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.

REFERENCES

1. Staff of the Los Angeles Times. 1994. *4:31, Images of the 1994 Los Angeles Earthquake.* Los Angeles, Calif.: Los Angeles Times.

2. Ding, Day, Christopher Arnold, et al. 1990. "Loma Prieta Earthquake Reconnaissance Report: Architecture, Building Contents, and Building Systems." *Earthquake Spectra*, Supplement to Volume 6.

3. Reitherman, Robert, et al. 1994. "Nonstructural Components." In *Northridge Earthquake, January 17, 1994, Preliminary Reconnaissance Report*, edited by John Hall. Oakland, Calif.: Earthquake Engineering Research Institute, and in-press Final Report to be published in *Earthquake Spectra*.

4. Federal Emergency Management Agency. 1981. *An Assessment of the Consequences and Preparations for a Catastrophic California Earthquake: Findings and Actions Taken.* Washington, D.C.: FEMA.

5. Steinbrugge, Karl V., and Eugene E. Schader. 1973. "Earthquake Damage and Related Statistics." In *San Fernando, California, Earthquake of February 9, 1971*, edited by Leonard Murphy. Vol. 1A, pp. 709-710 and 713. Washington D.C.: National Oceanic and Atmospheric Administration.

6. Wong, Kit M. 1993. *High Seismic Economic Risk Buildings: Research Report to the National Science Foundation.* Oakland, Calif.: Vickerman, Zachary, Miller.

7. Dobb, Linda, librarian, San Francisco State University. Personal communication.

8. Nigbor, Robert L. 1993. "Seismic Protection of Museum Contents," presented at the fall seminar of the Structural Engineers Association of Northern California. San Francisco: Structural Engineers Association of Northern California.

9. Building Seismic Safety Council. 1991. *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings.* Washington, D.C.: FEMA. [1994 edition in progress].

10. Shakal, A., et al. 1994. *CSMIP Strong-Motion Records from the Northridge, California, Earthquake of 17 January 1994.* Report No. OSMS 94-07. Sacramento: California Department of Conservation, Office of Strong Motion Studies.

11. Darragh, R., et al. 1994. *Processed Data for Sylmar - 6-story County Hospital from the Northridge Earthquake of 17 January 1994.* Report OSMS 94-11C. Sacramento: California Department of Conservation, Office of Strong Motion Studies.

12. International Conference of Building Officials. 1994. *Uniform Building Code.* Whittier, Calif.: ICBO.

13. Huttenbach, Robert A. 1980. *Policy on Seismic Hazard Reduction.* Santa Barbara, Calif.: University of California, Santa Barbara, Office of the Chancellor.

14. Steinmetz, William H. 1979. "How a Campus Handles an Earthquake Disaster," presented at the 26th National Conference on Campus Safety. Ann Arbor: University of Michigan.

The following references were used in compiling the checklists, details, and installation notes and are not cited specifically in the text:

15. California Office of the State Architect and California Office of Emergency Services. 1990. *Identification and Reduction of Nonstructural Earthquake Hazards in California Schools.* Sacramento and Oakland: California OSA and OES.

16. Reitherman, Robert, and Steve Minor. 1989. *Technical Guidelines for Earthquake Protection of Nonstructural Items in Communications Facilities*. Oakland: California Office of Emergency Services Earthquake Program.

17. Wiss, Janney, Elstner Associates, Inc. 1994. *Information on Protecting Your Home and Business from Nonstructural Earthquake Damage.* Los Angeles: California Office of Emergency Services.

18. California Office of the State Architect. 1993. *Earthquake Bracing of Water Heaters for Single-Family Homes.* Sacramento: California OSA.

19. Reitherman, Robert. 1991. *Nonstructural Earthquake Protection Manual for Idaho Schools*. Boise: Idaho Bureau of Disaster Services.

20. *Checklist of Nonstructural Earthquake Hazards.* Sacramento: California Office of Emergency Services Earthquake Project.

