food. For women who wear high heels, it may also be useful to keep a pair of flat shoes handy, since evacuation procedures often require women to remove their high heels. Other items like a jacket, mittens, hat, or thermal blanket might be useful depending upon the local climate.

MASTER EARTHQUAKE PLANNING CHECKLIST

The checklist in Figure 10 provides an overview of the tasks involved in establishing an earthquake protection program to address nonstructural components.

1. **Facility/organization name**

2. **Address**

3. **Building ownership:**_________ owned by occupant,________leased by occupant

4. **Type of organization:** _________company,__________government agency,______other

5. **Organizational structure** (overall organizational chart)

6. **Functional responsibilities**
   Who has responsibility for the following:
   - authorization for earthquake program, budgeting
   - detailed administration of earthquake program
   - safety training courses
   - posters, brochures, memos, newsletters
   - workplace safety, compliance with safety regulations
   - fire brigades, emergency response team
   - first aid, health care
   - personnel: absenteeism, help with personal problems
   - insurance
   - risk management, risk control
   - facilities management: new construction and remodeling
   - facilities management: A & E contracts
   - facilities management: maintenance
   - facilities management: operation of mechanical/electrical systems
   - facilities management: postearthquake safety inspections
   - security
   - operational authority for evacuations, building closing
   - public relations, press statements
   - communications
   - food service
   - transportation: personnel, cargo

7. **Relationship to off-site portions of the organization**
   Which communication/transportation/interaction links are most essential?

8. **Relationship to other organizations**
   Which links are essential?

9. **On-site functions**
   Which are essential?

Information-Gathering Checklist: Organizational Characteristics
Figure 9

1. **Task:** Establish executive policy requiring a nonstructural evaluation, and allocate funds for initial work.
Responsibility: Chief Executive Officer, Board of Directors, Manager, Executive Committee.

2. **Task:** Survey the facility for nonstructural vulnerabilities.
Responsibility: Outside consultant or in-house engineering, maintenance, safety, or other department.

3. **Task:** Analyze the conditions, and estimate future earthquake effects.
Responsibility: Same as for number 2.

4. **Task:** Develop a list of nonstructural items to be upgraded, with priorities and cost estimates. (If a Facilities Development Guideline document is to be produced, coordinate performance criteria to be used on future new construction with upgrade standards).
Responsibility: Same as for number 2; may include bids from contractors.

5. **Task:** Decide what items will be upgraded, how the work will be done, and by whom.
Responsibility: Same as for number 1, with input from number 2.

6. **Task:** Implement the upgrade program.
Responsibility: In-house staff or contractors, with administration of contracting or tasking by number 2 or in-house construction administration office.

7. **Task:** Develop an earthquake response plan that contemplates nonstructural damage, with pre-emergency, during, and post-emergency earthquake tasks and responsibilities itemized.
Responsibility: Consultant or in-house safety or other department, with general policy and budgeting same as for number 1.

8. **Task:** Train personnel in accordance with the plan developed in number 7.
Responsibility: Training, safety, or other department.

9. **Task:** Plan and implement exercises that will test the training of number 8 and the planning of number 7.
Responsibility: Same as for number 7 or number 8.

10. **Task:** Evaluate the performance of the above program, preferably within one year after inception or according to the deadlines set in an implementation schedule, and annually thereafter.
Responsibility: Same as for number 1 in smaller organizations, or same as for number 7.

Master Nonstructural Earthquake Protection Checklist
Figure 10

7 FACILITIES DEVELOPMENT GUIDELINES

For a large organization, the development of formalized nonstructural construction guidelines may be appropriate to control the work of architects, engineers, interior designer/space planners, contractors, and occupants. As a general rule regarding new construction or renovation, if the construction drawings do not show specific attachments and bracing and if the written specifications do not mention earthquake-protective devices, such as anchors, braces, and so on, then it is unreasonable to assume that the contractor who builds or installs the items will devise special protective measures and spend time and materials to incorporate them. Current building code provisions for nonstructural components generally apply to a limited number of items, so compliance with code requirements may not address all the potential hazards. For instance, furniture and contents weighing less than 400 pounds and mounted less than 4 feet above the floor are typically excluded from the provisions [9].

