11. Architectural, Mechanical, and Electrical Components

11.1 Scope

This chapter sets forth requirements for the seismic rehabilitation of existing architectural, mechanical, and electrical components and systems that are permanently installed in, or are an integral part of, a building system. Procedures of this chapter are applicable to both the Simplified and Systematic Rehabilitation Methods. Requirements are provided for nonstructural components that are rehabilitated to the Immediate Occupancy, Life Safety, and Hazards Reduced Nonstructural Performance Levels. The requirements for Operational Performance shall be as approved by the authority having jurisdiction.

Sections 11.2, 11.3, 11.4, and 11.5 provide requirements for condition assessment, component evaluation, Rehabilitation Objectives, and structural-nonstructural interaction. Section 11.6 defines acceleration and deformation sensitive components. Section 11.7 specifies procedures for determining design forces and deformations on nonstructural components. Section 11.8 identifies rehabilitation methods. Sections 11.9, 11.10, and 11.11 specify evaluation and acceptance criteria for architectural components; mechanical, electrical, and plumbing (MEP) systems; and other equipment.

New nonstructural components installed in existing buildings shall conform to the requirements of this standard. New nonstructural components designed to Life Safety or Hazards Reduced Performance Levels may be designed using the requirements of similar components for new buildings.

C11.1 Scope

The assessment process necessary to make a final determination of which nonstructural components are to be rehabilitated is not part of this standard, but the subject is discussed briefly in Section 11.3.

The core of this chapter is contained in Table 11-1, which provides:

1. A list of nonstructural components subject to the Hazards Reduced, Life Safety and Immediate Occupancy requirements of this standard.

2. Rehabilitation requirements related to the level of seismicity and Hazards Reduced, Life Safety, and Immediate Occupancy Performance Levels. Requirements for Operational Performance are not included in this standard. References that may be used to seismically qualify equipment and systems to achieve Operational Performance for some nonstructural components are provided in C1.5.2.1. Requirements for Hazards Reduced Performance will generally be based on the requirements for Life Safety Performance, so separate evaluation procedures and acceptance criteria have not been provided.

3. Identification of the required evaluation procedure (analytical or prescriptive).

Section 11.4 provides general requirements and discussion of Rehabilitation Objectives, Performance Levels, and Performance Ranges as they pertain to nonstructural components. Criteria for means of egress are not specifically included in this standard.

Section 11.5 briefly discusses structural-nonstructural interaction, and Section 11.6 provides general requirements for acceptance criteria for acceleration-sensitive and deformation-sensitive components, and those sensitive to both kinds of response.

Section 11.7 provides sets of equations for a simple "default" force analysis, as well as an extended analysis method that considers a number of additional factors. This section defines the Analytical Procedure for determining drift ratios and relative displacement, and outlines general requirements for the Prescriptive Procedure.

Section 11.8 notes the general ways in which nonstructural rehabilitation is carried out.

Sections 11.9, 11.10, and 11.11 provide the rehabilitation criteria for each component category identified in Table 11-1. For each component the following information is given.

1. Definition and scope.

2. Component behavior and rehabilitation concepts.

3. Acceptance criteria.

4. Evaluation requirements.

11.2 Procedure

Nonstructural components shall be rehabilitated by completing the following steps.

1. The rehabilitation objectives shall be established in accordance with Section 11.4, which includes selection of a Nonstructural Performance Level and earthquake hazard level. The level of seismicity shall be determined in accordance with Section 1.6.3. A target Building Performance Level that includes Nonstructural Performance Not Considered need not comply with the provisions of this chapter.

2. A walk-through and condition assessment shall be performed in accordance with Sections 11.2.1 and 11.2.2.

3. Analysis and rehabilitation requirements for the selected Nonstructural Performance Level and appropriate level of seismicity shall be determined for nonstructural components using Table 11-1. "Yes" indicates that rehabilitation shall be required if the component does not meet applicable acceptance criteria specified in Section 11.3.2.

4. Interaction between structural and nonstructural components shall be considered in accordance with Section 11.5.

5. The classification of each type of nonstructural component shall be determined in accordance with Section 11.6.

6. Evaluation shall be conducted in accordance with Section 11.7 using the procedure specified in Table 11-1. The acceptability of bracing components and connections between nonstructural components and the structure shall be determined in accordance with Section 11.3.2.

7. Nonstructural components not meeting the requirements of the selected Nonstructural Performance Level shall be rehabilitated in accordance with Section 11.8.

C11.2 Procedure

Where Hazards Reduced Performance is used, the engineer should consider the location of nonstructural components relative to areas of public occupancy. The authority having jurisdiction should be consulted to establish the areas of the building for which nonstructural hazards will be considered. Other nonstructural components, such as those designated by the owner also should be included in those that are evaluated.

11.2.1 Condition Assessment

A condition assessment of nonstructural components shall be performed as part of the nonstructural rehabilitation process. As a minimum, this assessment shall determine the following:

1. The presence and configuration of each type of nonstructural component and its attachment to the structure.

2. The physical condition of each type of nonstructural component and whether or not degradation is present.

3. The presence of nonstructural components that potentially influence overall building performance.

4. The presence of other nonstructural components whose failure could affect the performance of the nonstructural component being considered.

C11.2.1 Condition Assessment

For the purpose of visual observation, nonstructural component types should be based on the general types listed in Table 11-1. Further distinction can be made where difference in structural configuration of the component or its bracing exists.

Seismic interactions between nonstructural components and systems can have a profound influence on the performance of these systems. Where appropriate, the condition assessment should include an interaction review. A seismic interaction involves two components, a source and a target. An interaction source is the component or structure that could fail or displace and interact with another component. An interaction target is component that is being impacted, sprayed or spuriously activated. For an interaction to affect a component, it must be credible and significant. A credible interaction is one that can take place. For example, the fall of a ceiling panel located overhead from a motor control center is a credible interaction because the falling panel can reach and impact the motor control center. The target (the MCC) is said to be within the zone of influence of the source (the ceiling panel). A significant interaction is one that can result in damage to the target. For example, the fall of a light fixture on a 20” steel pipe may be credible (the light fixture being above the pipe) but may not be significant (the light fixture will not damage the steel pipe). An important aspect of the interaction review is engineering judgment, because only credible and significant sources of interaction should be considered in the condition assessment.

11.2.2 Sample Size

Direct visual inspection shall be performed on each type of nonstructural component in the building as follows:

1. If detailed drawings are available, at least one sample of each type of nonstructural component shall be observed. If no deviations from the drawings exist, the sample shall be considered representative of installed conditions. If deviations are observed, then at least 10% of all occurrences of the component shall be observed.

2. If detailed drawings are not available, at least three samples of each type of nonstructural component shall be observed. If no deviations among the three components are observed, the sample shall be considered representative of installed conditions. If deviations are observed, at least 20% of all occurrences of the component shall be observed.

Table 11-1 ***Nonstructural Components: Applicability of Hazards Reduced, Life Safety and Immediate Occupancy Requirements and Methods of Analysis***

	COMPONENT TYPE	Performance Level: IO	High & Moderate Seismicity: LS	High & Moderate Seismicity: HR	Low Seismicity: LS	Low Seismicity: HR	Evaluation Procedure
ARCHITECTURAL (Section 11.9)							
1.	**Exterior Wall Components**						
	Adhered Veneer	Yes	Yes	Yes[15]	No	No	F/D
	Anchored Veneer	Yes	Yes	Yes[15]	No	No	F/D
	Glass Blocks	Yes	Yes	Yes[15]	No	No	F/D
	Prefabricated Panels	Yes	Yes	Yes[15]	Yes	Yes[15]	F/D
	Glazed Exterior Wall Systems	Yes	Yes	Yes[15]	Yes	Yes[15]	F/D/PR
2.	**Partitions**						
	Heavy	Yes	Yes	Yes[15]	No	No	F/D
	Light	Yes	No	No	No	No	F/D

	Glazed	Yes	Yes	Yes[15]	Yes	Yes[15]	F/D/PR
3.	**Interior Veneers**						
	Stone, Including Marble	Yes	Yes[18]	Yes[15]	No	No	F/D
4.	**Ceilings**						
	Directly Applied to Structure	Yes	No[13]	No[15]	No	No	F
	Dropped Furred Gypsum Board	Yes	No	No	No	No	F
	Suspended Lath and Plaster	Yes	Yes	Yes[15]	No	No	F
	Suspended Integrated Ceiling	Yes	No[11]	No	No[11]	No	PR
5.	**Parapets and Appendages**	Yes	Yes	Yes[15]	Yes	Yes	F[1]
6.	**Canopies and Marquees**	Yes	Yes	Yes[15]	Yes	Yes	F
7.	**Chimneys and Stacks**	Yes	Yes	Yes[15]	No	No	F[2]
8.	**Stairs**	Yes	Yes	No	Yes	No	*
9	**Doors Required for Emergency Services Egress**	Yes	Yes	No	No	No	F/D
MECHANICAL EQUIPMENT (Section 11.10)							
1.	**Mechanical Equipment**						
	Boilers, Furnaces, Pumps, and Chillers	Yes	Yes	No	Yes	No	F
	General Mfg. and Process Machinery	Yes	No[3]	No	No	No	F
	HVAC Equipment, Vibration-Isolated	Yes	No[3]	No	No	No	F
	HVAC Equipment, Non-Vibration-Isolated	Yes	No[3]	No	No	No	F
	HVAC Equipment, Mounted In-Line with Ductwork	Yes	No[3]	No	No	No	PR
2.	**Storage Vessels and Water Heaters**						
	Structurally Supported Vessels (Category 1)	Yes	No[3]	No	No	No	Note[4]
	Flat Bottom Vessels (Category 2)	Yes	No[3]	No	No	No	Note[5]
3.	**Pressure Piping**	Yes	Yes	No	No	No	Note[5]
4.	**Fire Suppression Piping**	Yes	Yes	No	No	No	PR
5.	**Fluid Piping, not Fire Suppression**						
	Hazardous Materials	Yes	Yes	Yes[12]	Yes	Yes[12]	PR/F/D
	Nonhazardous Materials	Yes[14]	No	No	No	No	PR/F/D
6.	**Ductwork**	Yes	No[6]	No	No	No	PR
ELECTRICAL AND COMMUNICATIONS (Section 11.10)							
1.	**Electrical and Communications Equipment**	Yes	No[7]	No	No	No	F
2.	**Electrical and Communications Distribution Equipment**	Yes	No[8]	No	No	No	PR
3.	**Light Fixtures**						
	Recessed	No	No	No	No	No	PR[17]
	Surface Mounted	No	No	No	No	No	PR[17]
	Integrated Ceiling	Yes	Yes	Yes[15]	No	No	PR
	Pendant	Yes	No[9]	No	No	No	F/PR
FURNISHINGS AND INTERIOR EQUIPMENT (Section 11.11)							
1.	**Storage Racks**	Yes	Yes[10]	Yes[16]	No	No	F
2.	**Bookcases**	Yes	Yes	No	No	No	F
3.	**Computer Access Floors**	Yes	No	No	No	No	PR/FD
4.	**Hazardous Materials Storage**	Yes	Yes	No[12]	No[12]	No[12]	PR
5.	**Computer and Communication Racks**	Yes	No	No	No	No	PR/F/D
6.	**Elevators**	Yes	Yes	No	No	No	F/D/PR
7.	**Conveyors**	Yes	No	No	No	No	F/D/PR

1. Rehabilitation of unreinforced masonry parapets not over 4 ft. in height by the Prescriptive Design Concept shall be permitted.
2. Rehabilitation of residential masonry chimneys by the Prescriptive Design Concept shall be permitted.
3. Equipment type 1 or 2 that is 6 ft. or more in height, equipment type 3, equipment forming part of an emergency power system, and gas-fired equipment in occupied or unoccupied space shall be rehabilitated to the Life Safety Nonstructural Performance Level in areas of High Seismicity. In areas of Moderate Seismicity, this equipment need not be considered. Refer to Section 11.10.1.1 for equipment type designations.
4. Rehabilitation of residential water heaters with capacity less than 100 gal. by the Prescriptive Procedure shall be permitted. Other vessels shall meet the force provisions of Sections 11.7.3 or 11.7.4.
5. Rehabilitation of vessels or piping systems according to Prescriptive Standards shall be permitted. Storage vessels shall meet the force provisions of Sections 11.7.3 or 11.7.4. Piping shall meet drift provisions of Section 11.7.5 and the force provisions of Sections 11.7.3 or 11.7.4.
6. Ductwork that conveys hazardous materials, exceeds 6 sq. ft. in cross-sectional area, or is suspended more than 12 in. from top of duct to supporting structure at any support point shall meet the requirements of the selected Rehabilitation Objective.
7. Equipment that is 6 ft. or more in height, weighs over 20 lbs., or forms part of an emergency power and/or communication system shall meet the Life Safety Nonstructural Performance Level.
8. Equipment that forms part of an emergency lighting, power, and/or communication system shall meet the Life Safety Nonstructural Performance Level.
9. Fixtures that exceed 20 lbs. per support shall meet the Life Safety Nonstructural Performance Level.
10. Rehabilitation shall not be required for storage racks in unoccupied spaces.
11. Panels that exceed 2 lbs./sq. ft., or for which Enhanced Rehabilitation Objectives have been selected, shall meet the Life Safety Nonstructural Performance Level.
12. Where material is in close proximity to occupancy such that leakage could cause an immediate life safety threat, the requirements of the selected Rehabilitation Objective shall be met.
13. Plaster ceilings on metal or wood lath over 10 sq. ft. in area shall meet the Life Safety Nonstructural Performance Level.
14. Unbraced pressure pipes with a 2-inch or larger diameter and suspended more than 12 inches from the top of the pipe to the supporting structure at any support point shall meet the requirements of the selected Rehabilitation Objective.
15. Where heavy nonstructural components are located in areas of public occupancy or egress, the components shall meet the Life Safety Nonstructural Performance Level.
16. Storage racks in areas of public assembly shall meet the requirements of the selected Rehabilitation Objective.
17. Evaluation for the presence of an adequate attachment shall be checked as described in Section 11.10.9.3.
18. In areas of Moderate Seismicity, interior veneers of ceramic tile need not be considered.

Key:

HR Hazards Reduced Nonstructural Performance Level

LS Life Safety Nonstructural Performance Level

IO Immediate Occupancy Nonstructural Performance Level

PR Use of the Prescriptive Procedure of Section 11.7.2 shall be permitted.

F The Analytical Procedure of Section 11.7.1 shall be implemented and a force analysis shall be performed in accordance with Sections 11.7.3 or 11.7.4.

F/D The Analytical Procedure of Section 11.7.1 shall be implemented and a force and deformation analysis shall be performed in accordance with Sections 11.7.4 and 11.7.5, respectively.

* Individual components shall be rehabilitated as required.

