4. NONSTRUCTURAL RISK REDUCTION FOR EXISTING BUILDINGS

Nonstructural risk reduction programs may vary depending on whether the nonstructural components in question are in an existing building, a historic facility, an essential facility, a facility containing hazardous materials, or are planned for a new building. The current chapter addresses issues related to existing buildings; Chapter 5 addresses issues related to new construction. Portions of these chapters are written in parallel, yet they are unique to each chapter. If portions apply to either situation, they appear only once. For instance, the material on implementation strategies appears only in Chapter 4; the material on current code requirements and code enforcement appears only in Chapter 5.

There is considerable overlap between the *new* and *existing* building categories. For instance, if an existing building undergoes a major alteration and changes to a higher use category, then it would be required to comply with current codes in many jurisdictions and thus, the project requirements would closely resemble those for new construction. Conversely, a new building becomes an existing building as soon as the occupancy permit is issued. Thus, tenant improvements and the installation of furniture, fixtures, equipment, and contents for the first occupants of a leased portion of a new building often take place after the original design team is finished and the major architectural, mechanical, electrical, and plumbing components are installed; for this reason, many of the problems involved in coordinating the anchorage of the tenants' components with preexisting components are the same as for a project in an older existing building.

Historic buildings, essential buildings such as police and fire stations, or facilities that handle hazardous materials have special requirements, which are typically more complex than those for ordinary occupancies. While some issues related to these types of facilities are mentioned here, the treatment of nonstructural components in these facilities is beyond the scope of this guide. The list of references and additional sources of information may help to address these issues for specialized facilities.

4.1 Program Objectives and Scope

Several recent earthquakes in the United States have provided evidence suggesting that nonstructural damage may account for more than 50% of total damage in future domestic earthquakes. As advances are made in the structural design of buildings, and we experience fewer structural failures and fewer collapses as a result, the significance of nonstructural damage becomes more apparent. In addition, postearthquake operations are of increasing concern not only to essential facilities such as police and fire stations and hospitals, but also to manufacturing facilities, banks, mobile phone providers, and many other businesses concerned with loss of revenue or loss of market share that would result from a lengthy outage following an earthquake. Organizations and owners who want to reduce their seismic exposure will need to address the nonstructural hazards in their facilities.

Seismic improvements to existing buildings might be mandated by a governmental body or might be motivated by a desire to provide for postearthquake operations, to reduce future losses or liability, to reduce insurance premiums, or to increase the resale value of the property. In most cases, seismic improvements to existing facilities are undertaken on a voluntary basis and, as a result, organizations and owners have latitude in setting the objectives and defining the scope of a nonstructural risk reduction program for existing buildings.

4.1.1 Voluntary vs. Mandatory Risk Reduction

In general, a nonstructural risk reduction program for existing buildings would be considered a voluntary upgrade; that is, a program that is voluntarily undertaken by an owner to reduce the potential liability and losses in the event of an earthquake. Although current codes have requirements for bracing and anchorage of nonstructural items, most jurisdictions do not currently require nonstructural hazards to be addressed retroactively in existing facilities.

There are some notable exceptions, in cases where a jurisdiction may require mandatory retrofitting of existing nonstructural components. A few of these are listed below:

- Many jurisdictions in California have ordinances requiring that unreinforced masonry parapets, particularly those adjacent to a public right-of-way, be braced or anchored to prevent collapse in an earthquake.
- Some major cities including Chicago, New York, Boston, and Detroit have façade ordinances that mandate periodic inspection of building façades; while this is not intended as a seismic requirement, it has the benefit that the architectural cladding, veneer, ornamentation, and anchors are inspected and maintained on a regular basis.
- Seismic safety legislation (SB 1953) was passed in California in 1994, following the Northridge Earthquake. That earthquake resulted in the suspension of some or all services at 23 hospitals and in $3 billion in hospital-related damages. This legislation requires California hospitals to comply with specific nonstructural hazard mitigation deadlines, including: (1) major nonstructural items including emergency power supply, bulk medical gas systems, communication systems, fire alarm systems and exit lighting

are to be braced by 2002; (2) most nonstructural items within "critical care areas" are to be braced by 2008; and (3) most nonstructural components within the hospital are to be braced by 2030. This is an unfunded mandate; the burden of financing these improvements rests with the health care providers.

- Major alterations, additions, or changes of use may trigger code requirements to bring existing construction, including the nonstructural items, into compliance with the current code. For instance, conversion of a warehouse to a school building would trigger requirements for current code compliance in many jurisdictions; check for local requirements and exemptions.

The rules that apply for voluntary upgrades to existing facilities are typically different than those that apply to new construction or to mandatory upgrades. While it may be desirable to design the nonstructural anchorage details for existing equipment in existing buildings using the current code, it is not typically required for voluntary upgrades. In order to describe the spectrum of risk reduction objectives, it is useful to introduce some performance-based design concepts.