ANNOTATED BIBLIOGRAPHY

This brief bibliography can direct those who require more detailed information to other bibliographies, such as those contained in the references below, and thus is not meant to be comprehensive. This bibliography includes technical publications and nontechnical publications, both listed in alphabetical order, and also information on several organizations or government agencies with a specific focus on earthquake engineering issues. These organizations may be able to help the reader identify more recent publications than those listed here.

Technical Publications

Applied Technology Council. 1992. *ATC-29: Proceedings of Seminar and Workshop on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures*. Redwood City, Calif.: ATC.

○ These proceedings contain papers with performance data, analytical methods, and/or suggested details for many specific items, including elevated tanks, ceilings, fire sprinklers, HVAC ducts and equipment, and computer access floors. Most of these papers also contain extensive reference lists pertinent to each specific topic.

Ayres, J. M., T. Y. Sun, and F. R. Brown. 1973. "Nonstructural Damage to Buildings." In *The Great Alaska Earthquake of 1964: Engineering*. Washington D.C.: National Academy of Sciences.

Ayres, J. M., and T. Y. Sun. 1973. "Nonstructural Damage." In *The San Fernando, California, Earthquake of February 9, 1971*. Washington, D.C.: National Oceanic and Atmospheric Administration.

○ These were the first two comprehensive postearthquake damage analyses devoted to the topic of nonstructural components. The authors are mechanical engineers.

Building Seismic Safety Council. 1992. *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*. Part 1--Provisions (FEMA 222), Part 2--Commentary (FEMA 223). Washington, D.C.: FEMA.

○ The 1994 edition was in draft form at the time this document went to press.

Building Seismic Safety Council. 1992. *NEHRP Handbook for the Seismic Evaluation of Existing Buildings*. (FEMA 178). Washington, D.C.: FEMA.

Building Seismic Safety Council. 1992. *NEHRP Handbook for the Seismic Rehabilitation of Existing Buildings*. (FEMA 172). Washington, D.C.: FEMA.

○ Items 4, 5, and 6 are all part of a series of FEMA documents produced by the National Earthquake Hazards Reduction Program (NEHRP). These documents may be obtained without charge by writing to the address listed at the end of this bibliography.

Dowrick, D. J. 1977. *Earthquake Resistant Design: A Manual for Engineers and Architects*. New York: John Wiley & Sons.

○ A comprehensive text, including two chapters on nonstructural issues: "Earthquake Resistance

of Services," which concerns mechanical and electrical components, and "Architectural Detailing for Earthquake Resistance." The book has an international perspective with references to many different codes.

Earthquake Engineering Research Institute. 1984. *Nonstructural Issues of Seismic Design and Construction.* Publication No. 84-04. Oakland, Calif.: EERI.

○ This is a technical overview based on a workshop sponsored by the National Science Foundation. It includes several technical papers and a discussion of key issues, and it lists many additional references.

International Conference of Building Officials. 1994. *Uniform Building Code*, Volumes 1-3. Whittier, Calif.: ICBO.

○ See especially the "Earthquake Regulations." The UBC contains specific requirements for some items, such as steel storage racks. New editions of the UBC are issued every three years. The earthquake regulations are taken almost verbatim from the SEAOC "Blue Book," listed below, which also includes a useful commentary.

McGavin, Gary L. 1981. *Earthquake Protection of Essential Building Equipment: Design, Engineering, Installation.* New York: John Wiley & Sons.

○ A book-length treatment of the subject. Especially appropriate for large, complex projects, such as hospitals or power plants.

Office of the State Architect, Structural Safety Section. 1991. *Interpretation of Regulations #IR 23-7, Title 24 California Administrative Code: Anchorage of Non-Structural Building Components and Hospital Equipment.* Sacramento: California OSA.

○ The regulations legally pertain only to essential nonstructural items in California hospitals, but the regulations can provide a guide as to anchorage engineering of especially essential items for other types of buildings. The Office of the State Architect has been centrally involved in earthquake code regulations since the 1933 Long Beach earthquake.

Schiff, Anshel J. 1980. *Pictures of Earthquake Damage to Power Systems and Cost-Effective Methods to Reduce Seismic Failures of Electric Power Equipment.* West Lafayette, Ind.: Purdue Research Foundation.