11.3 Historical and Component Evaluation Considerations

11.3.1 Historical Information

Available construction documents, equipment specification and data, and as-built information shall be obtained as specified in Section 2.2. Data on nonstructural components and equipment shall be collected to estimate the year of manufacture or installation of nonstructural components to justify selection of rehabilitation approaches and techniques based on available historical information, prevailing codes, and assessment of existing conditions.

C11.3.1 Historical Information

The architectural, mechanical, and electrical components and systems of a historic building may be historically significant, especially if they are original to the building, very old, or innovative. Historic buildings may also contain hazardous materials, such as lead pipes and asbestos, that may or may not pose a hazard depending on their location, condition, use or abandonment, containment, and/or disturbance during the rehabilitation.

C11.3.1.1 Background

Prior to the 1961 *Uniform Building Code* and the 1964 Alaska earthquake, architectural components and mechanical and electrical systems for buildings had typically been designed with little, if any, regard to stability when subjected to seismic forces. By the time of the 1971 San Fernando earthquake, it became clear that damage to nonstructural components could result in serious casualties, severe building functional impairment, and major economic losses, even where structural damage was not significant (Lagorio, 1990). This historical perspective presents the background for the development of building code provisions, together with a historical review of professional and construction practices related to the seismic design and construction of nonstructural components. Since the 1964 Alaska earthquake, the poor performance of nonstructural components has been identified in earthquake reconnaissance reports. Subsequent editions of the *Uniform Building Code* (ICBO, 1994), as well as California and Federal codes and laws have increased both the scope and strictness of nonstructural seismic provisions in an attempt to achieve better performance. Table C11-1 and Table C11-2 provide a comprehensive list of nonstructural hazards that have been observed in these earthquakes.

The following quote, taken from statements made after the Alaska earthquake, characterizes the hazard nonstructural components pose to building occupants:

"If, during an earthquake, [building occupants] must exit through a shower of falling light fixtures and ceilings, maneuver through shifting and toppling furniture and equipment, stumble down dark corridors and debris-laden stairs, and then be met at the street by falling glass, veneers, or facade components, then the building cannot be described as a safe structure."

(Ayres and Sun, 1973a)

In reviewing the design and construction of architectural nonstructural components in this century, four general phases can be distinguished.

A. Phase 1: 1900 to 1920s

Buildings featured monumental classical architecture, generally with a steel frame structure using stone facing with a backing of unreinforced masonry and concrete. Interior partitions were of unreinforced hollow clay tile or brick unit masonry, or wood partitions with wood lath and plaster. These buildings had natural ventilation systems with hot water radiators (later, forced-air), and surface- or pendant-mounted incandescent light fixtures.

B. Phase 2: 1930s to 1950s

Buildings were characterized by poured-in-place reinforced concrete or steel frame structures, employing columns and (in California) limited exterior and interior shear walls. Windows were large and horizontal. Interior partitions of unreinforced hollow clay tile or concrete block unit masonry, or light wood frame partitions with plaster, were gradually replaced by gypsum. Suspended ceilings and fluorescent lights arrived, generally surface- or pendant-mounted. Air conditioning (cooling) was introduced and HVAC systems became more complex, with increased demands for duct space.

C. Phase 3: 1950s to 1960s

This phase saw the advent of simple rectangular metal or reinforced concrete frame structures ("International Style"), and metal and glass curtain walls with a variety of opaque claddings (porcelain enamel, ceramic tile, concrete, cement plaster). Interior partitions became primarily metal studs and gypsum board. Proprietary suspended ceilings were developed using wire-hung metal grids with infill of acoustic panels, lighting fixtures, and air diffusion units. HVAC systems increased in size, requiring large mechanical rooms and increased above-ceiling space for ducts. Sprinklers and more advanced electrical control systems were introduced, and more HVAC equipment was spring-mounted to prevent transmission of motor vibration.

D. Phase 4: 1960s to Date

This period saw the advent of exterior precast concrete and, in the 1980s, glass fibre reinforced concrete (GFRC) cladding. Interior partition systems of metal studs and gypsum board, demountable partitions, and suspended ceiling systems become catalog proprietary items. The evolution of the late 1970s architectural style ("Post-Modern") resulted in less regular forms and much more interior and exterior decoration, much of it accomplished by nonstructural components: assemblies of glass, metal panel, GFRC, and natural stone cladding for the exteriors, and use of gypsum board for exaggerated structural concealment and form-making in interiors. Suspended ceilings and HVAC systems changed little, but the advent of office landscaping often reduced floor-to-ceiling partitions to almost nothing in general office space. Starting in the 1980s, the advent of the "smart" office greatly increased electrical and communications needs and the use of raised floors, and increased the need for the mechanical and electrical systems to remain functional after earthquakes.

C11.3.1.2 Background to Mechanical and Electrical Considerations

Prior to the 1964 Alaska earthquake, mechanical and electrical systems for buildings had been designed with little, if any, regard to stability when subjected to seismic forces. The change in design from the heavily structured and densely partitioned structures of the pre-war era, with their simple mechanical, electrical and lighting systems, to the light frame and curtain wall, gypsum board and integrated ceiling buildings of the 1950s and onward, had been little reflected in the seismic building codes. The critical yet fragile nature of the new nonstructural systems was not fully realized, except for nuclear power plant design and other special-purpose, high-risk structures. Equipment supports were generally designed for gravity loads only, and attachments to the structure itself were often deliberately designed to be flexible to allow for vibration isolation or thermal expansion.

Few building codes, even in regions with a history of seismic activity, have contained provisions governing the behavior of mechanical and electrical systems until relatively recently. One of the earliest references to seismic bracing can be found in NFPA-13, *Standard for the Installation of Sprinkler Systems*. This pamphlet has been updated periodically since 1896, and seismic bracing requirements have been included since 1947. Piping systems for building sprinklers are static and do not require vibration isolation. They do, however, require flexibility where the service piping enters the building. The issue of protecting flexibly mounted piping was not studied until after the 1964 Alaska earthquake.

The designers of building mechanical systems must also address the seismic restraints required for emergency generators, fire protection pumps, and plumbing systems that are vital parts of an effective fire suppression system.

Studies published following the 1971 San Fernando earthquake all indicated that buildings that sustained only minor structural damage became uninhabitable and hazardous to life due to failures of mechanical and electrical systems.

C11.3.1.3 HVAC Systems

A study by Ayres and Sun (1973b) clearly identified the need to anchor tanks and equipment that did not require vibration isolation, and to provide lateral restraints on equipment vibration isolation devices. Some of these suggested corrective measures are now incorporated into manufactured products. The HVAC system designers had to become aware of the earthquake-induced forces on the system's components and the need for seismic restraints to limit damage; they also had to understand the requirements for the suspension and bracing of ceilings and light fixtures because of their adjacency to and interaction with the HVAC system components.

To provide technical guidance to HVAC system designers and installers, the Sheet Metal Industry Fund of Los Angeles published its first manual, *Guidelines for Seismic Restraint of Mechanical Systems* (Sheet Metal Industry Fund, 1976). This manual was updated in 1982 with assistance from the Plumbing and Piping Industry Council (PPIC). The most recent manual, *Seismic Restraint Guidelines for Mechanical Equipment* (SMACNA, 1991), is designed for use in California as well as other locations with lower seismic hazard levels.

Secondary effects of earthquakes (fires, explosions, and hazardous materials releases resulting from damaged mechanical and electrical equipment) have only recently being considered. In addition, the potential danger of secondary damage from falling architectural and structural components, which could inflict major damage to adjacent equipment and render it unusable, needs to be carefully assessed.

These secondary effects can represent a considerable hazard to the building, its occupants, and its contents. Steam and hot water boilers and other pressure vessels can release fluids at hazardous temperatures. Mechanical systems often include piping systems filled with flammable, toxic, or noxious substances, such as ammonia or other refrigerants. Some of the nontoxic halogen refrigerants used in air-conditioning apparatus can be converted to a poisonous gas (phosgene) upon contact with open flame. Hot parts of disintegrating boilers, such as portions of the burner and firebrick, are at high enough temperatures to ignite combustible materials with which they might come in contact.

Table C11-1 Nonstructural Architectural Component Seismic Hazards

Component	Principal Concerns
Suspended ceilings	Dropped acoustical tiles, perimeter damage, separation of runners and cross runners
Plaster ceilings	Collapse, local spalling
Cladding	Falling from building, damaged panels and connections, broken glass
Ornamentation	Damage leading to a falling hazard
Plaster and gypsum board walls	Cracking
Demountable partitions	Collapse
Raised access floors	Collapse, separation between modules
Recessed light fixtures and HVAC diffusers	Dropping out of suspended ceilings
Unreinforced masonry walls and partitions	Parapet and wall collapse and spalling, partitions debris and falling hazard

Table C11-2 Mechanical And Electrical Equipment Seismic Hazards

Equipment/Component	Principal Concerns
Boilers	Sliding, broken gas/fuel and exhaust lines, broken/bent steam and relief lines
Chillers	Sliding, overturning, loss of function, leaking refrigerant
Emergency generators	Failed vibration isolation mounts; broken fuel, signal, and power lines, loss of function, broken exhaust lines
Fire pumps	Anchorage failure, misalignment between pump and motor, broken piping
On-site water storage	Tank or vessel rupture, pipe break
Communications equipment	Sliding, overturning, or toppling leading to loss of function
Main transformers	Sliding, oil leakage, bushing failure, loss of function
Main electrical panels	Sliding or overturning, broken or damaged conduit or electrical bus
Elevators (traction)	Counterweights out of guide rails, cables out of sheaves, dislodged equipment
Other fixed equipment	Sliding or overturning, loss of function or damage to adjacent equipment
Ducts	Collapse, separation, leaking, fumes
Piping	Breaks, leaks

11.3.2 Component Evaluation

Nonstructural components shall be evaluated to achieve the Rehabilitation Objective selected in accordance with Section 1.4. Analysis and rehabilitation requirements for the Hazards Reduced, Life Safety, and Immediate Occupancy Nonstructural Performance Levels for the appropriate level of seismicity shall be as specified in Table 11-1. Design forces shall be calculated in accordance with Section 11.7.3 or 11.7.4, and design deformations shall be calculated in accordance with Section 11.7.5. Analysis and rehabilitation requirements for the Hazards Reduced Nonstructural Performance Level shall follow the requirements for the Life Safety Nonstructural Performance Level. Analysis and rehabilitation requirements for the Operational Nonstructural Performance Level shall be based on approved codes.

Acceptance criteria for nonstructural components being evaluated to the Life Safety and Immediate Occupancy Nonstructural Performance Levels shall be based on criteria listed in Sections 11.9 through 11.11. Forces on bracing and connections for nonstructural components calculated in accordance with Section 11.7 shall be compared to capacities using strength design procedures. Acceptance criteria for the Life Safety Nonstructural Performance Level shall be used for nonstructural components being evaluated to the Hazards Reduced Nonstructural Performance Level. For nonstructural components being evaluated to the Operational Nonstructural Performance Level, approved acceptance criteria shall be used.

C11.3.2 Component Evaluation

The Hazards Reduced Nonstructural Performance Level applies only to high hazard components as specified in Section 1.5.2.4 and Table 11-1. Life Safety Nonstructural Performance Level criteria-or other approved criteria-should be used for the Hazards Reduced Nonstructural Performance Level. Criteria for the Operational Nonstructural Performance Level has not been developed to date. Evaluation, rehabilitation, and acceptance criteria for the Immediate Occupancy Nonstructural Performance Level may be used for the Operational Nonstructural Performance Level if more appropriate data are not available.

Forces on nonstructural components calculated in accordance with Section 11.7 are at a strength design level. Where allowable stress values are available for proprietary products used as bracing for nonstructural components, these values shall be factored up to strength design levels. In the absence of manufacturer's data on strength values, allowable stress values can be increased by a factor of 1.4 to obtain strength design values.

Where nonstructural components are evaluated using Hazards Reduced Nonstructural Performance Level, the force level associated with Life Safety Nonstructural Performance in Section 11.7 should be used. In many instances, if bracing of the nonstructural component exists, or if it is rehabilitated, there would not be a substantial justification for evaluating or rehabilitating the component using a force level or acceptance criteria less stringent than Life Safety. However, in cases where it is not considered critical or feasible, the engineer may, with appropriate approval, evaluate or rehabilitate the nonstructural component using a criteria that is less stringent than Life Safety.

In cases where the Basic Safety Objective is not required-such as where the Limited Safety Performance Range applies-there may be more latitude in the selection of components or criteria for nonstructural rehabilitation.

A suggested general procedure for developing a mitigation plan for the rehabilitation of nonstructural components is as follows:

1. It is assumed that the building has been evaluated in a feasibility phase, using a procedure such as that described in ASCE 31. For nonstructural components, use of this procedure will have provided a broad list of deficiencies that are generally, but not specifically, related to a Rehabilitation Objective. Issues related to other objectives and possible nonstructural components not discussed in ASCE 31, as well as issues raised by

nonstructural rehabilitation unaccompanied by structural rehabilitation (e.g., planning, cost-benefit) are outlined in this commentary, and references are provided for more detailed investigation.

2. The decision is made to rehabilitate the building, either structurally, nonstructurally, or both.

3. From Chapter 1 of this standard, the designer reviews Rehabilitation Objectives and, in concert with the authority having jurisdiction, determines the objective. Alternatively, the objective may have been already defined in an ordinance or other policy.

4. Following a decision on the Rehabilitation Objective, which includes the Nonstructural Performance Level or Range as well as ground motion criteria, the designer consults Chapter 11 of this standard.

5. Using Chapter 11, the designer prepares a definitive list of nonstructural components that are within the scope of the rehabilitation, based on the selected Nonstructural Performance Level and an assessment of component condition. For the Life Safety Nonstructural Performance Level and, to some extent, the Immediate Occupancy Nonstructural Performance Level, Chapters 2 and 11 of this standard specify requirements. However, for other levels and ranges, there is a need to evaluate and prioritize. From the list of nonstructural components within the project scope, a design assessment is made to determine if the component requires rehabilitation and, from Table 11-1, the rehabilitation Analysis Method (Analytical or Prescriptive) for each component or component group is determined.

6. For those components that do not meet the criteria, an appropriate analysis and design procedure is undertaken, with the aim of bringing the component into compliance with the criteria appropriate to the Nonstructural Performance Level or Range and the ground motion criteria.

7. Nonstructural rehabilitation design documents are prepared.

11.4 Rehabilitation Objectives and Performance Levels

Rehabilitation objectives that include performance levels for nonstructural components shall be established in accordance with Section 1.4. The level of seismicity shall be determined in accordance with Section 1.6.3.

C11.4 Rehabilitation Objectives and Performance Levels

The nonstructural Rehabilitation Objective may be the same as the Structural Rehabilitation Objective, or it may differ. For the BSO, structural and nonstructural requirements specified in this standard must be met.