4.1.2 Performance-Based Design Concepts

The use of performance-based design concepts requires a discussion between building design professionals and their clients about performance expectations and seismic risk tolerance. Performance-based design provides terminology to characterize seismic risk and seismic performance and provides a framework for making comparisons between varying levels of seismic hazard, structural and nonstructural performance, postearthquake functionality, acceptable and unacceptable damage, and total earthquake losses over the expected life of the facility. Design professionals, organizational risk managers, building owners, business owners, and tenants all need to have an understanding of the tradeoffs between risk and reward; an understanding that seismic design and investment choices have a relationship to expected future performance and potential future losses. The parties all need to understand that they make choices, both passive and active, based on their understanding of the issues and their seismic risk tolerance. One may choose to live with known seismic risks or choose to initiate programs to reduce some or all of the known hazards; either way, a choice must be made.

Performance-based design concepts have been in development for several decades; this process is ongoing. These concepts are gradually finding their way into the building codes used for new construction, such as the *International Building Code* and ASCE/SEI 7 *Minimum Design Loads for Buildings and Other Structures*, and into the building standards used for the evaluation and retrofitting of existing structures, ASCE/SEI 31 *Seismic Evaluation of Existing Buildings* and ASCE/SEI 41 *Seismic Rehabilitation of Existing Buildings*, respectively. Previous editions of U.S. building codes were based on the philosophy that structures should not collapse in a major earthquake but might suffer severe structural and nonstructural damage; this was a minimum life safety standard and is roughly comparable to the Basic Safety Objective that is now described in ASCE/SEI 41-06 (ASCE, 2006). Although engineers were aware that a "code design" was only meeting minimum standards, it is not clear that building owners and occupants had a similar understanding. What is significant about performance-based design concepts is that they are used to describe a range of objectives and that they make the choice of performance objectives an explicit part of the design process; the design professional and the client need to discuss and agree on those performance objectives.

Analogy: Financial Risk Tolerance

One of the first things most financial advisors do with new clients is to present them with an investment questionnaire to gauge how they feel about risking their money; that is, to assess what is referred to as their "investment risk tolerance." The investment advisor cannot make reasonable recommendations on how to allocate the client's assets without knowing something about their tolerance for financial risk. Is the investor conservative, moderate, or aggressive? Given the tradeoffs between risk and reward, do they have a low, medium, or high tolerance for financial risk?

For existing buildings, ASCE/SEI 41-06 *Seismic Rehabilitation of Existing Buildings* (ASCE, 2007) provides a flexible approach for evaluation and improvement of nonstructural components. Nonstructural performance levels are:

- Hazards Reduced – a postearthquake damage state in which nonstructural components are damaged and could potentially create falling hazards, but high hazard nonstructural components are secured to prevent falling into public assembly areas. Other life-safety issues, such as preservation of egress and protections of fire suppression systems are not addressed.

- Life Safety – a postearthquake damage state in which nonstructural components are damaged but the damage is not life threatening. However, significant and costly damage is expected to occur.
- Immediate Occupancy – a postearthquake damage state in which nonstructural components are damaged but building access and life-safety systems generally remain available and operable.
- Operational – a postearthquake state in which nonstructural components are able to support the pre-earthquake functions of the building.

While it is not relevant to describe the engineering design process of ASCE/SEI 41-06 in detail here, it is relevant to describe the decision making process used to determine the scope and desired performance objectives for a voluntary upgrade. Note that in addition to the Basic Safety Objective, the standard provides guidance on choosing objectives for voluntary upgrades that are both more ambitious, "Enhanced," and less ambitious, "Limited," than the Basic Safety Objective. The choice of objective will determine which hazards are addressed, what performance is likely following a major earthquake, and how much structural and nonstructural damage the facility is likely to sustain.

Several key questions as posed in ASCE/SEI 41-06 are listed below. The array of performance options described in ASCE/SEI 41-06 is shown in Table 4.1.2-1:

- What are the retrofitting objectives?
- What earthquake scenario(s) are most relevant for this facility?
- What kind of postearthquake functionality is required for this facility?
- What target structural performance level is required for this facility?
- What target nonstructural performance level is required for the facility?
- What target building performance level is required for the facility, and how does that relate to the target levels of structural and nonstructural performance and to the expected postearthquake damage state for the facility?
- What combination of choices meet the ASCE/SEI 41-06 Basic Safety Objectives? Enhanced Objectives? Limited Objectives?

