3. SURVEY AND ASSESSMENT PROCEDURES FOR EXISTING BUILDINGS

The first step toward reducing the nonstructural hazards in an existing building is to perform a survey to assess the extent and magnitude of the potential risks. This chapter includes survey guidelines for nonstructural components and describes the inventory form, the checklist, and the risk ratings that are included in the appendices. In order to make informed decisions regarding nonstructural seismic risks, owners and managers will need to address the following questions:

- What types of nonstructural components are present in a particular facility?
- Are these items adequately braced or anchored?
- How will a specific nonstructural item perform in an earthquake, and what are the consequences of failure of that item in terms of life safety, property loss, and functional loss?
- If the decision is made to upgrade a facility, which problems should be addressed first?

The focus of this guide is on reducing nonstructural seismic hazards, particularly in those areas where the seismic shaking intensity is expected to be moderate or high and where significant structural hazards do not exist or will be addressed independently. A simplified map of probable shaking intensities is presented in Figure 3.2.1-1. If the expected shaking for the facility in question is minimal, then the survey procedures and seismic protection measures described in this guide might be undertaken on a voluntary basis but may not be necessary, and in most cases they would not be required for new construction.

3.1 Survey of Nonstructural Components

The nonstructural components listed in the tables and checklists provided in the appendices are at least initially within the scope of the construction of a building and its building permit. After occupancy of the building, these are items that are most commonly found in commercial, multiple-unit residential, or public buildings. A complex facility such as a hospital, research laboratory, or industrial plant will contain many additional types of specialized equipment that are not explicitly addressed in this guide.

The goal of a facility survey is to identify nonstructural components that may be vulnerable to earthquake damage. As noted earlier, it may be advisable to seek the help of a professional with expertise in this area. During the survey, the following three basic questions should be kept in mind as each nonstructural item is considered:

- Could anyone get hurt by this item in an earthquake? (Life Safety)
- Could a large property loss result? (Property Loss)
- Would interruptions and outages be a serious problem? (Functional Loss)

For some components, the answers to these three questions may not be immediately obvious, since failure of an item may result in both direct damage and indirect damage. It is important not only to view each item as a discrete object that could tip or fall and hurt someone directly, but also to consider the consequences of failure. Several examples will serve to illustrate the point:

- If a fire sprinkler line breaks, this may cause minor damage to the sprinkler itself but result in major damage to architectural finishes and contents of the building. Even if the building does not sustain any other damage, the occupants may not be able to use the facility until the fire safety system is repaired. The potential for direct and indirect property losses in this case are much greater than the repair cost for the sprinkler system.
- The battery rack used to start an emergency generator is generally located in a locked mechanical room and is unlikely to hurt anyone, even if the rack and batteries fall on the floor. In this case, even though the direct life safety threat is probably low, if the fallen batteries cannot start the emergency generator, building occupants may be injured attempting to evacuate the building in the dark, or the lives of hospital patients on life-support systems may be jeopardized. Thus the indirect losses are larger than the direct losses.
- Gas-fired residential water heaters have rarely injured anyone as they fall, but they have frequently caused postearthquake fires due to ruptured gas lines.

A word of caution is in order regarding the field survey. While it may be relatively straightforward to assess whether or not an item is positively restrained to resist earthquake forces, the effectiveness of the restraint must also be judged. In the case of bookshelves in an office area, there may be hardware anchoring the shelving to the wall, but unless the hardware is secured to a solid wall or directly to a stud in a partition wall that is also braced, the anchorage may be ineffective in a strong earthquake. The illustrated examples in Chapter 6 show many photos of unanchored, poorly anchored, and well anchored nonstructural components and provide seismic mitigation details for many common situations. As shown in the flowchart in Chapter 1, the reader is advised to complete Chapters 4 and 5 (as applicable) and to review the illustrations and details in Chapter 6 before performing a facility survey and reviewing the questions in the checklist. If the checklist asks whether or not something is securely anchored, then the existing situation should be compared to the seismic mitigation details shown in Chapter 6 for that or a similar item. Also, the installation notes in Section 6.6 provide general guidance on recommended hardware and procedures.