○ This is one of the few works in this subject area that is readable by the nontechnical audience. Engineering appendix and bibliography also included.

Structural Engineers Association of California. 1990. *Recommended Lateral Force Requirements and Commentary.* San Francisco: SEAOC.

○ Also known as the SEAOC "Blue Book." The "Requirements" are adopted almost verbatim into the Uniform Building Code, while the "Commentary" explains the assumptions, limitations, and caveats that must be understood for the regulations to be used intelligently. The Structural Engineers Association of California has been active in the development of seismic code regulations, standards of practice, research, and testing for several decades.

Structural Engineers Association of Northern California. 1993. *Fall Seminar: Non-Structural Components--Design and Detailing.* San

Francisco: SEAONC.

o These seminar notes include nine papers on the design and detailing of cladding, interior systems, and mechanical systems. Several of these papers also include extensive reference lists.

U.S. Department of Defense. 1982. *Seismic Design for Buildings*. Tri-Service Manual TM 5-809-10. Washington, D.C.: Superintendent of Documents.

o Commentary and calculation examples are provided; see especially Chapters 9, 10, and 11. Generally parallels the UBC but is written as a design aid rather than a code.

U.S. Department of Defense. 1986. *Seismic Design Guidelines for Essential Buildings*. Tri-Service Manual TM 5-809-10-1. Washington, D.C.: Superintendent of Documents.

o Chapters 6 and 7 cover nonstructural components and nonbuilding structures, respectively. Includes several design examples. (Revised edition by Wiss, Janney, Elstner Associates, Inc., due out in 1995).

U.S. Department of Defense. 1986. *Seismic Design Guidelines for Upgrading Existing Buildings*, Tri-Service Manual TM 5-809-10-2. Washington, D.C.: Superintendent of Documents.

o Portions of Chapter 6, Chapter 9, and the design examples in Appendix G are related to nonstructural items.

U.S. Department of Veterans Affairs, Office of Construction. 1976. *Study to Establish Seismic Protection Provisions for Furniture, Equipment, and Supplies for VA Hospitals*. Washington, D.C.: VA.

o This guide shows typical nonstructural damage inside a hospital and illustrated restraint techniques with cost estimates for a variety of types of hospital equipment and furnishings; it includes a brief engineering appendix. Relevant for buildings other than hospitals, especially if laboratories are present.

Yancey, C. W. C., and A. A. Camacho. 1978. *Seismic Design of Building Service Systems: The State of the Art*. National Bureau of Standards Technical Note 970. Washington, D.C.: NBS.

o A literature survey and review of present practice, especially with regard to the specific mandatory regulations of building codes. The National Bureau of Standards, a federal bureau, has been involved with earthquake research and postearthquake damage reports.

Rihal, Satwant, Barry J. Goodno, Hiroshi Ito, and Robert Reitherman. 1993. "Nonstructural Elements." In *Design of Low-Rise Buildings Subjected to Lateral Forces*, edited by Ajaya Kumar Gupta and Peter James Moss. Ann Arbor: CRC Press.

o A chapter in a book intended for architects, engineers, building officials, and university professors. Most of this chapter concerns earthquakes rather than wind, and additional references are listed.

Reitherman, Robert, and Steve Minor. 1989. *Technical Guidelines for Earthquake Protection of Nonstructural Items in Communications Facilities*. Oakland: California Office of Emergency Services Earthquake Program.

o Intended for the facilities staffs who install

and maintain telecommunications equipment. Includes simplified design guide for the selection of anchor bolts, drawings of anchorage and bracing details, and installation guidance.

Technical Standards

The following list of publications includes many of the specific design, fabrication, and/or installation requirements for particular nonstructural items.

American Institute of Steel Construction (AISC). 1989. *Manual of Steel Construction : Allowable Stress Design.* Ninth Edition.

American Petroleum Institute (API). 1988. *Welded Steel Tanks for Oil Storage.* API Standard 650.

American Society of Mechanical Engineers (ASME). 1990. *Safety Code of Elevators and Escalators.* ASME A17.1.