Table 4.1.2-1 Target Building Performance Levels (after ASCE/SEI 41-06)

Target Building Performance Level	Expected Postearthquake Damage State	Target Structural Performance Level	Target Nonstructural Performance Level
Operational Level	Backup utility services maintain function; very little structural or nonstructural damage	Immediate Occupancy	Operational
Immediate Occupancy	The building remains safe to occupy; any structural or nonstructural repairs are minor	Immediate Occupancy	Immediate Occupancy
Intermediate Level		Damage Control	
Life Safety	Structure remains stable and has significant reserve capacity; hazardous nonstructural damage is controlled	Life Safety	Life Safety
Intermediate Level		Limited Safety	Hazards Reduced
Collapse Prevention	The building remains standing, but only barely; the building may have severe structural and nonstructural damage	Collapse Prevention	Not Considered

As shown in Table 4.1.2-1, buildings are assigned a target performance level, which considers both structural and nonstructural performance objectives.

In contrast to the approach used in ASCE/SEI 7-10 for new buildings where the nonstructural performance level is tied to a single ground shaking hazard, the nonstructural performance levels in ASCE/SEI 41-06 are defined in a manner independent of the ground motion. To establish criteria for a seismic retrofit, a ground shaking hazard level and corresponding structural and nonstructural performance levels are selected. Often, several sets of ground shaking hazards and nonstructural performance levels are established. For example, a building might have target building performance levels of Immediate Occupancy for the design earthquake ground motion and Life Safety for the maximum considered earthquake. Combinations of ground shaking hazard and performance level can be created to suit the needs and resources of the building owner. The engineering approach to nonstructural design ASCE/SEI 41-06 is discussed in Chapter 6 for different types of components.

According to ASCE/SEI 41-06, the Basic Safety Objective is achieved by the following combination:

- Design for *Life Safety Building Performance* for Basic Safety Earthquake 1 (earthquake that occurs every 500 years), AND
- Design for *Collapse Prevention Building Performance* for Basic Safety Earthquake 2 (earthquake that occurs every 2500 years).

All other combinations of performance levels and seismic hazard levels are characterized as either Limited or Enhanced objectives (for more on this, see sidebar at right).

Limited and Enhanced Rehabilitation Objectives per ASCE/SEI 41-06

Besides the stated requirements for the Basic Safety Objective, all other combinations of performance levels and seismic hazard levels are characterized as either Enhanced or Limited objectives. In comparison with the Basic Safety Objective, a higher performance level correlates with less damage, lower losses, and increased functionality, whereas a lower performance level correlates with more damage, higher losses, and reduced functionality. The following are examples of Limited Rehabilitation Objectives:

- Address only serious nonstructural falling hazards considering a small, frequent seismic event, i.e., according to ASCE/SEI 41-06 terminology, target for a *Hazards Reduced* nonstructural performance level, considering the 50%/50 year event.
- Address all nonstructural life safety hazards without consideration of structural hazards, i.e., according to ASCE/SEI 41-06 terminology, target for a *Life Safety* nonstructural performance level for any chosen earthquake scenario.

In contrast, the following is an example for an Enhanced Rehabilitation Objective:

- Provide reduced damage and increased functionality, i.e., according to ASCE/SEI 41-06 terminology, design for *Immediate Occupancy* Building Performance for any earthquake hazard level. Note that to achieve this performance level, both structural and nonstructural upgrades may be required.

As seen in Table 4.1.2-1, an effort to preserve postearthquake operations at either the *Immediate Occupancy* level or the *Operational* levels require that both structural and nonstructural hazards be addressed. Indeed, the higher *Operational* standard for nonstructural components is what differentiates these two enhanced levels of building performance. Per ASCE/SEI 41-06, the differences in design between the different target levels of building performance are higher or lower seismic design forces and explicit design for more or fewer nonstructural components. Engineering analysis methods, such as nonlinear static and dynamic procedures, are available and can be used to check whether or not the design meets the target performance objectives. There are many other questions that may help refine the project objectives and scope of work, such as:

- What kind of losses can the business or organization tolerate after an earthquake?
- How much downtime can the organization tolerate before employees, clients, or customers go elsewhere?
- Does the organization have earthquake insurance? If so, how much of the losses are covered? What are the deductibles? What is the cost-benefit ratio of doing upgrades versus providing coverage and suffering a loss?
- Is this a historic building, essential facility, or facility with specialized or unique considerations?
- What nonstructural components are under your direct control? Architectural? Mechanical, electrical, and plumbing (MEP)? Furniture, fixtures, equipment (FF&E)? Contents? Or all of these?
- Will the project include upgrades to only MEP and architectural components, or will FF&E and contents be included as well?
- What are the most hazardous nonstructural components?
- For leased facilities, which elements are responsibilities of the owner and which are responsibilities of the occupants?
- If the owner has undertaken any seismic upgrades, is there a report available describing the project objectives or design level? Were nonstructural items addressed?
- Are there any incentives a lessee can offer a building owner to improve the safety of leased space?
- Do you need to consider relocation to another space that provides an increased level of seismic safety?