3.1.1 Survey Forms

The field survey may be performed by using the forms and checklists in Appendices C, D, and E.

Appendix C, the Nonstructural Inventory Form, shown in Figure 3.1.1-1 contains a blank nonstructural inventory form that can be used to record field observations. At the start of the survey, this form should be filled in, in order to identify the facility. This inventory form provides a place to record field observations made while walking through the facility and reviewing the questions in the checklist in Appendix D. When an item in the checklist is noncompliant, it should be entered as a line item in the inventory form. The form also contains space to add risk ratings from Appendix E according to the facility's seismic shaking intensity; this could be done during the field survey or could be added to the form later. The space provided for notes may be used to identify the type of problem observed, such as "unanchored" or "bolts undersized."

During the initial survey, it may be helpful to create a list containing a large number of items which may be shortened later, perhaps by dropping low-priority items. At the initial stage, it is better to be conservative and to overestimate vulnerabilities than to be too optimistic. In this version, Appendix C is provided as a sample of the inventory form prepared by the U.S. Bureau of Reclamation. The electronic file containing the sorting algorithm can be downloaded from the Bureau's website at http://www.usbr.gov/ssle/seismicsafety/onlineorders.html.

Nonstructural Survey Methods for Engineers

The survey method provided here was developed for use by non-engineers. Nonstructural survey methods for use by engineers are available both in ASCE 31/SEI 31-03 Seismic Evaluation of Existing Buildings (ASCE, 2003) and in Chapter 11 of ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings (ASCE, 2006).

The evaluation methods described in these ASCE documents are more quantitative than those presented here and often require that engineering calculations be performed to determine the adequacy of the existing conditions.

PRIORITIZED INVENTORY

ID	Description	Location	Quantity	Units	LS	PL	LF	Detail Type	Notes
					"H", "M", or "L"			NE, PR, ER	
1	Bookcase in the south east corner	Room 13	2	each	H	M	M	NE	The two wooden bookcases are unanchored an could tip over during an earthquake blocking egress. Relocate the bookcases away from the doorway or anchor them to the supporting floor or adjacent wall.
6	Computer monitor	04-N3	1	each	H	H	L	NE	Equipment stored less than four feet above the floor, like this computer monitor, is not a significant life safety hazard. However consideration should be made to securing these types of equipment to the desk top or adjacent wall.
82	Bookcase	02-12	3	each	H	M	M	NE	Tall shelving or bookcases that have width to height ratios greater than four should be attached to the supporting floor or adjacent wall.
182	Unreinforced Masonry parapet	South Elevation	50	LF	H	H	L	ER	
13	File cabinets	04-W4	3	each	M	M	M	NE	These flat files are three individual units stacked on top of each other. Without lateral restraints, they can easily slide off each other.
16	Hot water heater	04-W7	1	each	M	H	L	PR	Gas hot water heaters should be anchored to the floor or adjacent wall to prevent tipping and damage to water and gas lines.
65	Vending machine	02-15	1	each	M	M	L	NE	
83	Suspended ceiling	02-12	150	SF	M	M	M	PR	The suspended ceiling tiles are supported vertically to the roof structure. There are no lateral tie wires to compensate for lateral loads due to seismicity.
85	Natural gas supply line	02 North Elevation	200	each	M	M	M	ER	Each gas line that enters the building should have an automatic shutoff valve to prevent escaping gas from feeding a potential fire.
138	Credenza	04-N4	1	each	M	M	L	NE	The credenza should be anchored to the desk top or adjacent wall to prevent a potential falling hazard.
63	Computer cabinet	02-14a	1	each	L	H	M	NE	Computer hub should be anchored to the floor or adjacent wall to limit potential damage.
86	Communication hub	04-W8	1	each	L	L	L	NE	The communication equipment should be stored inside of protective cabinets to prevent potential damage from falling debris.
178	Desktop computer with monitor	04-E110	2	each	L	M	L	NE	Computers could be placed on the floor to limit potential damage to stored data or the computer's electrical components. The monitor should also be anchored to the desk.