NONSTRUCTURAL CONSTRUCTION GUIDELINES

Written guidelines may be useful for a large organization attempting to prevent or limit nonstructural damage. Such guidelines should be drafted with the assistance of architectural/engineering consultants and might include the elements described below.

Scope To what purchases, remodeling, or new construction do the guidelines apply? Guidelines cannot apply to all nonstructural items, since this broad definition would mean that furnishings such as wastepaper baskets, chairs, wall clocks, curtains, and so on, would all be included. Items that might appropriately be excluded are lightweight, nonhazardous, unessential, and inexpensive items that are not mounted overhead or above a certain height off the floor. The height criteria typically in use range from 42 inches to 5 feet, though desk or table height (30 inches) may be more appropriate for a facility where young children are present.

The guidelines might apply only to work done by outside designers and contractors, to in-house facilities work and maintenance, or to individual workplace standards. It is preferable to address these three audiences separately. The scope might include new construction only, renovations, or both. Including both cases is recommended.

Responsibility Who has the in-house responsibility for maintaining the guidelines and ensuring their implementation? This should usually be the same office that oversees or coordinates architecture and engineering projects. What responsibilities does the designer or contractor have for notifying or certifying to the owner that provisions of the guidelines are being followed? This responsibility should be written into the contract.

General Intent The importance of the nonstructural earthquake protection program should be stated, preferably in a cover letter or introductory statement from the chief executive, department head, or governing board. If the guidelines are the only ensured means of communicating about the earthquake hazard to designers or contractors, introductory information could be added as well (such as examples of the types of damage that might be expected to occur if the guidelines are not followed). This guide provides more background information on this topic than most designers or contractors have previously acquired, and portions or all of it could be made available to them to accomplish this purpose.

Performance Criteria If the client wants a design professional (architect or engineer) to do more than merely conform to the minimum requirements of the building code, it is desirable to explicitly describe the higher level of performance desired. This can be done in language such as the following: "In the event that a major earthquake occurs at the site (i.e., an earthquake with a ____ % probability of exceedance in _____ years), the following nonstructural items should remain undamaged and functional, assuming that the structure remains serviceable. For all other nonstructural items, only life safety is important, and the anchorage provisions of the local building code (or applicable code) should be followed, including anchorage of any item weighing more than _______ pounds, or located more than _______ above the floor and weighing more than _______ pounds." Another way to state the basic performance criteria would be, "Within _______ hours/days after the most severe earthquake that is expected to occur on average ______ (e.g., once a century), the following nonstructural items should be at least _______ percent functional."

As an alternative, other published criteria could be referenced. For example, some of the requirements imposed on California hospitals in Title 24 of the California Administrative Code might be appropriate for other essential facilities, but referencing that code would have to be done selectively because it includes many provisions that may not be applicable. Of course, it may not be easy to meet the desired level of performance, so this should be discussed with the engineering consultant prior to developing a specification. It is also sometimes difficult to verify whether the intent of a performance criterion has been met until the earthquake occurs.

The criteria should include an indication as to how much the client is willing to pay to obtain the higher level of protection. Estimates could be prepared for each job and approved by the client. Or a general statement could be made that "any cost up to _______ percent additional cost" (with the percentage specified in terms of total construction cost or estimated cost for that nonstructural item only) that the architect or engineer thinks reasonable is allowable. Costs estimated to be in excess of this limit would have to be brought to the attention of the client for explicit approval during design.

Quality Assurance What means of verifying and testing compliance with the guidelines will be required? For example, if upgrade details with anchorage into concrete slabs or walls is to be a common element of future projects, specific procedures for load testing (pulling) a percentage of installed anchor bolts could be specified. For installation of drill-in anchor bolts in concrete for hospitals in California, which are subject to stricter earthquake regulations than most buildings, the state requires in-place proof-testing of half of the bolts to twice their allowable loads. If any bolts pull out, then the adjacent bolts must also be tested.

Coordination with Nonseismic Specifications, Codes, and Guidelines The need to provide earthquake protection without sacrificing fire, security, or other requirements should be stated in the guidelines. One common conflict arises in the acoustically desirable use of vibration isolators to allow equipment such as air conditioning units or generators to operate without transmitting the full force of noisy vibrations into the building. The easiest earthquake solution is to bolt the equipment rigidly to the supporting structure, but this would compromise the spring-mount vibration isolation system. Restraining angles (snubbers) can be installed; properly designed snubbers will provide seismic restraint while also allowing the acoustic solution to operate unhindered. Another conflict arises in the design of fire and corridor doors. These doors must be tight to meet fire regulations but often jam closed due to interstory drift during an earthquake, making evacuation difficult.