ASCE/SEI 41-06 is in the last stages of an extensive revision. The new document, ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE/SEI 41-13) merges ASCE/SEI 41-06 and ASCE/SEI 31-03, *Seismic Evaluation of Existing Buildings*. The nonstructural provisions of ASCE/SEI 41-13 will be significantly different than those found in ASCE/SEI 41-06. Major changes include:

- In most cases, the design ground motions for the performance objectives have been reduced. For example, in ASCE/SEI 41-06, the Basic Safety Objective was achieved by meeting Life Safety structural performance criteria when subject to ground shaking having a 10% probability of exceedance in 50 years. In ASCE/SEI 41-13, Life Safety performance must be met for an earthquake having a 20% probability of exceedance in 50 years, a less severe event.

- The nonstructural performance objectives have been redefined.
    - In ASCE/SEI 41-06, nonstructural performance objectives, from lowest to highest are: Hazards Reduced, Life Safety, Immediate Occupancy, and Operational. While the Operational performance objective is defined, the specific procedures and acceptance criteria were not provided.
    - In ASCE/SEI 41-13, nonstructural performance objectives, from lowest to highest are: Life Safety, Position Retention, and Operational.
    - There is no direct correlation between the old and new nonstructural performance objectives. Table 4.1.2-2 below illustrates the approximate relationship, but only in a general sense. There have been substantive changes to the nonstructural provisions throughout ASCE/SEI 41-13. Note the table is limited to performance objectives for which procedures and acceptance criteria are actually defined:

Table 4.1.2-2 Approximate Relationship of Nonstructural Performance Objectives

ASCE/SEI 41-06	ASCE/SEI 41-13
Hazards Reduced	Life Safety
Life Safety	Position Retention
Immediate Occupancy	–
–	Operational

    - To achieve the Basic Performance Objective in ASCE/SEI 41-13, nonstructural components in essential buildings (Seismic Risk Category IV), such as hospitals, emergency operations centers, and fire stations must meet the "Position Retention" objective – for roughly equivalent to "Life Safety" in ASCE/SEI 41-06. This represents a considerable reduction in requirements compared to the earlier edition.

When FEMA E-74 is used in conjunction with ASCE/SEI 41-13, care must taken to properly determine the appropriate retrofit objective, design procedures, and acceptance criteria. This is of great importance since the term "Life Safety," used throughout this document, has been redefined in ASCE/SEI-41-13 to mean a lower retrofit objective.

The point of including this discussion is not to discourage the reader by presenting the design process as a complex system, tempting the reader to conclude that it would be much easier to do nothing. The point of the discussion is to emphasize that choices need to be made in deciding how to manage seismic risk. Resources are always limited, and seismic risks must be balanced against many other types of risk. Whatever seismic hazard reduction objectives are selected, they should be chosen with an understanding of the risks and rewards. A decision to mitigate known seismic hazards, particularly dangerous life safety hazards, would generally be considered both reasonable and prudent, even if it were not mandated by law. A decision to upgrade a complex facility to *Immediate Occupancy* or *Operational* performance level is a major and complex undertaking, since facility operations may depend on the continued function of hundreds or thousands of individual nonstructural components. Such an upgrade should not be undertaken without an understanding of the costs and benefits of such a program.

4.1.3 Legal Considerations

A common concern voiced by building owners who are considering seismic improvement projects for their building or its nonstructural contents and components is the question of legal liability. A persistent belief is that one should not do anything, because if a life safety issue is uncovered and is made known to the owner, then the owner may be liable for any injuries or deaths that arise due to a severe earthquake damaging their building. This “ignorance is bliss” approach is not supported by legal precedents.

The legal issues involved are not black and white and may depend on the type of the facility, the sophistication of the owner, and the number of occupants at risk. There are two ways of looking at these issues:

- One view is that the standard of care of any owner is to act reasonably and to exercise ordinary care in managing the property. This care includes inspecting and maintaining owned buildings in a safe condition. Safety is usually measured against the building standard in effect at the time when the building was constructed, not the current code or any current evaluation standard for existing buildings. Therefore, if owners choose to evaluate their building using a more modern standard and uncover issues in doing so, it is then at their discretion on how, when, and if to act on these data in a voluntary manner.
- Another view is that if an owner is aware of a dangerous condition on their property, they have an affirmative duty to warn those affected or to mitigate the hazard.

If an owner does undertake a project or program to study and possibly to improve the seismic performance of a building or a building's nonstructural components, then the following is recommended to provide transparency:

- Ensure that any inspection is conducted by competent, qualified, and experienced parties
- Use widely accepted inspection, design, and construction standards such as those from FEMA, ASCE or other national or internationally recognized standard organizations
- Develop clear and complete documentation of decisions and actions
- Establish processes to ensure that all work is performed properly
- Implement any remedial actions through experienced contractors
- Proceed without creating any dangerous conditions and without making the building performance worse than it was before
- Proceed in a reasonable and responsible manner

The position of the authors is that an owner is much better off being proactive and doing something to investigate or improve the performance of a building and its nonstructural components and contents than doing nothing. Ultimately, however, an owner's decision to undertake such a remediation project is his or hers alone, and many considerations, such as public relations, risk tolerance, affordability, and market conditions will undoubtedly be factored into the decision.