American Society of Mechanical Engineers (ASME). Including addenda through 1993. *Code for Pressure Piping.* ASME B31.

American Society of Mechanical Engineers (ASME). Including addendum through 1993. *Boiler and Pressure Vessel Code.*

American Society For Testing and Materials (ASTM). 1991. *Standard Specification for the Manufacture, Performance and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings.* ASTM C635.

American Society For Testing and Materials (ASTM). 1991. *Standard Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels.* ASTM C636.

American Water Works Association (AWWA). 1984. *Welded Steel Tanks for Water Storage.* D100.

Ceilings and Interior Systems Construction Association (CISCA). 1991. *Recommendations for Direct-Hung Acoustical Tile and Lay-In Panel Ceilings, Seismic Zones 0-2.*

Ceilings and Interior Systems Construction Association (CISCA). 1990. *Recommendations for Direct-Hung Acoustical Tile and Lay-In Panel Ceilings, Seismic Zones 3-4.*

Institute of Electrical and Electronic Engineers (IEEE). 1975. *Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.* IEEE Standard 344.

Manufacturers Standardization Society of the Valve and Fitting Industry (MSS). 1988. *Pipe Hangers and Supports : Materials, Design, and Manufacture.* SP-58.

National Fire Protection Association (NFPA). 1991. *Standard for the Installation of Sprinkler Systems.* NFPA-13.

Rack Manufacturers Institute (RMI). 1990. *Specification for the Design, Testing, and Utilization of Industrial Steel Storage Racks.*

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). 1985. *HVAC Duct Construction Standards, Metal and Flexible.*

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). 1980. *Rectangular Industrial Duct Construction Standards.*

Sheet Metal and Air Conditioning Contractors National Association (SMACNA), Sheet Metal Industry Fund of Los Angeles, and Plumbing Industry Council. 1992. *Guidelines for Seismic*

Restraint of Mechanical Systems and Plumbing Piping Systems.

Nontechnical References

California Office of the State Architect and California Office of Emergency Services. 1990. *Identification and Reduction of Nonstructural Earthquake Hazards in California Schools.* Sacramento and Oakland: California OSA and California OES

o Survey forms and drawings of bracing concepts for 27 nonstructural items.

FIMS, Inc., and VSP Associates. 1987. *Data Processing Facilities: Guidelines for Earthquake Hazard Mitigation.* Sacramento, Calif.: VSP, Inc.

o Intended for owners and operators of data processing facilities (DPF). Contains illustrative material on nonstructural hazards and upgrades for raised floors and mainframe computer systems, as well as components found in buildings in general. Not intended as a self-help guide, but provides DPF manager with a basis for discussing design criteria with an engineer.

Noson, Linda, Todd Perbix, and Padraic Burke. 1989. *Safer Schools: Earthquake Hazards, Nonstructural.* Olympia, Wash.: Washington Superintendent of Public Instruction.

o Includes background information on earthquakes in Washington, survey checklists, and 32 pages of illustrations of nonstructural hazard reduction measures.

Olshansky, Robert B. No date (c. 1992). *Reducing Earthquake Hazards in the Central U.S.: Nonstructural Hazards.* Memphis, Tenn.: Central United States Earthquake Consortium.

o Prepared for the U.S. Geological Survey by the University of Illinois at Urbana-Champaign, Department of Urban and Regional Planning. Illustrations and explanations of nonstructural damage.

Reid & Tarics Associates. 1982. *Seismic Restraint Handbook for Furniture, Equipment, and Supplies.* Washington, D.C.: Veterans Administration.

o In addition to detailed administration procedures applicable to VA hospitals, the handbook contains detailed forms for collecting nonstructural survey data and producing cost estimates or lists of required materials and labor. Includes 18 pages of restraint details. Originally intended for use by engineering staffs at VA medical facilities, without the use of outside contractors or additional design/analysis assistance.