Rank by LS
Rank by PL
Rank by LF
Rank by Highest Rank

Figure 3.1.1-1 Sample nonstructural inventory form (from Appendix C).

Appendix D, Checklist of Nonstructural Earthquake Hazards, shown in Figure 3.1.1-2 is a checklist with questions designed to help identify vulnerable nonstructural items and potential hazards associated with each item. The checklist should be carried during the field survey to help identify vulnerable items. The questions on the checklist are all stated in such a way that a "Noncompliantce (NC)" answer is indicative of a potential problem. Each nonstructural component with a potential problem should be listed as a line item on the nonstructural inventory form of Appendix C showing the location and quantity of the item with any relevant comments. If an example is available for this item in Chapter 6, it may be helpful to note the detail type and example number for future reference.

6.3	Architectural Components						
Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.3.1	**Exterior Wall Components**						*[Exterior falling hazards are a primary concern, especially items situated above 10 feet and items that may fall over exits, walkways, or sidewalks.]*
	Adhered veneer	Falling hazard	6.3.1.1				Is the adhered veneer adequately attached to the structure? [This includes relatively thin sections of tile, masonry, stone, terra cotta, ceramic tile, glass mosaic units, stucco, or similar materials attached to a structural wall or framework by means of an adhesive].
							Based on visual observations and/or tapping, is the veneer free of cracked or loose sections that may fall during an earthquake?
	Anchored veneer	Falling hazard	6.3.1.2				Is the anchored veneer adequately attached to the structure? [This includes thicker masonry, stone, or stone slab units that are attached to the structure by mechanical anchors].
							Is the masonry or other veneer supported by shelf angles or other elements at each floor?
							Is the masonry or other veneer connected to a structural back-up wall at adequate spacing?
							Has the veneer been adequately maintained? Are the anchors in good condition, free of significant corrosion, and inspected regularly?

Figure 3.1.1-2 Sample checklist questions from Appendix D.

Appendix E, Nonstructural Seismic Risk Ratings, summarizes estimated seismic risk ratings stated as Low, Medium, and High for many common components based on their exposure to Low, Moderate or High levels of shaking intensity map in Figure 3.2.1-1. The risk ratings are based on the risk to Life Safety, Property Loss and Functional Loss for unanchored or unbraced items located at or near the base of a low-rise building of ordinary occupancy. The risk ratings are further explained in Section 3.2.2 and in the introduction to Appendix E. A sample of the risk ratings in Appendix E is shown below.

6.3	Architectural Components					
Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
6.3.1	**Exterior Wall Components[1]**					
6.3.1.1	Adhered veneer	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.3.1.2	Anchored veneer	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.3.1.3	Prefabricated panels	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	M	

Figure 3.1.1-3 Sample risk ratings from Appendix E.