This standard is also intended to be applicable to the situation where nonstructural-but not structural-components are to be rehabilitated. Rehabilitation that is restricted to the nonstructural components will typically fall within the Limited Safety Nonstructural Performance Range unless the structure is already determined to meet a specified Rehabilitation Objective. To qualify for any Rehabilitation Objective higher than Limited Safety, consideration of structural behavior is necessary to properly take into account loads on nonstructural components generated by inertial forces or deformations imposed by the structure.

C11.4.1 Regional Seismicity and Nonstructural Components

Requirements for the rehabilitation of nonstructural components relating to the three Seismic Levels-High, Moderate, and Low-are shown in Table 11-1 and noted in each section, where applicable. In general, for levels of low seismicity, certain nonstructural components have no rehabilitation requirements with respect to the Life Safety Nonstructural Performance Level. Rehabilitation of these components, particularly where rehabilitation is simple, may nevertheless be desirable for damage control and property loss reduction.

C11.4.2 Means of Egress: Escape and Rescue

Preservation of egress is accomplished primarily by ensuring that the most hazardous nonstructural components are replaced or rehabilitated. The items listed in Table 11-1 for achieving the Life Safety Nonstructural Performance Level show that typical requirements for maintaining egress will, in effect, be accomplished if the egress-related components are addressed. These would include the following items listed in ASCE 31.

1. Walls around stairs, elevator enclosures, and corridors are not hollow clay tile or unreinforced masonry.

2. Stair enclosures do not contain any piping or equipment except as required for life safety.

3. Veneers, cornices, and other ornamentation above building exits are well anchored to the structural system.

4. Parapets and canopies are anchored and braced to prevent collapse and blockage of building exits.

Beyond this, the following list describes some conditions that might be commonly recognized as representing major obstruction; the building should be inspected to see whether these, or any similar hazardous conditions exist. If so, their replacement or rehabilitation should be included in the rehabilitation plan.

1. Partitions taller than six feet and weighing more than five pounds per square foot, if collapse of the entire partition-rather than cracking-is the expected mode of failure, and if egress would be impeded.

2. Ceilings, soffits, or any ceiling or decorative ceiling component weighing more than two pounds per square foot, if it is expected that large areas (pieces measuring ten square feet or larger) would fall.

3. Potential for falling ceiling-located light fixtures or piping; diffusers and ductwork, speakers and alarms, and other objects located higher than 42 inches off the floor.

4. Potential for falling debris weighing more than 100 pounds that, if it fell in an earthquake, would obstruct a required exit door or other component, such as a rescue window or fire escape.

5. Potential for jammed doors or windows required as part of an exit path-including doors to individual offices, rest rooms, and other occupied spaces.

Of these, the first four are also taken care of in the Life Safety Nonstructural Performance Level requirement. The last condition is very difficult to eliminate with any assurance, except for low levels of shaking in which structural drift and deformation will be minimal, and the need for escape and rescue correspondingly slight.

For essential facilities with post-disaster emergency functions that require access through doors, such as apparatus garage doors in fire stations, drift limits should be imposed on the structural lines at such door openings and a deformation compatibility analysis should be performed in accordance with Section 11.9.9 and Table 11-1.

11.5 Structural-Nonstructural Interaction

11.5.1 Response Modification

Nonstructural components shall be included in the mathematical model of the building in accordance with the requirements of Section 3.2.2.3. Nonstructural components included in the mathematical model of the building shall be evaluated for forces and deformations imposed by the structure, computed in accordance with Chapter 3.

11.5.2 Base Isolation

In a base-isolated structure, nonstructural components located at or above the isolation interface shall comply with the requirements in Section 9.2.6.2.1. Nonstructural components that cross the isolation interface shall comply with the requirements of Section 9.2.6.2.2. Nonstructural components located below the isolation interface shall comply with the requirements of this chapter.

11.6 Classification of Acceleration-Sensitive and Deformation-Sensitive Components

Nonstructural components shall be classified based on their response sensitivity as follows:

1. Nonstructural components that are sensitive to and subject to damage from inertial loading shall be classified as *acceleration-sensitive* components.

2. Nonstructural components that are sensitive and subject to damage imposed by drift or deformation of the structure shall be classified as deformation sensitive.

3. Nonstructural components that are sensitive to both inertial loading and drift and deformation of the structure shall be classified as deformation sensitive.

C11.6 Classification of Acceleration-Sensitive and Deformation-Sensitive Components

Classification of acceleration-sensitive or deformation-sensitive components are discussed, where necessary, in each component section (Sections 11.9, 11.10, and 11.11). Table C11-3 summarizes the sensitivity of nonstructural components listed in Table 11-1, and identifies which are of primary or secondary concern. The guiding principle for deciding whether a component requires a force analysis, as defined in Section 11.7, is that analysis of inertial loads generated within the component is necessary to properly consider the component's seismic behavior. The guiding principle for deciding whether a component requires a drift analysis, as defined in Section 11.7, is that analysis of drift is necessary to properly consider the component's seismic behavior.

Glazing or other components that can hazardously fail at a drift ratio less than 0.01 (depending on installation details) or components that can undergo greater distortion without hazardous failure resulting-for example, typical gypsum board partitions-should be considered.

Use of Drift Ratio Values as Acceptance Criteria.
The data on drift ratio values related to damage states are limited, and the use of single median drift ratio values as acceptance criteria must cover a broad range of actual conditions. It is therefore suggested that the limiting drift values shown in this chapter be used as a guide for evaluating the probability of a given damage state for a subject building, but not be used as absolute acceptance criteria. At higher Nonstructural Performance Levels, it is likely that the criteria for nonstructural deformation- sensitive components may control the structural rehabilitation design. These criteria should be regarded as a flag for the careful evaluation of structural/nonstructural interaction and consequent damage states, rather than the required imposition of absolute acceptance criteria that might require costly redesign of the structural rehabilitation.

Table C11-3 Nonstructural Components: Response Sensitivity

		Sensitivity	
COMPONENT		**Acc.**	**Def.**
ARCHITECTURAL (Section 11.9)			
1.	**Exterior Skin**	S	P
	Adhered Veneer	S	P
	Anchored Veneer	S	P
	Glass Blocks	S	P
	Prefabricated Panels	S	P
	Glazing Systems	S	P
2.	**Partitions**		
	Heavy	S	P
	Light	S	P
3.	**Interior Veneers**	S	P
	Stone, Including Marble	S	P
	Ceramic Tile	S	P
4.	**Ceilings**		
	Directly Applied to Structure	P	
	Dropped Furred Gypsum Board	P	
	Suspended Lath and Plaster	S	P
	Suspended Integrated Ceiling	S	P
5.	**Parapets and Appendages**	P	
6.	**Canopies and Marquees**	P	
7.	**Chimneys and Stacks**	P	
8.	**Stairs**	P	S
9.	**Doors Required for Emergency Services Egress**	S	P
MECHANICAL EQUIPMENT (Section 11.10)			
1.	**Mechanical Equipment**	P	
	Boilers and Furnaces	P	
	General Mfg. and Process Machinery	P	
	HVAC Equipment, Vibration-Isolated	P	
	HVAC Equipment, Non-Vibration-Isolated	P	
	HVAC Equipment, Mounted In-Line with Ductwork	P	
2.	**Storage Vessels and Water Heaters**		
	Structurally Supported Vessels (Category 1)	P	
	Flat Bottom Vessels (Category 2)	P	
3.	**Pressure Piping**	P	S
4.	**Fire Suppression Piping**	P	S
5.	**Fluid Piping, not Fire Suppression**		
	Hazardous Materials	P	S
	Nonhazardous Materials	P	S
6.	**Ductwork**	P	S

Acc. = Acceleration-Sensitive P = Primary Response
Def. = Deformation-Sensitive S = Secondary Response

11.7 Evaluation Procedures

One of the following evaluation procedures for nonstructural components shall be selected based on the requirements of Table 11-1:

1. Analytical Procedure.

2. Prescriptive Procedure.

11.7.1 Analytical Procedure

Where the Prescriptive Procedure is not permitted based on Table 11-1, forces and deformations on nonstructural components shall be calculated as follows:

1. If a force analysis only is permitted by Table 11-1 and either the Hazards Reduced or Life Safety Nonstructural Performance Level is selected, then use of the default equations given in Section 11.7.3 shall be permitted to calculate seismic design forces on nonstructural components.

2. If a force analysis only is permitted by Table 11-1 and a Nonstructural Performance Level higher than Life Safety is selected, then the default equations of Section 11.7.3 do not apply, and seismic design forces shall be calculated in accordance with Section 11.7.4.

3. If both force and deformation analysis are required by Table 11-1, then seismic design forces shall be calculated in accordance with Section 11.7.4 and drift ratios or relative displacements shall be calculated in accordance with Section 11.7.5. The deformation and associated drift ratio of the structural component(s) to which the deformation-sensitive nonstructural component is attached shall be determined in accordance with Chapter 3.

4. Alternatively, the calculation of seismic design forces and deformations in accordance with Section 11.7.6 shall be permitted.

C11.7.1 Analytical Procedure

For nonstructural components, the Analytical Procedure, which consists of the default equation and general equation approaches, is applicable to any case. The Prescriptive Procedure is limited by Table 11-1 to specified combinations of seismicity and component type for compliance with the Life Safety Nonstructural Performance Level.

11.7.2 Prescriptive Procedure

Where the Prescriptive Procedure is permitted in Table 11-1, the characteristics of the nonstructural component shall be compared with characteristics as specified in approved codes.

C11.7.2 Prescriptive Procedure

A Prescriptive Procedure consists of published standards and references that describe the design concepts and construction features that must be present for a given nonstructural component to be seismically protected. No engineering calculations are required in a Prescriptive Procedure, although in some cases an engineering review of the design and installation is required.

Suggested references for prescriptive requirements are listed in the commentary of the "Component Behavior and Rehabilitation Concepts" subsection of Sections 11.9 through 11.11 for each component type.

11.7.3 Force Analysis: Default Equations

Calculation of seismic design forces on nonstructural components using the following default Equations (11-1) and (11-2) shall be permitted in accordance with Section 11.7.1. Horizontal seismic design forces shall be computed using Equation (11-1). Where specifically required in Sections 11.9, 11.10, and 11.11 vertical seismic forces for horizontal cantilever components shall be determined using Equation (11-2). Vertical seismic forces for all other components shall be determined using Equation (11-3).

$$F_p = 1.6\, S_{XS} W_P \qquad (11\text{-}1)$$

$$F_{pv} = {}^{2}\!/_{3}\, F_p \qquad (11\text{-}2)$$

$$F_{pv}\ (\text{minimum}) = \pm\, 0.2 S_{XS}\, W_p \qquad (11\text{-}3)$$

where:

F_p = Component seismic design force applied horizontally at the center of gravity of the component or distributed according to the mass distribution of the component

F_{pv} = Component seismic design force applied vertically at the center of gravity of the component or distributed according to the mass distribution of the component

S_{XS} = Spectral response acceleration parameter at short periods for any Earthquake Hazard Level and any damping determined in accordance with Section 1.6.1.4 or 1.6.2.1

W_p = Component operating weight

11.7.4 Force Analysis: General Equations

11.7.4.1 Horizontal Seismic Forces

11.7.4.1.1 Life Safety and Hazards Reduced Nonstructural Performance Levels

Where default equations of Section 11.7.3 do not apply, horizontal seismic design forces on nonstructural components shall be determined in accordance with Equation (11-4).

$$F_p = \frac{0.4 a_p S_{XS} I_p W_p (1 + \frac{2x}{h})}{R_p} \qquad (11\text{-}4)$$

F_p calculated in accordance with Equation (11-4) shall be based on the stiffness of the component and ductility of its bracing and anchorage, but it need not exceed the default value of F_p calculated in accordance with Equation (11-1) and shall not be less than F_p computed in accordance with Equation (11-5).

$$F_p \text{ (minimum)} = 0.3 S_{XS} I_p W_p \qquad (11\text{-}5)$$

where:

a_p = Component amplification factor from Table 11-2

F_p = Component seismic design force applied horizontally at the center of gravity of the component and distributed according to the mass distribution of the component

S_{XS} = Spectral response acceleration parameter at short periods for any Earthquake Hazard Level and any damping determined in accordance with Section 1.6.1.4 or 1.6.2.1

h = Average roof elevation of structure, relative to grade elevation

I_p = Component performance factor; 1.0 shall be used for the Life Safety and Hazards Reduced Nonstructural Performance Levels

R_p = Component response modification factor from Table 11-2

x = Elevation in structure of the center of gravity of the component relative to grade elevation

11.7.4.1.2 Immediate Occupancy Nonstructural Performance Level

Seismic design forces for nonstructural components being evaluated to the Immediate Occupancy Nonstructural Performance Level shall be evaluated considering the dynamic characteristics of the building and the nonstructural component. The fundamental period of vibration of the nonstructural component (Tp) in each direction shall be estimated using Equation (11-5a).

$$T_p = 2\pi \sqrt{\frac{W_p}{K_p g}} \qquad (11\text{-}5a)$$

where:
T_p = Component fundamental period

W_p = Component operating weight
g = Gravitational acceleration
K_p = Approximate stiffness of the support system of the component, its bracing, and its attachment, determined in terms of load per unit deflection at the center of gravity of the component

Nonstructural seismic design forces shall be calculated based on Equation (11-5b).

$$F_p = \frac{I_p a_p A_x W_p}{R_p} \quad \text{(11-5b)}$$

where:
I_p = Component performance factor = 1.5
a_p = Component amplification factor determined based on the dynamic interaction between the nonstructural component and the building vibrational characteristics; in lieu of a rigorous analysis, the value of a_p may be obtained from Table 11-2
R_p = Component response modification factor from Table 11-2
A_x = Story acceleration at level x calculated based on a linear dynamic analysis of the building in accordance with Section 3.3.2; in lieu of a rigorous analysis, the value of A_x may be obtained using Equation (11-5c)

$$A_x = 0.4 S_{XS} (1 + \frac{2x}{h}) \quad \text{(11-5c)}$$

where:
S_{XS} = The 5% damped spectral response acceleration parameter at short periods for a given Earthquake Hazard Level determined in accordance with Section 1.6.1.4 or 1.6.2.1
h = Average roof elevation of structure, relative to grade elevation
x = Elevation in structure of the center of gravity of the component relative to grade elevation

C11.7.4.1 Horizontal Seismic Forces

Seismic forces for nonstructural components are generated based on three effects: the ground acceleration at the base of the building, the ratio of the floor acceleration at the location of the nonstructural component to the ground acceleration, and the dynamic amplification due to resonance between the nonstructural component and the building response. Equation (11-4) provides an estimate of the horizontal acceleration of a nonstructural component. The peak ground acceleration is calculated as 0.4 times the short period response acceleration (S_{XS}).

The ratio of the floor acceleration at the location of the nonstructural component is based on a linearly increasing variation of acceleration over the height of the building. The term $(1+2x/h)$ is used to calculate this variation based on a linearly variation of floor accelerations over the height of the building and is based on an assumed first mode response of a building with uniform stiffness and mass. For buildings, which have significant higher mode response, this linearly increasing assumption may overestimate the acceleration at floors below the roof. A linear dynamic analysis using a response spectrum can be used as an alternate method of estimating the variation of floor accelerations.