It is recommended that an owner concerned with these issues seek appropriate legal counsel with expertise in construction law and seismic mitigation issues, to assist in their decision making process.

4.2 Design considerations

The selection of design solutions must be consistent with the scope and objectives selected for the project. Some design solutions can be implemented without consideration of the building code and without engineering expertise. Other design solutions rely on building codes and standards, such as ASCE/SEI 7-10, ASCE/SEI 31-03, and ASCE/SEI 41-06, that all contain elements of the performance-based design methods discussed above. If engineering consultants are engaged to provide design solutions, the selection of seismic force levels, design coefficients, and design methods depends upon the performance objectives selected.

Specific design solutions for nonstructural items fall into three broad categories:

> NON-ENGINEERED (NE): These are typically simple, generic details or common sense measures that can be implemented by a handy worker or maintenance personnel using

standard items from any hardware store. Many of these solutions apply to contents that are not directly covered by building code provisions. As an example, Chapter 6 contains a detail showing the general configuration for anchoring a bookcase to a stud wall (see Figure 6.5.2.1-4) and identifies the parts needed but does not explicitly indicate the size of the angle bracket or screws needed; this is left to the handy worker based on the size and weight of the particular bookcase and the type and spacing of studs. Some of these types of solutions have failed in past earthquakes, usually due to undersized bolts and hardware or because bolts have failed to engage a structural member. As a result, non-engineered solutions are generally not appropriate for hospitals or other facilities that have chosen operational functionality as a performance level objective.

PRESCRIPTIVE (PR): Prescriptive design details are available in the public domain that have been engineered to meet or exceed code requirements for a set of common conditions and can be used directly in many situations. One prescriptive detail included in Chapter 6 is the anchorage detail for a residential or small commercial water heater (see Figure 6.4.2.4-6). This detail is applicable for the anchorage of a water heater, up to 100 gallons, attached to a wood stud wall. The detail calls out the required hardware and the size and spacing of fasteners.

While there are only a limited number of these details currently available, we anticipate that more such details will be developed as engineers, architects, and specialty contractors become more familiar with the new code requirements for nonstructural components. Some of the prescriptive details have been developed by or for the Office of Statewide Health Planning and Development (OSHPD), the entity in California responsible for overseeing hospital design.

ENGINEERING REQUIRED (ER): These are nonstructural anchorage details specifically developed by a design professional on a case-by-case basis for a specific set of conditions. First, the owner and design professional need to agree on the desired level of protection for the anticipated level of shaking, only then can the design professional develop details consistent with the objectives. Design methods and design coefficients are selected based on the performance objectives as discussed above. An anchorage detail designed for a lateral force of 1.0 g will generally be more robust and more costly than one designed for a lateral force of 0.1g. Higher design forces and more complex engineering methods may be required to meet higher performance objectives.

As part of the design process, it may be important to consider a number of issues:

- **Interaction of nonstructural components.** Many nonstructural systems are interconnected or interdependent; items in close proximity can impact one another and tall or overhead items can fall and damage items below. Lights, ceilings, diffusers, ducts, piping, sprinkler heads, and variable air volume boxes may all share the plenum space above the ceiling and it may be challenging to find ways to keep them separated and to provide independent support for all of them.
- **Interaction of nonstructural and structural components.** Nonstructural components may be damaged by the deformations of structural components. Items that cross seismic separations between buildings, connect at adjacent floor levels, or are located in base isolated structures have special design considerations based on the expected deformations of the structural system.
- **Strength of structural components.** Since nonstructural components typically anchor to structural slabs, walls, and framing, it is important that the capacity of these components be checked for adequacy when tall and heavy items are being anchored to them.
- **Location.** Design forces are typically higher for items located in mid- and high-rise buildings and on roofs. The location of the item in the building may influence the design.
- **Primary vs. secondary effects of failure.** If failure of an item may result in the release of water or hazardous materials such as toxins, chemicals, or asbestos, it may warrant additional attention to address these damaging secondary effects.
- **System performance.** Fire protection systems, emergency power generation systems, and computer and communication networks are systems that depend on the functionality of multiple components; the failure of any part might compromise the functionality of the system. All related components must be checked if the system is required for functionality.
- **Emergency egress.** Items located over exits, in stairways, and along exit corridors may warrant special attention in order to ensure the safe exit of building occupants.

4.3 Project planning and implementation strategies

There are a number of options to consider in implementing a program to reduce the vulnerability of nonstructural components. As described above, one of the critical first steps is to define the project objectives with a clear understanding of what these basic, enhanced, or limited objectives will mean in terms of the expected performance of the facility and amount of structural and nonstructural damage that is expected to occur for a given level of shaking.