Reitherman, Robert. 1989. *Nonstructural Earthquake Hazard Mitigation for Hospitals and Other Health Care Facilities.* FEMA Publication SM (Student Manual) 370. Washington, DC: FEMA.

o Six chapters devoted to the nonstructural topic, some of them generally applicable and others more specific to hospitals. This is a manual used for a two-day course devoted to earthquake hazard reduction and emergency preparedness for hospital facilities.

Organizations

1. Federal Emergency Management Agency (FEMA); California Office of Emergency Services (OES) Earthquake Program; Central United States Earthquake Consortium (CUSEC).

A wide variety of publications, brochures, checklists, videotapes, and slide sets related to earthquake preparedness and nonstructural hazard mitigation are available from many state and federal agencies. Some of the items are tailored to meet differing needs in particular areas of the United States. Some are tailored for specific types of facilities, such as hospitals, schools, day care centers, nursing homes, or single-family residences. Many are available free of charge.

FEMA has regional offices throughout the country, and most states have an office or department of emergency services that may have similar material. The list below includes only several key agencies.

Federal Emergency Management Agency
Mitigation Directorate
500 C Street. S.W.
Washington, D.C. 20472

State of California
Governor's Office of Emergency Services
Earthquake Program
2800 Meadowview Road
Sacramento, CA 95832
(Phone 916-262-1800; Fax 916-262-1840)

Central United States Earthquake Consortium
2630 East Holmes Road
Memphis, TN 38118
(Phone 901-345-0932; Fax 901-345-0998)

2. The National Center for Earthquake Engineering Research (NCEER) is associated with the State University of New York at Buffalo. Founded in 1987, NCEER sponsors academic research in earthquake engineering, publishes a quarterly bulletin, and has an extensive list of technical reports available by mail. NCEER also has a bibliographic database called QUAKELINE that covers the literature of earthquake engineering and natural hazards mitigation. The database contained over 24,000 records as of January 1994; approximately 400 additions are made each month. The database is accessible on Internet, through both academic computing services and commercial providers.

National Center for Earthquake Engineering Research
State University of New York at Buffalo
Red Jacket Quadrangle, Box 610025
Buffalo, NY 14621-0025
(Phone 716-645-3391; Fax 716-645-3399; QUAKELINE Info: Phone 716-645-3377)

3. The Earthquake Engineering Research Institute (EERI) was organized in 1949 as a nonprofit corporation with the objective of reducing the impact of earthquakes by means of seismic studies, inspection of earthquake damage, education, and technology transfer, including conferences and the publication of newsletters, reports, technical papers, and conference proceedings. EERI has members in 47 states and 51 foreign countries, including many practicing engineers, architects, and seismologists, as well as university professors and government personnel. *Earthquake Spectra,* a monthly publication of EERI, contains articles covering a wide range of topics related to earthquakes. EERI has an extensive publication list that also includes videotapes and annotated slide sets showing examples of damage during many past earthquakes.

Earthquake Engineering Research Institute
499 14th Street
Oakland, CA 94612-1902
(Phone 510-451-0905; Fax 510-451-5411)

4. The Earthquake Engineering Research Center (EERC) is associated with the University of California at Berkeley. In addition to the extensive shake table testing program, which has been going on for many years and which has produced hundreds of research reports, EERC has an extensive library of earthquake-related materials and a large collection of earthquake slides, and it publishes a newsletter. EERC reports and slide sets are available for sale.

The National Information Service for Earthquake Engineering (NISEE) distributes computer software for earthquake engineering and is associated with EERC. NISEE also maintains a computer database of information on earthquake engineering, accessible through Internet.

Earthquake Engineering Research Center
University of California, Berkeley
1301 South 46th Street
Richmond, CA 94804-4698
(Phone 510-231-9554)

5. The Applied Technology Council (ATC) is a nonprofit corporation serving the structural engineering profession. The majority of its publications are related to technical topics in seismic analysis and design, postearthquake damage evaluations, new technological advances in seismic design, and so on. The specific focus of the organization is to provide a link between academic research and professional practice. ATC sponsors several technical workshops each year.

Applied Technology Council
555 Twin Dolphin Drive, Suite 270
Redwood City, CA 94065
(Phone 415-595-1542; Fax 415-593-2320)