Nonstructural Design Requirements Most design and construction contract language will require compliance with locally applicable codes. However, since the code provisions apply to a limited number of nonstructural items, most codes would not require earthquake anchorage or restraint for a computer, a tall file cabinet, a heavy mirror, or small containers of chemicals. In addition, a client might desire to provide a higher level of protection than the code minimum to some items that are listed in the code. If the guidelines call for measures that are in excess of local code requirements, this should be clearly stated. "Whichever requirements are more restrictive" is a phrase that could be used to indicate that the code must be met or, if the guidelines so require, exceeded. This is related to the subtopic Performance Criteria above.

The design force level is another question that should be addressed in the guidelines. Force level is the term for the amount of earthquake inertial force an item is designed to resist. The building code specifies different percentages of the weight of an object to be used as the horizontal earthquake force, as described in Chapter 2. Since many items are not covered by the code, the client or design professional must select the inertial force level to be used for the design of items that fall outside the code provisions. A design coefficient of 100% (if the object weighs 100 pounds, then its anchorage must be able to resist a horizontal force of 100 pounds) would be a generally conservative criterion for most items in most buildings in most parts of the United States. The cost of this extra conservatism is often small, since the labor cost will probably be the same and the difference in hardware costs is generally quite small.

Prescriptive Details If there are efficient and reliable specific methods to address repetitive nonstructural problems, then these might be detailed with drawings and required, where applicable. Chapter 4 provides a starting point for the development of such standard details, which should be reviewed by a knowledgeable design professional to ensure their appropriateness for the cases at hand. The references listed in the annotated bibliography provide additional sources of information.

STRUCTURAL/NONSTRUCTURAL INTERACTION

Although the focus of this guide is on nonstructural performance, there are a variety of ways to design or modify the structural system of a building in an effort to limit nonstructural damage. For new construction, it may useful for the owner, architect, and engineer to discuss the advantages and disadvantages of various structural systems at the very early stages of the project. It is important for the owner to understand the interaction between the structural system and the nonstructural components. Structural systems are often described in terms of their lateral stiffness or flexibility. For instance, a concrete shear wall building is generally stiffer than a steel frame structure of comparable size. The design team might choose a flexible frame system, which may appear more economical because such systems can often be designed for lower earthquake forces by code than a shear wall system of comparable size. Buildings designed to have less drift, or horizontal sway, such as shear wall buildings or buildings with a frame that is stiffer than the code minimum, will experience less nonstructural damage. If the increment of cost to upgrade the structural framing system is small, it may be advantageous to exceed the minimum code requirements and select a structural system that will provide improved nonstructural performance. It may also be desirable to provide movement joints to allow for protection of windows and partitions during earthquakes. The design of these joints is also related to the flexibility or expected seismic drift in the building.

If a client wants to reduce the potential for nonstructural earthquake damage and expects to receive extra attention in the structural, architectural, mechanical, or electrical design of the many features that make up a modern building, then it is vital that the client and the design team discuss these issues at the outset in order to develop a clear picture of the project objectives.

FEES FOR PROFESSIONAL SERVICES

If the architect, engineer, or interior designer/space planner is called upon to perform a service not usually provided, the fee will logically be higher. In most cases the engineer's drawings, specifications, and calculations cover only the building structure. The architect, mechanical engineer, and interior designer specify the nonstructural components of the building, but they may not have the expertise to adequately address the subject of earthquake performance. Designing upgrade details for a wide variety of nonstructural components can be time consuming. If the consultant has to make field visits to observe the construction, this will also involve additional time and expense.

GLOSSARY

Base - The portion of a building embedded in or resting on the ground surface.

Base isolation - A method whereby a building superstructure is separated from its foundation using flexible bearings in order to reduce the earthquake forces. This method can also be used as an upgrade technique for some types of large and/or sensitive equipment.

Bending - The curvature of structural or nonstructural components in response to certain types of applied loading. (For example, a beam bends or flexes in response to the weight it supports).