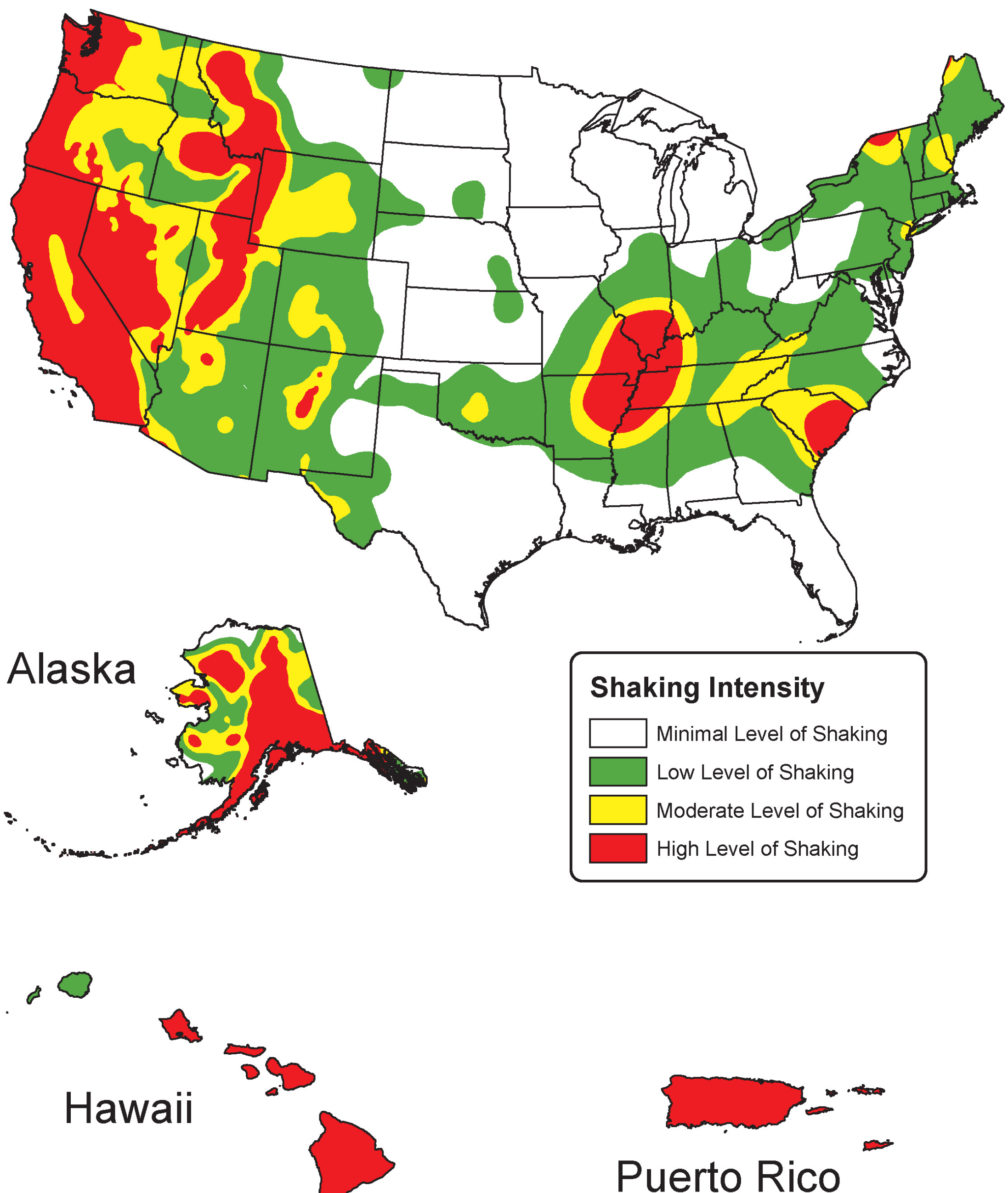
3.2 Estimating Seismic Risk

There are two aspects of the estimated seismic risk for a given item:

- What is the seismic shaking intensity that can be expected at the site?
- For a given level of shaking, what is the seismic risk rating of a given nonstructural item in terms of life safety, property loss, and functional loss?

3.2.1 Estimating Seismic Shaking Intensity

Estimating site specific seismic hazards can be a difficult technical problem, requiring many factors to be taken into account. For the purposes of this nonstructural survey, the shaking intensity is based solely on regional seismicity. For a particular geographic location in the United States, the shaking intensity may be estimated by using the map in Figure 3.2.1-1 that shows the areas that are likely to experience minimal, low, moderate, or high levels of ground shaking during future probable maximum considered earthquake events. The ground shaking has been estimated for a stiff soil site. The information in Figure 3.2.1-1 may be summarized as follows:



The above figure was prepared by Ken Rukstales of the USGS and is based on the Figure R301.2(2) that was developed by the USGS for the 2006 International Residental Code where the Minimial Level = SDC A, Low Level = SDC B, Moderate Level = SDC C and the High Level = SDC D. Figure R301.2(2) was based on the MCE Design Value Maps prepared by the USGS for the 2003 NEHRP Recommended Provisions and presumes that the site soil classifiction is Site Class D and structure has Normal Occupancy (II).