The a_p factor provides an estimate of the dynamic amplification due to the resonance of response of the nonstructural component with one of the modes of vibration of the building. Table 11-2 provides an estimate of this amplification for most nonstructural components. In Table 11-2, components assumed to be rigid are assigned an a_p value of 1 and components assumed to be flexible are assigned an a_p value of 2.5. A period of vibration of 0.06 seconds is used to distinguish between rigid and flexible components. The engineer should verify that the a_p value used is appropriate for the actual component and its support system.

For many buildings, the primary mode of vibration in each direction will have the most influence on the dynamic amplification of nonstructural components. For buildings primary mode periods greater than 1 second, the second or third mode of vibration may also cause some dynamic amplification.

Equation 11-5c provides a slightly revised form of Equation 11-5b for use where checking nonstructural components for Immediate Occupancy Performance Level. In Equation 11-5c, the factor (a_p) is defined as the dynamic amplification factor considering resonance of the nonstructural component with one of the modes of the building. The intent is to consider this dynamic amplification effect for nonstructural components for Immediate Occupancy Performance Level. Guidelines for considering this effect are provided in the Tri-Services Seismic Design for Buildings (TM5-809-10) and Seismic Design Guidelines for Essential Buildings (TM5-809-10-1). Other approved procedures could also be used. It is permissible to use the a_p factors from Table 11-2.

Equation 11-5c also provides a factor A_x, which represents the floor accelerations. The intent is that a linear dynamic analysis of the building be performed to determine the actual story accelerations based on the ground motion considered for a sufficient number of modes of vibration for the range of periods of vibration of the nonstructural components to be designed. The modal story accelerations can be combined using standard modal combination procedures. Linear dynamic analysis procedures are considered sufficiently accurate for estimating the story accelerations since buildings checked for Immediate Occupancy Performance Level are expected to behave nearly elastically for the design earthquake.

11.7.4.2 Vertical Seismic Forces

Where the default equations of Section 11.7.3 do not apply, and where specifically required by Sections 11.9, 11.10, and 11.11, vertical seismic design forces on nonstructural components shall be determined in accordance with Equation (11-6).

$$F_{pv} = \frac{0.27 a_p S_{XS} I_p W_p}{R_p} \qquad (11\text{-}6)$$

F_p calculated in accordance with Equation (11-6) need not exceed F_p calculated in accordance with Equation (11-2) and shall not be less than F_{pv} (minimum) computed in accordance with Equation (11-7).

$$F_{pv}(\text{minimum}) = 0.2\, S_{XS} I_p W_p \qquad (11\text{-}7)$$

where:

F_{pv} = Component seismic design force applied vertically at the center of gravity of the component or distributed according to the mass distribution of the component

All other terms in Equations (11-6) and (11-7) shall be as defined in Section 11.7.4.1.

11.7.5 Deformation Analysis

Where nonstructural components are anchored by connection points at different levels x and y on the same building or structural system, drift ratios (D_r) shall be calculated in accordance with Equation (11-8).

$$D_r = \left(\delta_{xA} - \delta_{yA}\right) / (X - Y) \qquad (11\text{-}8)$$

Where nonstructural components are anchored by connection points on separate buildings or structural systems at the same level *x*, relative displacements (D_p) shall be calculated in accordance with Equation (11-9).

$$D_p = \left|\delta_{xA}\right| + \left|\delta_{xB}\right| \qquad (11\text{-}9)$$

where:

D_p = Relative seismic displacement

D_r = Drift ratio

X = Height of upper support attachment at level x as measured from grade

Y = Height of lower support attachment at level y as measured from grade

$\delta_{\mathrm{A\Xi}}$ = Deflection at building level x of Building A, determined by analysis as defined in Chapter 3

δ_{xB} = Deflection at building level y of Building A, determined by analysis as defined in Chapter 3

δ_{xB} = Deflection at building level x of Building B, determined by analysis as defined in Chapter 3 or equal to 0.03 times the height X of level x above grade or as determined using other approved approximate procedures

The effects of seismic displacements shall be considered in combination with displacements caused by other loads that are present.

11.7.6 Other Procedures

Other approved procedures shall be permitted to determine the maximum acceleration of the building at each component support and the maximum drift ratios or relative displacements between two supports of an individual component.

C11.7.6 Other Procedures

Linear and nonlinear procedures may be used to calculate the maximum acceleration of each component support and the story drifts of the building, taking into account the location of the component in the building. Consideration of the flexibility of the component, and the possible amplification of the building roof and floor accelerations and displacements in the component, would require the development of roof and floor response spectra or acceleration time histories at the nonstructural support locations, derived from the dynamic response of the structure. If the resulting floor spectra are less than demands calculated in accordance with Sections 11.7.3 and 11.7.4, it may be advantageous to use this procedure.

Relative displacements between component supports are difficult to calculate, even with the use of acceleration time histories, because the maximum displacement of each component support at different levels in the building might not occur at the same time during the building response.

Guidelines for these dynamic analyses for nonstructural components are given in Chapter 6 of *Seismic Design Guidelines for Essential Buildings*, a supplement to TM5-809-10.1.

These other analytical procedures are considered too complex for the rehabilitation of nonessential building nonstructural components for Immediate Occupancy and Life Safety Nonstructural Performance Levels.

Recent research (Drake and Bachman) has shown that the analytical procedures in Sections 11.7.3 and 11.7.4, which are based on FEMA 302 analytical procedures, provide an upper bound for the seismic forces on nonstructural components.

Table 11-2 Nonstructural Component Amplification and Response Modification Factors

Architectural Component or Component (Section 11.9)	a_p [a]	R_p [d]
Interior nonstructural walls and partitions [b]		
Plain masonry walls	1.0	1.5
All other walls and partitions	1.0	2.5
Cantilever Components, unbraced or braced (to structural frame) below their centers of mass		
Parapets and cantilevered interior nonstructural walls	2.5	2.5
Chimneys and stacks where laterally supported by structures	2.5	2.5
Cantilever components, braced (to structural frame) above their centers of mass		
Parapets	1.0	2.5
Chimneys and stacks	1.0	2.5
Exterior nonstructural walls [b]	1.0	2.5
Exterior nonstructural wall components and connections [b]		
Wall component	1.0	2.5
Body of wall-panel connections	1.0	2.5
Fasteners of the connecting system	1.25	1.0
Veneer		
High deformability components and attachments	1.0	2.5
Low deformability components and attachments	1.0	1.5
Penthouses (except where framed by an extension of the building frame)	2.5	3.5
Ceilings		
All	1.0	2.5
Cabinets		
Storage cabinets and laboratory equipment	1.0	2.5
Storage Racks [e]	2.5	4.0
Access floors		
Special access floors	1.0	2.5
All other	1.0	1.5
Appendages and ornamentation	2.5	2.5
Signs and billboards	2.5	2.5
Other rigid components		
High deformability components and attachments	1.0	3.5
Limited deformability components and attachments	1.0	2.5
Low deformability components and attachments	1.0	1.5
Other flexible components		
High deformability components and attachments	2.5	3.5
Limited deformability components and attachments	2.5	2.5
Low deformability components and attachments	2.5	1.5
Mechanical and Electrical Components (Section 11.10)		
Air-side HVAC, fans, air handlers, air conditioning units, cabinet heaters, air distribution boxes, and other mechanical components constructed of sheet metal framing.	2.5	3.0
Wet-side HVAC, boilers, furnaces, atmospheric tanks and bins, chillers, water heaters, heat exchangers, evaporators, air separators, manufacturing or process equipment, and other mechanical components constructed of high deformability materials.	1.0	2.5

Engines, turbines, pumps, compressors, and pressure vessels not supported on skirts and not within the scope of Section 9.14..	1.0	2.5
Skirt-supported pressure vessels not within the scope of Section 9.14.	2.5	2.5
Elevator and escalator components.	1.0	2.5
Generators, batteries, inverters, motors, transformers, and other electrical components constructed of high deformability materials.	1.0	2.5
Motor control centers, panel boards, switch gear, instrumentation cabinets, and other components constructed of sheet metal framing.	2.5	3.0
Communication equipment, computers, instrumentation and controls.	1.0	2.5
Roof mounted chimneys, stacks, cooling and electrical towers laterally braced below their center of mass.	2.5	3.0
Roof mounted chimneys, stacks, cooling and electrical towers laterally braced above their center of mass.	1.0	2.5
Lighting fixtures.	1.0	1.5
Other mechanical or electrical components.	1.0	1.5
Vibration Isolated Components and Systems[c]		
Components and systems isolated using neoprene components and neoprene isolated floors with built-in or separate elastomeric snubbing devices or resilient perimeter stops.	2.5	2.5
Spring isolated components and systems and vibration isolated floors closely restrained using built-in or separate elastomeric snubbing devices or resilient perimeter stops.	2.5	2.0
Internally isolated components and systems.	2.5	2.0
Suspended vibration isolated equipment including in-line duct devices and suspended internally isolated components.	2.5	2.5
Distribution Systems		
Piping in accordance with ASME B31, including in-line components with joints made by welding or brazing	2.5	12.0
Piping in accordance with ASME B31, including in-line components, constructed of high or limited deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings.	2.5	6.0
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Piping and tubing not in accordance with ASME B31, including in-line components, constructed of high or limited deformability materials, with joints made by threading, bonding, compression couplings, or grooved couplings	2.5	4.5
Piping and tubing constructed of low deformability materials, such as cast iron, glass, and nonductile plastics.	2.5	3.0
Ductwork, including in-line components, constructed of high deformability materials, with joints made by welding or brazing.	2.5	9.0
Ductwork, including in-line components, constructed of high or limited deformability materials with joints made by means other than welding or brazing.	2.5	6.0
Ductwork, including in-line components, constructed of low deformability materials, such as cast iron, glass, and nonductile plastics.	2.5	3.0
Electrical conduit, bus ducts, rigidly mounted cable trays, and plumbing.	1.0	2.5
Manufacturing or process conveyors (nonpersonnel).	2.5	3.0
Suspended cable trays.	2.5	6.0
Furnishings and Interior Equipment (Section 11.11)		
Storage Racks[4]	2.5	4
Bookcases	1	3
Computer Access Floors	1	3
Hazardous Materials Storage	2.5	1

Computer and Communications Racks	2.5	6
Elevators	1	3
Conveyors	2.5	3

[a] A lower value for a_p is permitted where justified by detailed dynamic analyses. The value for a_p shall not be less than 1.0. The value of a_p equal to 1.0 is for rigid components and rigidly attached components. The value of a_p equal to 2.5 is for flexible components and flexibly attached components.

[b] Where flexible diaphragms provide lateral support for concrete or masonry walls or partitions, the design forces for anchorage to the diaphragm shall be as specified in Sec. 2.6.7.1.

[c] Components mounted on vibration isolators shall have a bumper restraint or snubber in each horizontal direction. The design force shall be taken as $2F_p$ if the nominal clearance (air gap) between the equipment support frame and restraint is greater than 1/4 in. If the nominal clearance specified on the construction documents is not greater than 1/4 in., the design force may be taken as F_p .

[d] The value of R_p used to determine the forces in the connected part shall not exceed 1.5 unless the component anchorage is governed by the strength of a ductile steel component.

[e] Storage racks over six feet in height shall be designed in accordance with the provisions of Section 11.11.1

]

11.8 Rehabilitation Approaches

Nonstructural rehabilitation shall be accomplished by approved methods based on the classification of the nonstructural component and the performance level desired for the nonstructural component.

1. For the rehabilitation of nonstructural components that are acceleration sensitive for Hazards Reduced or Life Safety Performance Levels, the rehabilitation approach shall provide for position retention. Position retention shall be defined as providing bracing, anchorage, attachment, or other approved methods to prevent the nonstructural component from becoming dislodged during earthquake shaking.

2. The rehabilitation of nonstructural components for Immediate Occupancy Performance Level shall provide for position retention. In addition, the rehabilitation of mechanical and electrical components shall prevent damage to the components that will affect the occupancy of the building.

3. For the rehabilitation of nonstructural components that are deformation sensitive, the rehabilitation approach shall provide for sufficient deformation capability for the nonstructural components to allow the nonstructural component to undergo the calculated deformation while maintaining position retention.

C11.8 Rehabilitation Approaches

A general set of alternate methods is available for the rehabilitation of nonstructural components. These are briefly outlined in this section with examples to clarify the intent. However, the choice of rehabilitation technique and its design is the responsibility of the design professional, and use of alternative approaches to those noted below or otherwise customarily in use is acceptable, provided that it can be shown to the satisfaction of the building official that the acceptance criteria are met.

For Hazards Reduced and Life Safety Performance Levels, most nonstructural components that are acceleration sensitive should be rehabilitated considering position retention. Nonstructural components that are drift sensitive should be rehabilitated to allow for imposed deformation. Nonstructural components that are drift sensitive need not be designed to prevent damage to the nonstructural component or its attachments provided that stability of the component is maintained. Components that are both acceleration sensitive in one direction and drift sensitive in the other direction should be rehabilitated considering both effects.

C11.8.1 Replacement

Replacement involves the complete removal of the component and its connections, and its replacement by new components; for example, the removal of exterior cladding panels, the installation of new connections, and installation of new panels. As with structural components, the installation of new nonstructural components as part of a seismic rehabilitation project should be the same as for new construction.

C11.8.2 Strengthening

Strengthening involves additions to the component to improve its strength to meet the required force levels; for example, additional members might be welded to a support to prevent buckling.

C11.8.3 Repair

Repair involves the repair of any damaged parts or members of the component to enable the component to meet its acceptance criteria; for example, some corroded attachments for a precast concrete cladding system might be repaired and replaced without removing or replacing the entire panel system.

C11.8.4 Bracing

Bracing involves the addition of members and attachments that brace the component internally or to the building structure. A suspended ceiling system might be rehabilitated by the addition of diagonal wire bracing and vertical compression struts.

C11.8.5 Attachment

Attachment refers to methods that are primarily mechanical, such as bolting, by which nonstructural components are attached to the structure or other supporting components. Typical attachments are the bolting of items of mechanical equipment to a reinforced concrete floor or base. Supports and attachments for mechanical and electrical equipment should be designed according to accepted engineering principles. The following guidelines are recommended.

1. Attachments and supports transferring seismic loads should be constructed of materials suitable for the application, and designed and constructed in accordance with a nationally recognized standard.

2. Attachments embedded in concrete should be suitable for cyclic loads.

3. Rod hangers may be considered seismic supports if the length of the hanger from the supporting structure is 12 inches or less. Rod hangers should not be constructed in a manner that would subject the rod to bending moments.

4. Seismic supports should be constructed so that support engagement is maintained.

5. Friction clips should not be used for anchorage attachment.

6. Expansion anchors should not be used for mechanical equipment rated over 10 hp, unless undercut expansion anchors are used.