It is important to understand at the outset the level of commitment that is required from the organization in order to achieve the desired objectives. In order to achieve the *Hazards Reduced* nonstructural performance level, the bracing or anchoring of several obvious nonstructural falling hazards at a small commercial location may be accomplished by a skilled laborer over several weekends without any employee involvement. On the other hand, achieving the enhanced objectives which would allow for *Immediate Occupancy* or *Operational* performance levels requires a major commitment from the top down in an organization. Achieving a level of readiness that will allow a facility to remain fully operational will likely require both structural and nonstructural upgrades and a commitment of capital, both initial and ongoing; time for employee training; downtime for implementation; incorporation with purchasing, operations, maintenance, facilities, and clear assignment of responsibilities for implementation and ongoing program maintenance.

Additional References for Architects and Engineers

FEMA has published a series of guides addressing the incremental seismic rehabilitation of various types of facilities, including the related nonstructural components, as follows:

FEMA 395	Schools (FEMA, 2003)
FEMA 396	Hospitals (FEMA, 2003)
FEMA 397	Offices (FEMA, 2003)
FEMA 398	Multifamily Apartment Buildings (FEMA, 2004)
FEMA 399	Retail Buildings (FEMA, 2004)
FEMA 400	Hotel and Motel Buildings (FEMA, 2004)

It is also important that someone at the planning stage takes a broad view of what is proposed. A facility survey will identify the items and areas of the facility that will be affected. As the objective is to improve seismic safety, it is important to also take note of existing seismic protections and see that these components are not compromised. It may be necessary to evaluate the strength of existing partition walls and floor or roof framing to see that these components have sufficient capacity to support the nonstructural items to be anchored. In some cases, structural components may need strengthening in order to support the loads from the nonstructural components.

Once the project objectives are defined, there are a range of different strategies that can be used for implementation. Installation of protective measures can be done immediately, in phases, as part of routine maintenance or scheduled remodeling. A comparison of preliminary cost estimates and schedules for several different implementation strategies consistent with the project objectives may help in deciding which implementation strategy will work best.

4.3.1 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 to properly mitigate nonstructural hazards that they may discover as they survey the building for other purposes or to mitigate 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.

Once nonstructural bracing and anchorage are installed, maintenance personnel should be trained to inspect and monitor the installations and be responsible for the upkeep of the protective measures where appropriate. For facilities with specialized equipment, this maintenance function must be performed by someone familiar with the equipment to ensure that the protective measures are installed and maintained without compromising the equipment functionality.

4.3.2 Integration with 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, piping, and other built-in features. 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. Newly installed components will need to comply with current code requirements. Depending on the scope, the remodel may also trigger requirements to bring some existing components of the facility into compliance with current code; check the requirements for additions and alterations with the local jurisdiction.

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. It is important not to compromise existing seismic protections; it is also important not to overload partition walls, floor or roof framing, or an existing ceiling grid by using them to brace or anchor items that are too heavy. In some instances, the remodeling scope may need to be extended to include ceilings, partitions, or structural components so that the strength of these components can be upgraded to support additional loading.

4.3.3 Phased or 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, such as during planned renovations.

4.3.4 Integration with 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, and server racks should come with seismic detailing. Increasingly, vendors are marketing items with "seismic-resistant" details such as predrilled holes for anchorage. There are also many vendors that supply hardware and kits for seismic anchorage of equipment and furniture; these items should be stockpiled or ordered routinely along with each new equipment purchase. The effective use of these guidelines requires coordination between the purchasing and facilities or operations functions.

Integration with purchasing may be used in conjunction with any of the other strategies. If used alone, it will improve the safety of newly purchased items, but will not enhance the safety of existing items or address architectural items such as parapets, partitions, or ceilings. Over time, the safety of the facility will gradually improve as new items are purchased and existing items are replaced.

4.4 Responsibility and Program Management

4.4.1 Responsibility

Successful implementation of a nonstructural risk reduction program may involve many steps, including integration of the risk reduction program with the overall mission or business plan and balancing the seismic risks with other risks that businesses and organizations face. Program tasks may include planning, budgeting, scheduling, allocation of in-house resources and personnel, selection of outside consultants and contractors, contract negotiation and administration, coordination of numerous trades, managing outages or disruption, facility surveys, installation, inspection, oversight, purchasing, evaluation, and ongoing maintenance of the seismic protection measures. Assigning clear responsibility for each task is important to the success of any risk reduction program. Figure 4.4.1-1 shows an example of a responsibility matrix that could be readily adapted by listing the nonstructural components for a particular project. This example format can be used to track who is responsible for design, design review, installation, and observation. If special inspection is required, this could also be added to the table. Appendix B contains templates for use in assigning responsibility for design, construction and inspection of nonstructural installations governed by ASCE/SEI 7-10. The responsibility matrices are intended to be used in conjunction with the construction specification in Appendix A.