Distortion - The change in the configuration of an object or building as it bends or twists out of shape in response to earthquake loading.

Drift - The horizontal displacement of a building resulting from the application of lateral forces, usually forces from earthquake or wind.

Earthquake shaking - The vibratory movement of the earth's crust caused by seismic activity.

Expansion joint - A separation joint provided to allow for thermal expansion and contraction.

Flexible connection - The anchorage of an object to a structural member or braced nonstructural component, usually using hardware such as springs, cables, or corrugated tubing, which is designed to allow the object to move relative to the structural member or braced nonstructural component. For example, flexible hose connections are advisable for all gas-fired equipment.

Force level - The intensity of earthquake forces.

Foundation - That part of a structure which serves to transmit vertical and lateral forces from the superstructure of a building to the ground.

Frame - A type of structural system in which the loads are carried by a grid or framework of beams and columns, rather than by load-bearing walls.

Inertial forces - Forces necessary to overcome the tendency for a body at rest to stay at rest or for a body in motion to stay in motion.

Intensity - See **Shaking intensity**.

Interstory drift - The horizontal displacement that occurs over the height of one story of a building resulting from the application of lateral forces, usually forces from earthquake or wind.

Lateral force resisting system - The elements of a structure that resist horizontal forces. These elements are typically frames, braces or shear walls.

Magnitude - A measure of earthquake size which describes the amount of energy released.

Mitigation - An action taken to reduce the consequences of an earthquake.

Moment - The moment of a force about a given point, typically referred to as "the moment", is the turning effect, measured by the product of the force and its perpendicular distance from the point.

Positive connection - A means of anchorage between a nonstructural item and a structural member or braced nonstructural component that does not rely on friction to resist the anticipated earthquake forces. Positive connections are typically made using hardware such as bolts, steel angles, or cables rather than C-clamps or thumb screws. Nails, adhesives and toggle bolts typically do not have enough capacity to provide positive connections for the seismic anchorage of nonstructural items.

Pounding - The impact of two structures during an earthquake. Pounding frequently occurs when the seismic gap between two adjacent wings of a building, or two neighboring buildings separated only by a few inches, is insufficient to accommodate the relative lateral movement of both buildings.

Rigid connection - The anchorage of an object to a structural member or braced nonstructural component, usually using hardware such as bolts or brackets, which is designed to prohibit the object to move relative to the structural member or braced nonstructural component.

Schematic upgrade detail - A drawing outlining the basic elements of an upgrade scheme, but lacking dimensions, element sizes, and other specific information necessary for construction.

Seismic - Of, relating to, or caused by an earthquake.

Seismic drift - The horizontal displacement of a building resulting from the application of lateral earthquake forces.

Seismic gap or seismic joint - The distance between adjacent buildings, or two portions of the same building, which is designed to accommodate relative lateral displacements during an earthquake.

Seismic risk - The chance of injury, damage, or loss resulting from earthquake activity.

Seismic stop - A rigidly mounted bumper used to limit the range of lateral motion of spring-mounted mechanical equipment.

Seismic upgrade - Improvement of the resistance of a structural or nonstructural component to provide a higher level of safety or resistance to earthquake forces. For nonstructural components, seismic upgrade schemes typically involve the addition of anchorage hardware or braces to attach the nonstructural item to the surrounding structure. In some instances, the nonstructural item may also require internal strengthening.

Separation joint - The distance between adjacent buildings, or two portions of the same building, which is designed to accommodate relative displacements between the two structures. Seismic gaps and expansion joints are two types of separation joint.

Shaking intensity - The amount of energy released by an earthquake as measured or experienced at a particular location. Intensity is subjectively measured by the effects of the earthquake on people and structures.

Shear wall - A wall designed to resist lateral forces parallel to the wall.

Snubber - A device, such as a mechanical or hydraulic shock absorber, used to absorb the energy of sudden impulses or shocks in machinery or structures. Snubbers are often used to brace pipe runs where thermal expansion and contraction is an important consideration.

Upgrade detail - A drawing presenting the necessary elements of an upgrade scheme, including dimensions, element sizes, and other specific information in sufficient detail so that the drawing can be used for construction.

Vertical force resisting system - The elements of a structure that resist the gravity loads or self-weight.

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