Figure 3.2.1-1 Map of probable shaking intensity in the United States.

- High level of shaking: Most of California and Nevada; significant portions of Alaska, Washington, Oregon, Montana, Wyoming, Idaho, and Utah; the areas near New Madrid, Missouri and Charleston, South Carolina; small pocket areas in Arizona, New Mexico, upper New York, and upper Maine; the islands of Hawaii, Puerto Rico, and Guam (not shown).

- Moderate level of shaking: Areas adjacent to the areas of high shaking plus pocket areas in New England, New Mexico, Arizona, West Texas, Colorado, and Oklahoma.

- Low level of shaking: A portion of the western States, a significant portion of the central region of the continental United States east of the Rockies and most of New England.

- Minimal level of shaking: Remaining portions of mid-western, southern continental United States.

Shaking intensity estimates based on the probable shaking intensity map in Figure 3.2.1-1 should be adequate for evaluating components situated at or near the ground in simple, nonessential facilities. For other situations, it may be advisable to choose the next higher shaking intensity or to seek the advice of professional consultants. Note that in areas with minimal shaking, upgrade of nonstructural components generally would not be warranted unless an owner is particularly risk averse or special circumstances exist; the current code would not require many of the protective measures recommended herein, even for new construction.

Engineering Design Forces

Estimating the earthquake forces acting on a particular item in a particular building can be a difficult technical problem. In order to perform engineering calculations, an engineer may have to consider the following factors:

- the proximity of the building site to an active fault
- soil conditions at the site (other than stiff soil)
- the flexibility of the building structure
- the location of the item in the building
- the flexibility of the floor framing or walls in the immediate vicinity of the item
- the flexibility and strength of the item and its attachments
- the weight and configuration of the item
- the characteristics of any connection details between the item and the structure
- the expected relative displacement between two connection points in adjacent stories or across a seismic gap
- the function of the item
- the function of the facility

Refer to the current International Building Code (IBC) and ASCE/SEI 7 for seismic design requirements for nonstructural components and ASCE/SEI 41 for existing construction.

One reason why the use of professional consultants is recommended for complex facilities is that the generalized shaking intensity map does not take many engineering factors into consideration (see sidebar). Clearly, the complexity and detail of engineering calculations should commensurate with the complexity and importance of the facility and the item in question. It should be noted that current design codes and standards such as the *International Building Code*, ASCE/SEI 7 *Minimum Design Loads for Buildings and Other Structures*, and ASCE/SEI 41 *Seismic Rehabilitation of Existing Buildings*, reference detailed digitized seismic maps of the United States prepared by the U.S. Geological Survey (USGS). These maps consider locations and seismic activity of all known seismic sources and faults which may affect a given site, and the standards provide procedures for adjusting the mapped ground motions for site soil conditions. For designs requiring compliance with building code or national standard requirements, the maps referenced by the code or standard in effect at the time must be used to establish minimum criteria.

In addition, it may be appropriate to consider more than one earthquake scenario for a particular facility, since earthquakes of different magnitudes may occur at different average time intervals. For some facilities, it may be useful to evaluate more probable frequent events, such as those that are likely to occur every 100 years. While new construction projects have to anticipate the most severe shaking, others who are doing voluntary retrofits may find it more economical to plan for a smaller, more frequent event.