One of the initial tasks is to assess the capabilities of in-house resources and the need for outside consultants. The answer depends on the nature of the physical conditions in the facility and the characteristics of the organization.

- In-house implementation can be adequate where the potential hazard is small or the in-house familiarity with engineering and construction is greater than average.
- Specialized consultants with experience in the evaluation and reduction of nonstructural risks may be required for essential facilities or larger and more complex facilities where the potential hazards or potential losses are high.
- Facilities with moderate risk may fall in between these two examples and use a combination of expert advice and in-house implementation. For example, after an initial survey is conducted and a report is prepared by an expert, the remainder of the implementation might be handled in-house without further assistance.

Job Aid:
Nonstructural Component Seismic Resistance Responsibility Matrix
Who is Responsible for:

Type of Nonstructural Component or System	Design	Design Review	Installation	Observation
■ Access Floor (raised)				
■ Ceilings				
Suspended T-bar				
Gypsum Board (hung)				
■ Electrical Equipment				
Busduct / Cable Trays				
Power Generator				
Light fixtures				
Main Service Panel				
Transformers				
■ Elevator				
Cable guides				
■ Escalator				
■ Exterior Cladding:				
EIFS				
GFRC				
Metal Panels				
Precast Concrete				
■ Exterior Window Walls				
■ Fire Sprinkler System				
■ Fluid Tanks				
■ Mechanical Equipment				
Air Handlers				
Boilers				
Chillers				
Cooling Tower				
Condensers				
Ductwork / VAV box				
Fans				
Furnaces				
Piping Systems				
Pumps				
■ Interior Partitions				
■ Other Equipment				
■ Stairs				
■ Storage Racks				
■ Veneer				
Brick				
Stone				
■ Water Heater				

Figure 4.4.1-1 Example responsibility matrix.

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 is 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 is 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.

Consultants and design professionals could be used to assist with any or all of the tasks from program planning through implementation. Outside consultants that could facilitate planning, design, and implementation may include the following:

- Risk managers
- Earthquake engineers
- Structural engineers
- Civil engineers
- Architects
- Mechanical engineers
- Electrical engineers
- Interior designers
- Specialty contractors
- Special inspectors
- Vendors of specialty hardware and seismic protection devices

Many architects and engineers are qualified to design bracing or anchorage for simple nonstructural items. However, the design of anchorage and bracing for specialized equipment or for the systems needed to maintain operations in a hospital or manufacturing facility requires specialized experience with seismic design for nonstructural components. While there currently is not a recognized professional designation for someone with this type of experience, there may be one in the future. The job requires familiarity with MEP equipment and piping, architectural components, issues such as fire protection, and requirements of the Americans with Disabilities Act, computer networks, industrial storage racks, and all the other categories of nonstructural components and contents. When selecting outside consultants, check that they have experience with nonstructural seismic design, preferably specific experience with the type of equipment or facility in question.

4.4.2 Sustaining Protection

On an organizational level, sustaining protection generally requires a serious commitment from management and may include development of seismic planning guidelines for the organization, development of purchasing guidelines, ongoing personnel training, periodic facility audits, and incorporation into annual staff reviews. It is sometimes more problematic to maintain the human aspects than hardware aspects of nonstructural protection. Over time, interior fastenings and restraints may be removed as people move equipment or other items and fail to reinstall the protective devices. Chains used to restrain gas cylinders or elastic shock cords on bookshelves are effective only when they are in use. This is also true of tethers on office copiers, countertop lab equipment, or vending machines. Some nonstructural protection devices, such as anchorage hardware for exterior objects, may deteriorate with time if not protected from rust. New items may be purchased and installed without seismic protection in the absence of purchasing guidelines. 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, lab and office equipment, and chemicals are properly stored. Maintenance personnel may periodically survey the building to find out whether or not earthquake protection measures are still effectively protecting mechanical equipment such as emergency generators, water heaters, and specialized equipment. Additionally, supervisors can be made responsible for an annual review of their work spaces. If there is a separate facility or physical plant office in an organization, it 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 risk reduction 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 campus wide 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 (Huttenbach, 1980; Steinmetz, 1979).

4.4.3 Program Evaluation

To assess whether the nonstructural risk reduction program was worth the cost, the strong points and deficiencies of the program need to be established. There are two program evaluation 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 plan all been implemented?
- How well have the measures been implemented?
- Have the upgrade details been correctly installed?
- Is the training taken seriously?
- Do we need to modify (either enhance or reduce) our objectives going forward?

The second evaluation technique is to ask:

- If the earthquake happened today, how much would the losses be reduced by due to the nonstructural protection program?
- Have the costs been worth the benefits?

4.5 Cost benchmarks – Examples

4.5.1 Example 1 – Manufacturing Facility

The nonstructural components throughout a 500,000 square foot manufacturing facility located in the heart of the New Madrid Seismic Zone were upgraded for improved seismic performance. The facility was originally built in the late 1970's with several periodic expansions constructed into the early 1990's. The project included anchorage and bracing of existing nonstructural components in both manufacturing and office space.