7. Drilled and grouted-in-place anchors for tensile load applications should use either expansive cement or expansive epoxy grout.

8. Supports should be specifically evaluated if weak-axis bending of cold-formed support steel is relied on for the seismic load path.

9. Components mounted on vibration isolation systems should have a bumper restraint or snubber in each horizontal direction. The design force should be taken as $2F_p$.

10. Oversized washers should be used at bolted connections through the base sheet metal if the base is not reinforced with stiffeners.

Lighting fixtures resting in a suspended ceiling grid may be rehabilitated by adding wires that directly attach the fixtures to the floor above, or to the roof structure to prevent their falling.

11.9 Architectural Components: Definition, Behavior, and Acceptance Criteria

11.9.1 Exterior Wall Components

11.9.1.1 Adhered Veneer

11.9.1.1.1 Definition and Scope

Adhered veneer shall include the following types of exterior finish materials secured to a backing material, which shall be masonry, concrete, cement plaster, or to a structural framework material by adhesives:

1. Tile, masonry, stone, terra cotta, or other similar materials.

2. Glass mosaic units.

3. Ceramic tile.

4. Exterior plaster (stucco).

C11.9.1.1.1 Definition and Scope

Adhered veneers are generally thinner materials, although thicker veneers, especially masonry, stone, and terra cotta, may be encountered. While the behavior of the thicker veneers is still dominated by the behavior of the substrate, the threat to life safety due to failure may rise significantly for thicker, heavier veneers. The height of the veneer, as well as the likely size of falling fragments should be considered.

Tile, masonry, stone, terracotta, and similar materials are typically less than 1 inch thick. Glass mosaic blocks are typically 2 inches by 2 inches by 3/8 inch thick.

11.9.1.1.2 Component Behavior and Rehabilitation Methods

Adhered veneer shall be considered deformation-sensitive.

Adhered veneer not conforming to the acceptance criteria of Section 11.9.1.1.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.1.1.2 Component Behavior and Rehabilitation Methods

Adhered veneers are predominantly deformation-sensitive. Deformation of the substrate leads to cracking or separation of the veneer from its backing. Poorly adhered veneers may be dislodged by direct acceleration.

Nonconformance requires limiting drift, special detailing to isolate substrate from structure to permit drift, or replacement with drift-tolerant material. Poorly adhered veneers should be replaced.

11.9.1.1.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

1. **Life Safety Nonstructural Performance Level**. Backing shall be adequately anchored to resist seismic forces computed in accordance with Section 11.7.3 or 11.7.4. The drift ratio calculated in accordance with Section 11.7.5 shall be limited to 0.02.

2. **Immediate Occupancy Nonstructural Performance Level**. Backing shall be adequately attached to resist seismic design forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.01.

11.9.1.1.4 Evaluation Requirements

Adhered veneer shall be evaluated by visual observation and tapping to discern looseness or cracking.

C11.9.1.1.4 Evaluation Requirements

Tapping may indicate either defective bonding to the substrate or excessive flexibility of the supporting structure.

11.9.1.2 Anchored Veneer

11.9.1.2.1 Definition and Scope

Anchored veneer shall include the following types of masonry or stone units that are attached to the supporting structure by mechanical means:

1. Masonry units.

2. Stone units.

3. Stone slab units.

The provisions of this section shall apply to units that are more than 48 inches above the ground or adjacent exterior area.

C11.9.1.2.1 Definition and Scope

Masonry units are typically five inches or less in thickness. Stone slab units are typically two inches or less in thickness.

11.9.1.2.2 Component Behavior and Rehabilitation Methods

Anchored veneer shall be considered both acceleration-sensitive and deformation-sensitive.

Anchored veneer and connections not conforming to the acceptance criteria of Section 11.9.1.2.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.1.2.2 Component Behavior and Rehabilitation Methods

Anchored veneer is both acceleration- and deformation-sensitive. Heavy units can be dislodged by direct out-of-plane acceleration, which distorts or fractures the mechanical connections. Special attention should be paid to corners and around openings, which are likely to experience large deformations. In-plane or out-of-plane deformations of the supporting structure, particularly if it is a frame, may similarly affect the connections, and the units may be displaced or dislodged by racking. Thick anchored veneer may posses significant in-plane stiffness, which can greatly amplify the demands placed on the connections, if the supporting structure racks.

Drift analysis is necessary to establish conformance with drift acceptance criteria related to performance level. The drift analysis should consider the construction and behavior of the veneer and its backing to assess the individual parts of the nonstructural component that are required to deform in order to accommodate the required drift. These parts of the nonstructural component should be checked for their capability to allow for the calculated deformation of the structure. Nonconformance requires limiting structural drift, or special detailing to isolate substrate from structure to permit drift. Defective connections must be replaced.

11.9.1.2.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

1. **Life Safety Nonstructural Performance Level.** Backing shall be adequately anchored to resist seismic forces computed in accordance with Section 11.7.3 or 11.7.4. The drift ratio calculated in accordance with Section 11.7.5 shall be limited to 0.02.

2. **Immediate Occupancy Nonstructural Performance Level.** Backing shall be adequately attached to resist seismic design forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.01.

C11.9.1.2.3 Acceptance Criteria

As an alternative to the drift limits in Section 11.9.1.2.3, the nonstructural component and its backing can be shown by approved testing or analysis to meet the intended performance level for the calculated drift.

11.9.1.2.4 Evaluation Requirements

Stone units shall have adequate stability, joint detailing, and maintenance to prevent moisture penetration from weather that could destroy the anchors. The anchors shall be visually inspected and tested to determine capacity if any signs of deterioration are visible.

11.9.1.3 Glass Block Units and Other Nonstructural Masonry

11.9.1.3.1 Definition and Scope

Glass block and other units that are self-supporting for static vertical loads, held together by mortar and structurally detached from the surrounding structure, shall be rehabilitated in accordance with this section.

11.9.1.3.2 Component Behavior and Rehabilitation Methods

Glass block units and other nonstructural masonry shall be considered both acceleration- and deformation-sensitive.

Rehabilitation of individual walls less than 144 square feet or 15 feet in any dimension using Prescriptive Procedures based on Section 2110 of *IBC* (2000) shall be permitted. For walls larger than 144 square feet or 15 feet in any dimension, the analytical procedure shall be used.

Glass block units and other nonstructural masonry not conforming with the requirements of Section 11.9.1.3.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.1.3.2 Component Behavior and Rehabilitation Methods

Glass block and nonstructural masonry are both acceleration- and deformation sensitive. Failure in-plane generally occurs by deformation in the surrounding structure that results in unit cracking and displacement along the cracks. Failure out-of-plane takes the form of dislodgment or collapse caused by direct acceleration.

Nonconformance with deformation criteria requires limiting structural drift, or special detailing to isolate the glass block wall from the surrounding structure to permit the required drift. The drift analysis should consider the construction and behavior of the veneer and its backing to assess the individual parts of the nonstructural component that are required to deform in order to accommodate the required drift. These parts of the nonstructural component should be checked for their capability to allow for the calculated deformation of the structure. Sufficient reinforcing must be provided to deal with out-of-plane forces. Large walls may need to be subdivided by additional structural supports into smaller areas that can meet the drift or force criteria.

11.9.1.3.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

1. **Life Safety Nonstructural Performance Level.** Glass block and other nonstructural masonry walls and their enclosing framing, shall be capable of resisting both in-plane and out-of-plane forces computed in accordance with Section 11.7.3 or 11.7.4, or shall meet the requirements of the Prescriptive Procedure if permitted. The drift ratio calculated in accordance with Section 11.7.5 shall be limited to 0.02.

2. **Immediate Occupancy Nonstructural Performance Level.** Glass block and other nonstructural masonry walls and their enclosing framing shall be capable of resisting both in-plane and out-of-plane forces computed in accordance with Section 11.7.4. The drift ratio calculated in accordance with Section 11.7.5 shall be limited to 0.01.

11.9.1.3.4 Evaluation Requirements

Glass block units and other nonstructural masonry shall be evaluated based on the criteria of Section 2110 of *IBC* (2000).

11.9.1.4 Prefabricated Panels

11.9.1.4.1 Definition and Scope

The following types of prefabricated panels designed to resist wind, seismic, and other applied forces shall be rehabilitated in accordance with this section:

1. Precast concrete, and concrete panels with facing (generally stone) laminated or mechanically attached.

2. Laminated metal-faced insulated panels.

3. Steel strong-back panels with insulated, water- resistant facing, or mechanically attached metal or stone facing.

C11.9.1.4.1 Definition and Scope

Prefabricated panels are generally attached at discreet locations around their perimeters to the structural framing with mechanical connections.

11.9.1.4.2 Component Behavior and Rehabilitation Methods

Prefabricated panels shall be considered both acceleration- and deformation-sensitive.

Prefabricated panels not conforming to the acceptance criteria of Section 11.9.1.4.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.1.4.2 Component Behavior and Rehabilitation Methods

Lightweight panels may be damaged by racking; heavy panels may be dislodged by direct acceleration, which distorts or fractures the mechanical connections. The imposed in-plane and out-of-plane deformations are generally accommodated by the connections and not by the prefabricated panels. These connections need to be checked for the detailing to accommodate the required drift. This is generally accomplished by a connection detailed to allow sliding with a slotted or oversize hole. Drift can also be accommodated by deformation of the connections.

Excessive deformation of the supporting structure - most likely if it is a frame - may result in the panels imposing external racking forces on one another and distorting or fracturing their connections, with consequent displacement or dislodgment.

Drift analysis is necessary to establish conformance with drift acceptance criteria related to the Nonstructural Performance Level. The drift analysis should consider the construction and behavior of the panel and its connections to assess the individual parts of the nonstructural component that are required to deform in order to accommodate the required drift.

Nonconformance requires limiting structural drift, or special detailing to isolate panels from the structure to permit the required drift; this generally requires panel removal. Defective connections must be replaced.

11.9.1.4.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

1. **Life Safety Nonstructural Performance Level.** Prefabricated panels and connections shall be capable of resisting in-plane and out-of-plane forces computed in accordance with Section 11.7.3 or 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.02.

2. **Immediate Occupancy Nonstructural Performance Level.** Prefabricated panels and connections shall be capable of resisting in-plane and out-of-plane forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.01.

11.9.1.4.4 Evaluation Requirements

Connections shall be visually inspected and tested to determine capacity if any signs of deterioration or displacement are visible.

11.9.1.5 Glazed Exterior Wall Systems

11.9.1.5.1 Definition and Scope

Glazed exterior wall systems shall include the following types of assemblies:

1. Glazed curtain wall systems that extend beyond the edges of structural floor slabs, and are assembled from prefabricated units (e.g., "unitized" curtain wall systems) or assembled on site (e.g., "stick" curtain wall systems).

2. Glazed storefront systems that are installed between structural floor slabs and are prefabricated or assembled on site.

3. Structural silicone glazing in which silicone sealant is used for the structural transfer of loads from the glass to its perimeter support system and for the retention of the glass in the opening.

C11.9.1.5.1 Definition and Scope

The following types of glass are used within each of the glazed exterior wall systems:

1. Annealed glass.

2. Heat-strengthened glass.

3. Fully tempered glass.

4. Laminated glass.

5. Sealed insulating glass units.

The use of some of these glass types is regulated in building codes.

There are two glazing methods for installing glass in glazed curtain wall and glazed storefront systems:

1. Wet glazing, which can utilize three types of materials:
    1.1. Pre-formed tape.
    1.2. Gunable elastomeric sealants.
        a. Non-curing.
        b. Curing.
    1.3. Putty and glazing compounds.
2. Dry glazing, which utilizes extruded rubber gaskets as one or both of the glazing seals.

11.9.1.5.2 Component Behavior and Rehabilitation Methods

Glazed exterior wall systems shall be considered both deformation-sensitive and acceleration-sensitive.

Glazed exterior wall systems not conforming to the acceptance criteria of Section 11.9.1.5.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.1.5.2 Component Behavior and Rehabilitation Methods

Glazed exterior wall systems are predominantly deformation-sensitive but may also become displaced or detached by large acceleration forces. Glass components within glazed exterior wall systems are deformation-sensitive. Glass performance during earthquakes, which is a function of the wall system type, glazing type, and glass type, falls into one of four categories:

1. Glass remains unbroken in its frame or anchorage.
2. Glass shatters but remains in its frame or anchorage while continuing to provide a weather barrier, and remains otherwise serviceable.
3. Glass shatters and remains in its frame or anchorage in a precarious condition, liable to fall out at any time.
4. Glass falls out of its frame or anchorage, either in fragments, shards, or whole panels.

Drift analysis and testing or compliance with prescriptive procedures are necessary to establish conformance with drift acceptance criteria related to performance level. Nonconformance requires limiting structural drift, or special detailing to isolate the glazing system from the structure to accommodate drift, or selection of a glass type that will shatter safely or remain in the frame when shattered. This would require removal of the glass or glazed wall system and replacement with an alternative design.

11.9.1.5.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

1. **Life Safety Nonstructural Performance Level.** Glazed exterior wall systems and their supporting structure shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4. Glass components meeting any of the following criteria need not be rehabilitated for the Hazards Reduced or Life Safety Nonstructural Performance Level:

   1.1. Any glass component with sufficient clearance from the frame such that physical contact between the glass and the frame will not occur at the relative seismic displacement that the component must be designed to accommodate, as demonstrated by Equation (11-10).

$$D_{clear} \geq 1.25 D_p \qquad (11\text{-}10)$$

where:

$$D_{clear} = 2c_1\left(1 + \frac{h_p c_2}{b_p c_1}\right)$$

h_p = height of rectangular glass

b_p = width of rectangular glass

c_1 = clearance (gap) between vertical glass edges and the frame

c_2 = clearance (gap) between horizontal glass edges and the frame

D_p = relative seismic displacement that the component must be designed to accommodate. D_p shall be determined by Equation (11-9) over the height of the glass component under consideration.

   1.2. Fully tempered monolithic glass that is located no more than 10 ft. above a walking surface.

   1.3. Annealed or heat-strengthened laminated glass in single thickness with interlayer no less than 0.03 in. that is captured mechanically in a wall system glazing pocket, and whose perimeter is secured to the wall system frame by a wet-glazed perimeter bead of 1/2 in. minimum glass contact width, or other approved anchorage system.

1.4. Any glass component that meets the relative displacement requirement of Equation (11-11).

$$\Delta_{fallout} \geq 1.25 D_p \qquad (11\text{-}11)$$

or 0.5 inch, whichever is greater,

where:

D_p = relative seismic displacement that the component must be designed to accommodate

$\Delta_{fallout}$ = relative seismic displacement (drift) causing glass fallout from the curtain wall, storefront, or partition, as determined in accordance with an approved engineering analysis method

2. **Immediate Occupancy Nonstructural Performance Level.** Glazed exterior wall systems and their supporting structure shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4. Glass components meeting any of the following criteria need not be rehabilitated for performance levels higher than the Life Safety Nonstructural Performance Level:

2.1. Any glass component with sufficient clearance from the frame such that physical contact between the glass and the frame will not occur at the relative seismic displacement that the component must be designed to accommodate, as demonstrated by Equation (11-10).