3.2.2 Estimating Seismic Risk Ratings

The risk ratings provided in Appendix E are based on a review of damage to nonstructural components in past earthquakes and on the judgment of the authors and their advisory panel. Estimates of future earthquake damage to either the structural or nonstructural components of a building are only that—estimates—and should be used with discretion. The approximations provided in this guide are adequate for the purpose of making an initial determination of the seismic risk of the nonstructural components of a simple facility. For a facility that is more complex, or for one where the potential risk is high, more detailed analyses should be performed by an in-house engineer or a professional consultant. In this document, the seismic risks for life safety, property loss, and functional loss have been rated simply as high, medium, or low for different levels of shaking intensity. Note that these ratings refer to primary losses caused by damage to the item in question; potential consequences or secondary losses are not considered. Appendix E contains more detailed notes concerning the definitions and assumptions used in assigning risk ratings. Stated briefly:

- Life Safety risk is the risk of direct injury by the item.
- Property Loss risk is the risk of incurring a cost to repair or replace the item as a result of damage incurred.
- Functional Loss risk is the risk that the item will not function as a result of the damage incurred.

The estimated risk ratings shown in Appendix E assume that the item is unbraced and unanchored and are intended for buildings with ordinary occupancies, not for essential facilities. The primary purpose of this information is to assist in assigning priority ratings, described below, and to help in identifying the most critical hazards.

3.2.3 Assigning Priority Ratings

Prioritization may be based on budget constraints, risk considerations (i.e., those elements that pose the greatest risks to safety, property or function are retrofitted first), availability of unoccupied space, or to achieve the highest cost to benefit ratio.

A simplified priority rating system might be used to indicate which items are more vulnerable to earthquake damage and to indicate those items whose failure is most likely to have serious consequences. All components could be assigned a high, medium, or low priority, or each item or type of item could be ranked in order from highest to lowest. The highest priority might be assigned to those components for which all three risk ratings are high. If loss of function is not a serious concern, then the highest priority might be assigned to items for which the life safety risk is high and the upgrade cost is lowest, since these hazards could be reduced most cost-effectively. The assignment of priorities may vary widely for different types of facilities, and this document merely provides some guidelines that can be used to establish a ranking system. In assigning the rating priorities, the requirements for new construction should be considered. If it is not required for new construction, then it does not make much sense to do a seismic retrofit of that item in an existing facility.

3.2.4 Application of Nonstructural Guidelines

When estimating seismic risk and assigning priority ratings, it should be noted that current building codes and seismic design standards for new construction do not require seismic design of anchorage and bracing for nonstructural components in every part of the United States.

- In areas denoted as experiencing minimal levels of seismic shaking intensity in Figure 3.2.1-1, no seismic anchorage or bracing of nonstructural components is required.
- For most buildings in areas denoted as experiencing low levels of seismic shaking intensity, only parapets are required to be braced. For essential facilities, all architectural components are required to be anchored and braced.
- In areas denoted as experiencing moderate levels of seismic shaking, all architectural components are required to anchored and braced. However, in most buildings, electrical and mechanical components and systems do not require anchorage and bracing. For essential facilities, mechanical and electrical components are required to be braced.
- In general, in areas denoted as experiencing high levels of seismic shaking intensity, all architectural, mechanical, and electrical components are required to be anchored and braced in all buildings.

In addition, current seismic codes and standards also exempt mechanical and electrical components from bracing or anchoring, regardless of seismic area, in nonessential facilities, if they weigh less than 400 pounds and are mounted at a height 4 feet or less above the floor or, if elevated, weigh less than 20 pounds. Distributed systems in nonessential facilities, such as piping or HVAC ducting, are also exempt from bracing or anchoring if they weigh less than 5 pounds per lineal foot and are provided with flexible connections.

Current seismic codes and standards do not provide much guidance on when seismic anchorage and bracing are required for contents except for cabinets and computer access floors which are treated as architectural components. The reason why they are typically not treated in standards for new construction is that furniture, fixture, equipment and contents are usually installed after the building has been approved for occupancy by the building official; thus, the building official no longer has any control over the installation after occupancy approval has been given.