Following a structural evaluation confirming life safety structural performance, a facility-wide nonstructural earthquake risk assessment was conducted and concluded that many of the nonstructural components failed to satisfy the life safety performance objective defined in ASCE/SEI 41-06. A subsequent engineering design phase was performed to design bracing and anchorage for nonstructural components not meeting the performance objective. The strengthening measures included bracing for all natural gas piping and equipment, fire protection piping systems, and emergency power systems as well as items whose damage could pose a threat to the life safety or the egress of building occupants. This included restraints for overhead office lights, bracing of tall unreinforced masonry walls and equipment suspended overhead, and anchorage of floor mounted equipment whose overturning or sliding could block the emergency exit routes for the facility.

The design began in 2006 with an 8 month construction schedule completed in mid-2008. The facility was fully operational throughout construction. Regular communication between the owner, design team, and contractor were cited as key to the project success. Scheduling requirements such as night shifts and work sequencing were incorporated into the design documents and the construction schedule to give the entire construction team a clear understanding of the challenges of working in a 24/7 manufacturing facility.

The approximate cost breakdown for the project in 2007 dollars is summarized in Table 4.5.1-1.

Table 4.5.1-1 Approximate Cost Breakdown for Manufacturing Facility Upgrade Project

	Project Cost
Consultant Fees (Design & Construction)	$200,000
Construction Costs	$700,000
Inspection and Testing	$25,000
Total	$925,000
Average Cost	$2/square foot

4.5.2 Example 2 – School District

A pilot project was undertaken to determine the magnitude of costs associated with implementation of nonstructural damage mitigation measures in a California school district. The pilot project addressed contents and equipment, overhead components and hazardous materials. Nonstructural hazards were surveyed and prioritized in three groups. The highest priority category included those items judged to pose the greatest safety risk. Among the components included were tall bookshelves and filing cabinets, suspended lighting, heavy ceiling systems, and hazardous materials. Roughly half of the items at risk were judged to be in the highest priority category.

A total of seventeen schools were included in the pilot program. The current cost to address the highest priority items ranged from roughly $20,000 per school (primarily to address tall cabinets and files) to $400,000 per school in 2008 dollars (requiring work on suspended components as well as floor- and wall-mounted items).

4.5.3 Example 3 – California Hospital

Seismic upgrading of nonstructural components was undertaken as a stand-alone project in response to SB 1953 regulations, which require California Hospitals to comply with specified nonstructural hazard reduction milestones by December 31, 2008 (see discussion in Section 4.1.1).

The subject hospital is a 228-bed acute care hospital of roughly 230,000 gross square feet, built in the 1970s. The project included anchoring and bracing nonstructural components in designated areas throughout the hospital including central and sterile supply, clinical laboratory service spaces, pharmacy, radiology, intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, delivery rooms, emergency rooms, operating rooms, and recovery rooms. Also included in the scope was the anchorage and bracing of mechanical and electrical equipment serving the designated areas.

Floor-mounted equipment, wall-mounted items weighing over 20 pounds, suspended equipment, piping, and ceilings were included among the items addressed in the project. Seismic anchorage was designed for compliance with 2001 California Building Code requirements.

The primary project challenge was to maintain uninterrupted hospital services 24/7 while accomplishing the mandated work. This required planning efforts by hospital administrators, doctors, nurses, the design team consisting of architects, structural, mechanical, and electrical engineers, contractors and subcontractors. Planning commenced in mid-2003; construction was completed at the end of 2007. The work was successfully completed by working in small areas at a time, often at nights for short durations. In order to complete the work in the intensive care unit, an available wing of the hospital was completely remodeled as “swing space” to enable patients to be relocated from the intensive care unit to the remodeled wing, thereby providing the contractor unrestricted access to complete nonstructural upgrading in the intensive care unit. Work throughout the hospital was complicated by the presence of asbestos in the fireproofing at the underside of the floors. Hazardous material abatement preceded all work.

The cost breakdown for the project in 2007 dollars is summarized in Table 4.5.3-1.

Table 4.5.3-1 Cost Breakdown for California Hospital Upgrade Project

	Base Project	Swing Space	Total
Consultant fees	$2,600,000	$795,000	$3,395,000
Construction	$8,844,000	$5,190,000	$14,034,000
HAZMAT abatement	$986,000	$140,000	$1,126,000
User equipment	$0	$760,000	$760,000
Permits, inspection, testing	$2,014,000	$810,000	$2,824,000
Total	**$14,444,000**	**$7,695,000**	**$22,139,000**

Most of the project cost was attributable to the logistics of making improvements while maintaining uninterrupted hospital operations. The total construction cost of roughly $100 per square foot demonstrates that the most cost effective nonstructural mitigation is undertaken when space is unoccupied such as during planned renovations.