2.2. Annealed or heat-strengthened laminated glass in single thickness with interlayer no less than 0.03 in. that is captured mechanically in a wall system glazing pocket, and whose perimeter is secured to the wall system frame by a wet-glazed perimeter bead of 1/2 in. minimum glass contact width, or other approved anchorage system.

2.3. Any glass component that meets the relative displacement requirement of Equation (11-12).

$$\Delta_{fallout} \geq 1.5 \text{ x } 1.25 D_p \qquad (11\text{-}12)$$

or 0.5 inch, whichever is greater.

C11.9.1.5.3 Acceptance Criteria

One method of determining $\Delta_{fallout}$, which is used in Equation (11-11), is to use AAMA 501.4.

D_{clear} in Equation (11-10) is derived from a similar equation in Bouwkamp and Meehan (1960) that permits calculation of the story drift required to cause glass-to-frame contact in a given rectangular window frame. Both equations are based on the principle that a rectangular window frame (specifically one that is anchored mechanically to adjacent stories of the primary structural system of the building) becomes a parallelogram as a result of story drift, and that glass-to-frame contact occurs when the length of the shorter diagonal of the parallelogram is equal to the diagonal of the glass panel itself.

The 1.25 factor in Equations (11-11) and (11-12) reflect uncertainties associated with calculated inelastic seismic displacements in building structures. Wright (1989) stated that "post-elastic deformations calculated using the structural analysis process may well underestimate the actual building deformation by up to 30%. It would therefore be reasonable to require the curtain wall glazing system to withstand 1.25 times the computed maximum story displacement to verify adequate performance." Wright's comments form the basis for using the 1.25 factor.

11.9.1.5.4 Evaluation Requirements

To establish compliance with criteria 1.1, 1.2, 1.3, 2.1, or 2.2 in 11.9.1.5.3, glazed exterior wall systems shall be evaluated visually to determine glass type, support details, mullion configuration, sealant type, and anchors. To establish compliance with criteria 1.4 or 2.3, an approved analysis shall be used.

C11.9.1.5.4 Evaluation Requirements

Alternatively, to establish compliance with criteria 1.4 or 2.3, glazed exterior wall systems may be tested in accordance with AAMA 501.4.

11.9.2 Partitions

11.9.2.1 Definition and Scope

Partitions shall include vertical non-load-bearing interior components that provide space division.

Heavy partitions shall include partitions constructed of masonry materials or assemblies.

Light partitions shall include partitions constructed of metal or wood studs surfaced with lath and plaster, gypsum board, wood, or other facing materials.

11.9.2.1.1 Evaluation Requirements

Glazed partitions that span from floor to ceiling or to the underside of floor or roof above shall be rehabilitated in accordance with Section 11.9.1.5.

C11.9.2.1 Definition and Scope

Heavy partitions include hollow clay tile or concrete block. Only non-load bearing partitions are considered in this section. Structural partitions including heavy masonry partitions shall be rehabilitated in accordance with Chapter 7.

Partitions may span laterally from floor to underside of floor or roof above, with connections at the top that may or may not allow for isolation from in-plane drift. Other partitions extend only up to a hung ceiling, and may or may not have lateral bracing above that level to structural support, or may be freestanding.

Modular office furnishings that include movable partitions are considered as contents rather than partitions, and as such are not within the scope of this standard.

11.9.2.2 Component Behavior and Rehabilitation Methods

Partitions shall be considered both acceleration- and deformation-sensitive.

Partitions not meeting the acceptance criteria of Section 11.9.2.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.2.2 Component Behavior and Rehabilitation Methods

Partitions attached to the structural floors both above and below, and loaded in-plane, can experience shear cracking, distortion and fracture of the partition framing, and detachment of the surface finish because of structural deformations. Similar partitions loaded out-of-plane can experience flexural cracking, failure of connections to structure, and collapse. The high incidence of unsupported block partitions in low and moderate seismic levels represents a significant collapse threat.

Partitions subject to deformations from the structure can be protected by providing a continuous gap between the partition and the surrounding structure, combined with attachment that provides for in-plane movement but out-of-plane restraint. Lightweight partitions that are not part of a fire-resistive system are regarded as replaceable.

11.9.2.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.2.3.1 Life Safety Nonstructural Performance Level

1. **Heavy Partitions.** Nonstructural heavy partitions shall be capable of resisting out-of-plane forces computed in accordance with Section 11.7.3 or 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.01.

2. **Light Partitions.** Nonstructural light partitions need not be rehabilitated for the Life Safety Nonstructural Performance Level.

11.9.2.3.2 Immediate Occupancy Nonstructural Performance Level

1. **Heavy Partitions.** Nonstructural heavy partitions shall be capable of resisting out-of-plane forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.005.

2. **Light Partitions.** Nonstructural light partitions shall be capable of resisting the out-of-plane forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.01.

11.9.2.4 Evaluation Requirements

Partitions shall be evaluated to ascertain the type of material.

C11.9.2.4 Evaluation Requirements

For concrete block partitions, presence of reinforcing and connection conditions at edges are important. For light partitions, bracing or anchoring of the top of the partitions is important.

11.9.3 Interior Veneers

11.9.3.1 Definition and Scope

Interior veneers shall include decorative-finish materials applied to interior walls and partitions. These provisions of this section shall apply to veneers mounted four feet or more above the floor.

11.9.3.2 Component Behavior and Rehabilitation Methods

Interior veneers shall be considered deformation-sensitive.

Interior veneers not conforming to the acceptance criteria of Section 11.9.3.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.3.2 Component Behavior and Rehabilitation Methods

Interior veneers typically experience in-plane cracking and detachment, but may also be displaced or detached out-of-plane by direct acceleration. Interior partitions loaded out-of-plane and supported on flexible backup support systems can experience cracking and detachment.

Drift analysis is necessary to establish conformance with drift acceptance criteria related to the Nonstructural Performance Level. Nonconformance requires limiting structural drift, or special detailing to isolate the veneer support system from the structure to permit drift; this generally requires disassembly of the support system and veneer replacement. Inadequately adhered veneer must be replaced.

11.9.3.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.3.3.1 Life Safety Nonstructural Performance Level

Backing shall be adequately attached to resist seismic design forces computed in accordance with Section 11.7.3 or 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to 0.02.

11.9.3.3.2 Immediate Occupancy Nonstructural Performance Level

Backing shall be adequately attached to resist seismic design forces computed in accordance with Section 11.7.4. The drift ratio computed in accordance with Section 11.7.5 shall be limited to is 0.01.

11.9.3.4 Evaluation Requirements

Backup walls or other supports and the attachments to that support shall be evaluated, as well as the condition of the veneer itself.

11.9.4 Ceilings

11.9.4.1 Definition and Scope

Ceilings shall be categorized as one of the following types:

1. **Category a.** Surface-applied or furred with materials that are applied directly to wood joists, concrete slabs, or steel decking with mechanical fasteners or adhesives.

2. **Category b.** Short-dropped gypsum board sections (less than 2 feet drop) attached to wood or metal furring supported by carrier members.

3. **Category c.** Dropped gypsum board sections greater than 2 feet and suspended metal lath and plaster.

4. **Category d.** Suspended acoustical board inserted within T-bars, together with lighting fixtures and mechanical items, to form an integrated ceiling system.

C11.9.4.1 Definition and Scope

Furring materials include wood or metal furring acoustical tile, gypsum board, plaster, or metal panel ceiling materials.

Some older buildings have heavy decorative ceilings of molded plaster, which may be directly attached to the structure or suspended; these are typically Category a or Category c ceilings.

11.9.4.2 Component Behavior and Rehabilitation Methods

Ceiling systems shall be considered both acceleration- and deformation-sensitive.

Ceilings not conforming to the acceptance criteria of Section 11.9.4.3 shall be rehabilitated in accordance with Section 11.8.

Where rehabilitation is required for ceilings in Category a or b, they shall be strengthened to resist seismic design forces computed in accordance with Section 11.7.3 or 11.7.4. Where rehabilitation is required for ceilings in Category d, they shall be rehabilitated by the Prescriptive Procedure of Section 11.2.

C11.9.4.2 Component Behavior and Rehabilitation Methods

Surface-applied or furred ceilings are primarily influenced by the performance of their supports. Rehabilitation of the ceiling takes the form of ensuring good attachment and adhesion. Metal lath and plaster ceilings depend on their attachment and bracing for large ceiling areas. Analysis is necessary to establish the acceleration forces and deformations that must be accommodated. Suspended integrated ceilings are highly susceptible to damage if not braced, causing distortion of grid and loss of panels; however, this is not regarded as a life safety threat with lightweight panels (less than two pounds per square foot).

Rehabilitation takes the form of bracing, attachment, and edge details designed to prescriptive design standards such as *CISCA 1991* for seismic levels 0-2 and in *CISCA 1990* for seismic levels 3 and 4.

11.9.4.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.4.3.1 Life Safety Nonstructural Performance Level

Ceilings in Categories a, b, or d need not be rehabilitated for the Life Safety Performance Level except as noted in the footnotes to Table 11-1. Ceilings in Category c shall be capable of accommodating the relative displacement computed in accordance with Section 11.7.3 or 11.7.4.

11.9.4.3.2 Immediate Occupancy Nonstructural Performance Level

Ceilings in category a or b shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4. Ceilings in category c shall be capable of accommodating the relative displacement computed in accordance with Section 11.7.5. Ceilings in category d shall be rehabilitated by the Prescriptive Procedure of Section 11.7.2.

11.9.4.4 Evaluation Requirements

The condition of the ceiling finish material, its attachment to the ceiling support system, the attachment and bracing of the ceiling support system to the structure, and the potential seismic impacts of other nonstructural systems on the ceiling system shall be evaluated.

11.9.5 Parapets and Appendages

11.9.5.1 Definition and Scope

Parapets and appendages shall include exterior nonstructural features that project above or away from the building. They shall include sculptures and ornamental features in addition to concrete, masonry, or terra cotta parapets. The following parapets and appendages shall be rehabilitated in accordance with this section.

1. Unreinforced masonry parapets with an aspect ratio greater than 1.5.

2. Reinforced masonry or reinforced concrete parapets with an aspect ratio greater than 3.0.

3. Cornices or ledges constructed of stone, terra cotta, or brick, unless supported by a steel or reinforced concrete structure.

4. Sculptures and ornamental features constructed of stone, terra cotta, masonry, or concrete with an aspect ratio greater than 1.5.

The aspect ratio of parapets and appendages shall be defined as the height of the component above the level of anchorage (h) divided by the width of the component (d) as shown in Figure 11-1. For horizontal projecting appendages, the aspect ratio shall be defined as the ratio of the horizontal projection beyond the vertical support of the building to the perpendicular dimension.

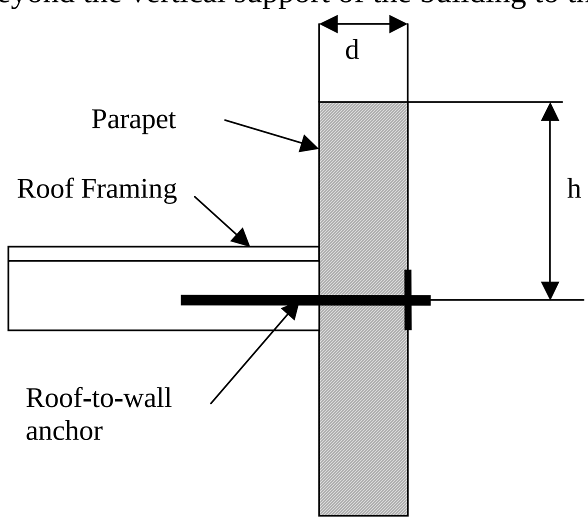

Figure 11-1 Parapet Aspect Ratio

C11.9.5.1 Definition and Scope

Other appendages, such as flagpoles and signs that are similar to the above in size, weight, or potential consequence of failure, may be rehabilitated in accordance with this section.

11.9.5.2 Component Behavior and Rehabilitation Methods

Parapets and appendages shall be considered acceleration-sensitive in the out-of-plane direction.

Parapets and appendages not conforming to the requirements of Section 11.9.5.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.5.2 Component Behavior and Rehabilitation Methods

Materials or components that are not properly braced may become disengaged and topple; the results are among the most seismically serious consequences of any nonstructural components.

Prescriptive design strategies for masonry parapets not exceeding four feet in height consist of bracing in accordance with the concepts shown in FEMA 74 and FEMA 172, with detailing to conform to accepted engineering practice. Braces for parapets should be spaced at a maximum of eight feet on center and, where the parapet construction is discontinuous, a continuous backing component should be provided. Where there is no adequate connection, roof construction should be tied to parapet walls at the roof level. Other parapets and appendages should be analyzed for acceleration forces, and braced and connected according to accepted engineering principles.

11.9.5.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.5.3.1 Life Safety Nonstructural Performance Level

Parapets and appendages exceeding the aspect ratios from Section 11.9.5.1 shall be capable of resisting seismic forces computed in accordance with Section 11.7.4.

11.9.5.3.2 Immediate Occupancy Nonstructural Performance Level

Parapets and appendages shall be capable of resisting seismic forces computed in accordance with Section 11.7.4.

11.9.5.4 Evaluation Requirements

The condition of mortar and masonry, connection to supports, type and stability of the supporting structure, and horizontal continuity of the parapet coping, shall be considered in the evaluation.

11.9.6 Canopies and Marquees

11.9.6.1 Definition and Scope

Canopies shall include projections from an exterior wall that are extensions of the horizontal building structure or independent structures that are tied to the building. Marquees shall include free-standing structures. Canvas or other fabric projections need not be rehabilitated in accordance with this section.

C11.9.6.1 Definition and Scope

Canopies and marquees are generally used to provide weather protection.

Marquees are often constructed of metal or glass.

11.9.6.2 Component Behavior and Rehabilitation Methods

Canopies and marquees shall be considered acceleration-sensitive.

Canopies and marquees not conforming to the acceptance criteria of Section 11.9.6.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.6.2 Component Behavior and Rehabilitation Methods

The variety of design of canopies and marquees is so great that they must be independently analyzed and evaluated for their ability to withstand seismic forces. Rehabilitation may take the form of improving attachment to the building structure, strengthening, bracing, or a combination of measures.

11.9.6.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.6.3.1 Life Safety Nonstructural Performance Level

Canopies and marquees shall be capable of resisting both horizontal and vertical seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.9.6.3.2 Immediate Occupancy Nonstructural Performance Level

Canopies and marquees shall be capable of resisting both horizontal and vertical seismic design forces computed in accordance with Section 11.7.4.

11.9.6.4 Evaluation Requirements

Buckling in bracing, connection to supports, and type and stability of the supporting structure shall be considered in the evaluation.

11.9.7 Chimneys and Stacks

11.9.7.1 Definition and Scope

Chimneys and stacks that are cantilevered above building roofs shall be rehabilitated in accordance with this section. Light metal residential chimneys need not comply with the provisions of this document.

11.9.7.2 Component Behavior and Rehabilitation Methods

Chimneys and stacks shall be considered acceleration-sensitive.

Chimneys and stacks not conforming to the acceptance criteria of Section 11.9.7.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.7.2 Component Behavior and Rehabilitation Methods

Chimneys and stacks may fail through flexure, shear, or overturning. They may also disengage from adjoining floor or roof structures and damage them, and their collapse or overturning may also damage adjoining structures. Rehabilitation may take the form of strengthening and/or bracing and material repair. Residential chimneys may be braced in accordance with the concepts shown in FEMA 74.

11.9.7.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.7.3.1 Life Safety Nonstructural Performance Level

Chimneys and stacks shall be capable of resisting seismic forces computed in accordance with Section 11.7.3 or 11.7.4. Residential chimneys shall be permitted to meet the prescriptive requirements of Section 11.7.2.

11.9.7.3.2 Immediate Occupancy Nonstructural Performance Level

Chimneys and stacks shall be capable of resisting seismic forces computed in accordance with Section 11.7.4. Residential chimneys shall be permitted to meet the prescriptive requirements of Section 11.7.2.

11.9.7.4 Evaluation Requirements

The condition of the mortar and masonry, connection to adjacent structure, and type and stability of foundations shall be considered in the evaluation.

Concrete shall be evaluated for spalling and exposed reinforcement. Steel shall be evaluated for corrosion.

11.9.8 Stairs and Stair Enclosures

11.9.8.1 Definition and Scope

Stairs shall include the treads, risers, and landings that make up passageways between floors, as well as the surrounding shafts, doors, windows, and fire-resistant assemblies that constitute the stair enclosure.

11.9.8.2 Component Behavior and Rehabilitation Methods

Each of the separate components of the stairs shall be defined as either acceleration- or deformation-sensitive depending on the predominant behavior. Components of stairs that are attached to adjacent floors or floor framing shall be considered deformation sensitive. All other stair components shall be considered acceleration-sensitive.

Stairs not conforming to the acceptance criteria of Section 11.9.8.3 shall be rehabilitated in accordance with Section 11.8.

C11.9.8.2 Component Behavior and Rehabilitation Methods

The stairs themselves may be independent of the structure, or integral with the structure. If integral, they should form part of the overall structural evaluation and analysis, with particular attention paid to the possibility of response modification due to localized stiffness. If independent, the stairs must be evaluated for normal stair loads and their ability to withstand direct acceleration or loads transmitted from the structure through connections.

Stair enclosure materials may fall and render the stairs unusable due to debris.

Rehabilitation of integral or independent stairs may take the form of necessary structural strengthening or bracing, or the introduction of connection details to eliminate or reduce interaction between stairs and the building structure.

Rehabilitation of enclosing walls or glazing should follow the requirements of the relevant sections of this document.

11.9.8.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.8.3.1 Life Safety Nonstructural Performance Level

Stairs shall be capable of resisting the seismic design forces computed in accordance with Section 11.7.3 or 11.7.4 and shall be capable of accommodating the expected relative displacement computed in accordance with Section 11.7.5.

11.9.8.3.2 Immediate Occupancy Nonstructural Performance Level

Stairs shall be capable of resisting the seismic design forces computed in accordance with Section 11.7.4 and shall be capable of accommodating the expected relative displacement computed in accordance with Section 11.7.5.

11.9.8.4 Evaluation Requirements

The materials and condition of stair members and their connections to supports, and the types and stability of supporting and adjacent walls, windows, and other portions of the stair shaft system shall be considered in the evaluation.

11.9.9 Doors Required for Emergency Services Egress in Essential Facilities

11.9.9.1 Definition and Scope

Doors shall include apparatus garage door systems, their connections to fire stations, and other door systems and connections that are critical for egress of emergency services from buildings immediately following earthquakes.

C11.9.9.1

Door systems in essential facilities, such as fire stations or other structures necessary for emergency operations, can become jammed or otherwise inoperable due to building movements and racking of door openings and subsequently delay emergency response after an earthquake. Recent reports (Bello et al., 2006) have documented the vulnerability of fire station apparatus garage doors in past earthquakes and made recommendations for how this risk should be addressed.

11.9.9.2 Component Behavior and Rehabilitation Methods

Each of the separate components of the door systems shall be defined as either acceleration- or deformation-sensitive depending on the predominant behavior. Door jambs, vertical and horizontal tracks, rollers, and their connections shall be considered deformation sensitive.

11.9.9.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.9.9.3.1 Life Safety Nonstructural Performance Level

Door systems shall be capable of resisting the seismic design forces computed in accordance with Section 11.7.4. Doors and connections shall be capable of accommodating a drift ratio of 0.01 computed in accordance with Section 11.7.5. A deformation compatibility analysis shall demonstrate that door systems can accommodate the drifts such that the door can be manually opened or closed without binding.

11.9.9.3.2 Immediate Occupancy Nonstructural Performance Level

Door systems shall be capable of resisting the seismic design forces computed in accordance with Section 11.7.4. Doors and connections shall be capable of accommodating a drift ratio of 0.005 computed in accordance with Section 11.7.5. A deformation compatibility analysis shall demonstrate that door systems can accommodate the drifts such that the door can be manually opened or closed without binding.

11.9.9.4 Evaluation Requirements

The components of door systems, their connections to supports, and gaps and tolerances between the components shall be considered in the evaluation.

11.10 Mechanical, Electrical, and Plumbing Components: Definition, Behavior, and Acceptance Criteria

11.10.1 Mechanical Equipment

11.10.1.1 Definition and Scope

Equipment used for the operation of the building, and that meets one or more of the following criteria shall be rehabilitated in accordance with this section.

1. All equipment weighing over 400 pounds.
2. Unanchored equipment weighing over 100 pounds that does not have a factor of safety against overturning of 1.5 or greater where design loads, calculated in accordance with Section 11.7.3 or 11.7.4, are applied.
3. Equipment weighing over 20 pounds that is attached to ceiling, wall, or other support more than four feet above the floor.
4. Building operation equipment including
   - 4.1. Boilers and furnaces.
   - 4.2. Conveyors (nonpersonnel).
   - 4.3. HVAC system equipment, vibration-isolated.
   - 4.4. HVAC system equipment, non-vibration-isolated.
   - 4.5. HVAC system equipment mounted in-line with ductwork.

C11.10.1.1 Definition and Scope

Equipment such as manufacturing or processing equipment related to the occupant's business should be evaluated separately for the effects that failure due to a seismic event could have on the operation of the building.

11.10.1.2 Component Behavior and Rehabilitation Methods

Mechanical equipment shall be considered acceleration-sensitive.

Mechanical equipment not conforming to the acceptance criteria of Section 11.10.1.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.1.2 Component Behavior and Rehabilitation Methods

The provisions of Section 11.10 focus on position retention, which is a primary consideration for the Life Safety Performance Level.

At the Immediate Occupancy Performance Level, position retention alone may be insufficient to assure conformance with the stated goals of the performance level. The expectation is that while some nonstructural damage is expected, the building will function following the earthquake, provided utilities are available. To achieve this level of functionality, the designer must consider the essential post-earthquake functions of the building, and then identify those mechanical, electrical, and plumbing components that must operate for the building to function. Components may be identified as critical (components that must be functional) and non-critical (those components where function following an earthquake is desirable, but not essential to the continued occupancy of the building). For critical components where operability is vital, the requirements of Section 2.4.5 of the 2003 NEHRP Provisions provide methods for seismically qualifying the component.

Position retention failure of components consists of sliding, tilting, or overturning of floor- or roof-mounted equipment off its base, and possible loss of attachment (with consequent falling) for equipment attached to a vertical structure or suspended, and failure of piping or electrical wiring connected to the equipment

Construction of mechanical equipment to nationally recognized codes and standards, such as those approved by the American National Standards Institute, provides adequate strength to accommodate all normal and upset operating loads.

For position retention, basic rehabilitation consists of securely anchoring floor-mounted equipment by bolting, with detailing appropriate to the base construction of the equipment. ASHRAE RP–812 (ASHRAE, 1999) provides more information on designing and detailing seismic anchorage.

Function and operability of mechanical and electrical components is affected only indirectly by increasing design forces. However, on the basis of past earthquake experience, it may be reasonable to conclude that if structural integrity and stability are maintained, function and operability after an earthquake will be provided for many types of equipment components. For complex components, testing or experience may be the only reasonable way to improve the assurance of function and operability. Testing is a well-established alternative method of seismic qualification for small to medium size equipment. Several national standards have testing requirements adaptable for seismic qualification.

Seismic forces can be established by analysis using the default Equations (11-1) and (11-2). Equipment weighing over 400 pounds and located on the third floor or above (or on a roof of equivalent height) should be analyzed using Equations (11-4) and (11-5).

Existing attachments for attached or suspended equipment must be evaluated for seismic load capacity, and strengthened or braced as necessary. Attachments that provide secure anchoring eliminate or reduce the likelihood of piping or electrical distribution failure.

11.10.1.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.1.3.1 Life Safety Nonstructural Performance Level

Equipment anchorage shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.10.1.3.2 Immediate Occupancy Nonstructural Performance Level

Equipment anchorage shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.10.1.4 Evaluation Requirements

Equipment shall be analyzed to establish acceleration-induced forces, and supports, hold-downs, and bracing shall be visually evaluated.

C11.10.1.4 Evaluation Requirements

Existing concrete anchors may have to be tested by applying torque to the nuts to confirm that adequate strength is present.

11.10.2 Storage Vessels and Water Heaters

11.10.2.1 Definition and Scope

Storage vessels and water heaters shall include all vessels that contain fluids used for building operation.

Vessels shall be classified into one of the following two categories:

1. **Category 1.** Vessels with structural support of contents, in which the shell is supported by legs or a skirt.

2. **Category 2.** Flat-bottom vessels in which the weight of the contents is supported by the floor, roof, or a structural platform.

C11.10.2.1 Definition and Scope

The vessel may be fabricated of materials such as steel or other metals, or fiberglass, or it may be a glass-lined tank. These requirements may also be applied, with judgment, to vessels that contain solids that act as a fluid, and vessels containing fluids not involved in the operation of the building.

11.10.2.2 Component Behavior and Rehabilitation Methods

Tanks and vessels shall be considered acceleration-sensitive.

Tanks and vessels not conforming to the acceptance criteria of Section 11.10.2.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.2.2 Component Behavior and Rehabilitation Methods

Category 1 vessels fail by stretching of anchor bolts, buckling and disconnection of supports, and consequent tilting or overturning of the vessel. A Category 2 vessel may be displaced from its foundation, or its shell may fail by yielding near the bottom, creating a visible bulge or possible leakage. Displacement of both types of vessel may cause rupturing of connecting piping and leakage.

Category 1 residential water heaters with a capacity no greater than 100 gallons may be rehabilitated by prescriptive design methods, such as concepts described in FEMA 74 or FEMA 172. Category 1 vessels with a capacity less than 1000 gallons should be designed to meet the force provisions of Section 11.7.3 or 11.7.4, and bracing strengthened or added as necessary. Other Category 1 and Category 2 vessels should be evaluated against a recognized standard, such as API 650 for vessels containing petroleum products or other chemicals, or AWWA D100-96 for water vessels. ASHRAE RP–812 (ASHRAE, 1999) provides more information on designing and detailing seismic anchorage and bracing.

11.10.2.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.2.3.1 Life Safety Nonstructural Performance Level

1. **Category 1 Equipment.** If the analytical procedure is selected based on Table 11-1, Category 1 equipment and supports shall be capable of resisting seismic forces computed in accordance with Section 11.7.3 or 11.7.4. If the prescriptive procedure is selected based on

Table 11-1, Category 1 equipment shall meet prescriptive requirements in accordance with Section 11.7.2.

2. **Category 2 Equipment.** If the analytical procedure is selected based on Table 11-1, Category 2 equipment and supports shall be capable of resisting seismic forces computed in accordance with Section 11.7.3 or 11.7.4. If the prescriptive procedure is selected based on Table 11-1, Category 2 equipment shall meet prescriptive requirements in accordance with Section 11.7.2.

11.10.2.3.2 Immediate Occupancy Nonstructural Performance Level

1. **Category 1 Equipment.** If the analytical procedure is selected based on Table 11-1, Category 1 equipment and supports shall be capable of resisting seismic forces computed in accordance with Section 11.7.4. If the prescriptive procedure is selected based on Table 11-1, Category 1 equipment shall meet prescriptive requirements in accordance with Section 11.7.2.

2. **Category 2 Equipment.** If the analytical procedure is selected based on Table 11-1, Category 2 equipment and supports shall be capable of resisting seismic forces computed in accordance with Section 11.7.4. If the prescriptive procedure is selected based on Table 11-1, Category 2 equipment shall meet prescriptive requirements in accordance with Section 11.7.2.

11.10.2.4 Evaluation Requirements

All equipment shall be visually evaluated to determine the existence of hold-downs, supports, and bracing.

C11.10.2.4 Evaluation Requirements

Existing concrete anchors may have to be tested by applying torque to the nuts to confirm that adequate strength is present.

11.10.3 Pressure Piping

11.10.3.1 Definition and Scope

The requirements of this section shall apply to all piping (except fire suppression piping) that carries fluids which, in their vapor stage, exhibit a pressure of 15 psi, gauge, or higher.

11.10.3.2 Component Behavior and Rehabilitation Methods

Piping shall be considered acceleration-sensitive. Piping that runs between floors or across seismic joints shall be considered both acceleration- and deformation-sensitive.

Piping not conforming to the acceptance criteria of Section 11.10.3.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.3.2 Component Behavior and Rehabilitation Methods

Appendix Chapter 6 of the 2003 NEHRP Provisions provides preliminary criteria for the establishment of such performance criteria and their use in the assessment and design of piping systems. The performance criteria, from least restrictive to most severe, are: position retention, leak tightness and operability. In particular, the interaction of systems and interface with the relevant piping design standards is addressed. For the Life Safety Performance level, the focus is on position retention, which is defined as the condition of a piping system characterized by the absence of collapse or fall of any part of the system.

For the Immediate Occupancy Nonstructural Performance Level, leak tightness, the condition of a piping system characterized by containment of contents or maintenance of a vacuum with no discernable leakage, is required. Operability, the condition of a piping system characterized by leak tightness as well as continued delivery, shutoff or throttle of pipe contents flow by means of unimpaired operation of equipment and components such as pumps, compressors and valves, is desirable, but requires significantly higher level of effort to achieve.

The most common failure of piping is joint failure, caused by inadequate support or bracing.

Rehabilitation is accomplished by prescriptive design approaches to support and bracing. Piping systems should be evaluated for compliance with consensus standards such as ASME B31, B31.1, B31.3, B31.4, B31.5, B31.8, B31.9, and B31.11 and ASHRAE where applicable. For large critical piping systems, the building official or responsible engineer must establish forces and evaluate supports. ASHRAE RP–812 (ASHRAE, 1999) provides more information on designing and detailing seismic bracing.

11.10.3.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.3.3.1 Life Safety Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, piping shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, piping shall be capable of resisting seismic forces computed in accordance with Section 11.7.3 or 11.7.4. Piping that runs between floors or across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.3.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, piping shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, piping shall be capable of resisting seismic forces computed in accordance with Section 11.7.4.

Piping that runs between floors or across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.3.4 Evaluation Requirements

High-pressure piping shall be tested by an approved method. Lines shall be hydrostatically tested to 150% of the maximum anticipated pressure of the system.

C11.10.3.4 Evaluation Requirements

High-pressure piping may be tested in accordance with ASME B31.9.

11.10.4 Fire Suppression Piping

11.10.4.1 Definition and Scope

Fire suppression piping shall include fire sprinkler piping consisting of main risers and laterals weighing, loaded, in the range of 30 to 100 pounds per lineal foot, with branches of decreasing size to two pounds per foot.

11.10.4.2 Component Behavior and Rehabilitation Methods

Fire suppression piping shall be considered acceleration-sensitive. Fire suppression piping that runs between floors or across seismic joints shall be considered both acceleration- and deformation-sensitive.

Fire suppression piping not conforming to the acceptance criteria of Section 11.9.4.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.4.2 Component Behavior and Rehabilitation Methods

The most common failure of fire suppression piping is joint failure, caused by inadequate support or bracing, or by sprinkler heads impacting adjoining materials.

Rehabilitation is accomplished by prescriptive design approaches to support and bracing. The prescriptive requirements of NFPA-13 should be used.

11.10.4.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.4.3.1 Life Safety Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, fire suppression piping shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, fire suppression piping shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4. Fire suppression piping that runs between floors or across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.4.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, fire suppression piping shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, fire suppression piping shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4. Fire suppression piping that runs between floors or across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.4.4 Evaluation Requirements

The support, flexibility, protection at seismic movement joints, and freedom from impact from adjoining materials at the sprinkler heads shall be evaluated.

C11.10.4.4 Evaluation Requirements

The support and bracing of bends of the main risers and laterals, as well as maintenance of adequate flexibility to prevent buckling, are especially important.

11.10.5 Fluid Piping other than Fire Suppression

11.10.5.1 Definition and Scope

Piping, other than pressure piping or fire suppression lines, that transfers fluids under pressure by gravity, or that are open to the atmosphere-including drainage and ventilation piping, hot, cold, and chilled water piping; and piping carrying liquids, as well as fuel gas lines-shall meet the requirements of this section.

Fluid piping other than fire suppression piping shall be classified into one of the following two categories:

1. **Category 1.** Hazardous materials and flammable liquids that would pose an immediate life safety danger if exposed, because of inherent properties of the contained material.

2. **Category 2.** Materials that, in case of line rupture, would cause property damage, but pose no immediate life safety danger.

C11.10.5.1 Definition and Scope

Hazardous materials and flammable liquids that would pose an immediate life safety danger if exposed are defined in NFPA 325-94, 49-94, 491M-91, and 704-90.

11.10.5.2 Component Behavior and Rehabilitation Methods

Fluid piping other than fire suppression piping shall be considered acceleration-sensitive. Piping that runs between floors or across seismic joints shall be considered both acceleration- and deformation-sensitive.

Fluid piping not conforming to the acceptance criteria of Section 11.10.5.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.5.2 Component Behavior and Rehabilitation Methods

The most common failure is joint failure, caused by inadequate support or bracing.

Category 1 piping rehabilitation is accomplished by strengthening support and bracing, using the prescriptive methods of SP-58. The piping systems themselves should be designed to meet the force provisions of Section 11.7.3 or 11.7.4 and relative displacement provisions of Section 11.7.5. The effects of temperature differences, dynamic fluid forces, and piping contents should be taken into account.

Category 2 piping rehabilitation is accomplished by strengthening support and bracing using the prescriptive methods of SP-58 as long as the piping falls within the size limitations of those guidelines. Piping that exceeds the limitations of those guidelines shall be designed to meet the force provisions of Section 11.7.3 or 11.7.4 and relative displacement provisions of Section 11.7.5.

More information on designing and detailing seismic bracing can be found in ASHRAE RP–812 (ASHRAE, 1999).

11.10.5.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.5.3.1 Life Safety Nonstructural Performance Level

1. **Category 1 piping systems.** If the Prescriptive Procedure is selected based on Table 11-1, fluid piping supports and bracing shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, fluid piping shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4. Piping that runs between floors and across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

2. **Category 2 piping systems.** If the Prescriptive Procedure is selected based on Table 11-1, fluid piping supports and bracing shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, fluid piping shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or

11.7.4. Piping that runs between floors and across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.5.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, fluid piping supports and bracing shall meet the prescriptive requirements of Section 11.7.2 for essential facilities. If the Analytical Procedure is selected based on Table 11-1, fluid piping shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4. Piping that runs between floors and across seismic joints shall be capable of accommodating relative displacements computed in accordance with Section 11.7.5.

11.10.5.4 Evaluation Requirements

The support, flexibility, and protection at seismic joints of fluid piping other than fire suppression piping shall be evaluated.

Piping shall be insulated from detrimental heat effects.

C11.10.5.4 Evaluation Requirements

The support and bracing of bends in the main risers and laterals, as well as maintenance of adequate flexibility to prevent buckling, are especially important.

11.10.6 Ductwork

11.10.6.1 Definition and Scope

Ductwork shall include HVAC and exhaust ductwork systems. Seismic restraints shall not be required for ductwork that is not conveying hazardous materials, and that meets either of the following conditions:

1. HVAC ducts are suspended from hangers 12 inches or less in length from the top of the duct to the supporting structure. Hangers shall be installed without eccentricities that induce moments in the hangers.

2. HVAC ducts have a cross-sectional area of less than six square feet.

11.10.6.2 Component Behavior and Rehabilitation Methods

Ducts shall be considered acceleration-sensitive. Ductwork that runs between floors or across seismic joints shall be considered both acceleration- and deformation-sensitive.

Ductwork not conforming to the acceptance criteria of Section 11.10.6.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.6.2 Component Behavior and Rehabilitation Methods

Damage to ductwork is caused by failure of supports or lack of bracing that causes deformation or rupture of the ducts at joints, leading to leakage from the system.

Rehabilitation consists of strengthening supports and strengthening or adding bracing. Prescriptive design methods may be used in accordance with SMACNA 1998. More information on designing and detailing seismic bracing can be found in ASHRAE RP–812 (ASHRAE, 1999).

11.10.6.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.6.3.1 Life Safety Nonstructural Performance Level

Ductwork shall meet the requirements of prescriptive standards in accordance with Section 11.7.2.

11.10.6.3.2 Immediate Occupancy Nonstructural Performance Level

Ductwork shall meet the requirements of prescriptive standards in accordance with Section 11.7.2.

11.10.6.4 Evaluation Requirements

Ductwork shall be evaluated visually to determine its length, connection type, and cross-sectional area.

11.10.7 Electrical and Communications Equipment

11.10.7.1 Definition and Scope

All electrical and communication equipment, including panel boards, battery racks, motor control centers, switch gear, and other fixed components located in electrical rooms or elsewhere in the building that meet any of the following criteria shall comply with the requirements of this section:

1. All equipment weighing over 400 pounds.

2. Unanchored equipment weighing over 100 pounds that does not have a factor of safety against overturning of 1.5 or greater where design loads computed in accordance with Section 11.7.3 or 11.7.4 are applied.

3. Equipment weighing over 20 pounds that is attached to ceiling, wall, or other support more than four feet above the floor.

4. Building operation equipment.

11.10.7.2 Component Behavior and Rehabilitation Methods

Electrical equipment shall be considered acceleration-sensitive.

Electrical equipment not conforming to the acceptance criteria of Section 11.10.7.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.7.2 Component Behavior and Rehabilitation Methods

Failure of these components consists of sliding, tilting, or overturning of floor- or roof-mounted equipment off its base, and possible loss of attachment (with consequent falling) for equipment attached to a vertical structure or suspended, and failure of electrical wiring connected to the equipment.

Construction of electrical equipment to nationally recognized codes and standards, such as those approved by the American National Standards Institute (ANSI), provides adequate strength to accommodate all normal and upset operating loads.

Basic rehabilitation consists of securely anchoring floor-mounted equipment by bolting, with detailing appropriate to the base construction of the equipment.

11.10.7.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.7.3.1 Life Safety Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, electrical equipment shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, electrical equipment shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.10.7.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, electrical equipment shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, electrical equipment shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.10.7.4 Evaluation Requirements

Equipment shall be visually evaluated to determine its category and the existence of the hold-downs, supports, and braces.

C11.10.7.4 Evaluation Requirements

Larger equipment requiring the Analytical Procedure must be analyzed to determine forces, and visually evaluated. Concrete anchors may have to be tested by applying torque to the nuts to confirm that adequate strength is present.

11.10.8 Electrical and Communications Distribution Components

11.10.8.1 Definition and Scope

All electrical and communications transmission lines, conduit, and cables, and their supports, shall comply with the requirements of this section.

11.10.8.2 Component Behavior and Rehabilitation Methods

Electrical distribution equipment shall be considered acceleration-sensitive. Wiring or conduit that runs between floors or across expansion or seismic joints shall be considered both acceleration- and deformation-sensitive.

Electrical and communications distribution components not conforming to the acceptance criteria of Section 11.10.8.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.8.2 Component Behavior and Rehabilitation Methods

Failure occurs most commonly by inadequate support or bracing, deformation of the attached structure, or impact from adjoining materials.

Rehabilitation may be accomplished by strengthening support and bracing using the prescriptive methods contained in *SMACNA 1980* and *1985*.

11.10.8.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.8.3.1 Life Safety Nonstructural Performance Level

Electrical and communications distribution components shall meet the requirements of prescriptive standards in accordance with Section 11.7.2.

11.10.8.3.2 Immediate Occupancy Nonstructural Performance Level

Electrical and communications distribution components shall meet the requirements of prescriptive standards for essential facilities in accordance with Section 11.7.2.

11.10.8.4 Evaluation Requirements

Components shall be visually evaluated to determine the existence of supports and bracing.

11.10.9 Light Fixtures

11.10.9.1 Definition and Scope

Lighting fixtures shall be classified into one of the following categories:

Category 1. Lighting recessed in ceilings.

Category 2. Lighting surface-mounted to ceilings or walls.

Category 3. Lighting supported within a suspended ceiling system (integrated ceiling).

Category 4. Lighting suspended from ceilings or structure by a pendant or chain.

11.10.9.2 Component Behavior and Rehabilitation Methods

Light fixtures not conforming to the acceptance criteria of Section 11.10.9.3 shall be rehabilitated in accordance with Section 11.8.

C11.10.9.2 Component Behavior and Rehabilitation Methods

Failure of Category 1 and 2 components occurs through failure of attachment of the light fixture and/or failure of the supporting ceiling or wall. Failure of Category 3 components occurs through loss of support from the T-bar system, and by distortion caused by deformation of the supporting structure or deformation of the ceiling grid system, allowing the fixture to fall. Failure of Category 4 components is caused by excessive swinging that results in the pendant or chain support breaking on impact with adjacent materials, or the support being pulled out of the ceiling.

Rehabilitation of Category 1 and 2 components involves attachment repair or fixture replacement in association with necessary rehabilitation of the supporting ceiling or wall. Rehabilitation of Category 3 components involves the addition of independent support for the fixture from the structure or substructure in accordance with FEMA 74 design concepts. Rehabilitation of Category 4 components involves strengthening of attachment and ensuring freedom to swing without impacting adjoining materials.

11.10.9.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.10.9.3.1 Life Safety Nonstructural Performance Level

1. **Categories 1 and 2.** The connection to ceiling or wall shall be present with no visible signs of distress.

2. **Category 3.** Systems bracing and support shall meet prescriptive requirements in accordance with Section 11.7.2.

3. **Category 4.** Fixtures weighing over 20 pounds shall be adequately articulated or connections to the building shall be ductile and the fixture shall be free to swing without impacting adjoining materials.

11.10.9.3.2 Immediate Occupancy Nonstructural Performance Level

1. **Categories 1 and 2.** The connection to ceiling or wall shall be present with no visible signs of distress.

2. **Category 3.** Systems bracing and support shall meet prescriptive requirements for essential facilities.

3. **Category 4.** Fixtures weighing over 20 pounds shall be articulated or connections to the building shall be ductile and the fixture shall be free to swing without impacting adjoining materials.

11.10.9.4 Evaluation Requirements

Light fixture supports shall be visually evaluated to determine the connection type and adequacy.

11.11 Furnishings and Interior Equipment: Definition, Behavior, and Acceptance Criteria

11.11.1 Storage Racks

11.11.1.1 Definition and Scope

Storage racks shall include systems for holding materials either permanently or temporarily.

C11.11.1.1 Definition and Scope

Storage racks are usually constructed of metal. Storage racks are generally purchased as proprietary systems installed by a tenant and are often not under the direct control of the building owner. Thus, they are usually not part of the construction contract, and often have no foundation or foundation attachment. However, they are often permanently installed, and their size and loaded weight make them an important hazard to either life, property, or the surrounding structure. Storage racks in excess of four feet in height located in occupied locations shall be considered where the Life Safety Nonstructural Performance Level is selected.

11.11.1.2 Component Behavior and Rehabilitation Methods

Storage racks shall be considered acceleration-sensitive.

Storage racks not conforming to the acceptance criteria of Section 11.11.1.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.1.2 Component Behavior and Rehabilitation Methods

Storage racks may fail internally-through inadequate bracing or moment-resisting capacity-or externally, by overturning caused by absence or failure of foundation attachments.

Rehabilitation is usually accomplished by the addition of bracing to the rear and side panels of racks and/or by improving the connection of the rack columns to the supporting slab. In rare instances, foundation improvements may be required to remedy insufficient bearing or uplift load capacity.

Seismic forces can be established by analysis in accordance with Section 11.7.3 or 11.7.4. However, special attention should be paid to the evaluation and analysis of large, heavily loaded rack systems because of their heavy loading and lightweight structural members.

11.11.1.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.1.3.1 Life Safety Nonstructural Performance Level

Storage racks shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.11.1.3.2 Immediate Occupancy Nonstructural Performance Level

Storage racks shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.11.1.4 Evaluation Requirements

Buckling or racking failure of storage rack components, connection to support structures, and type and stability of supporting structure shall be considered in the evaluation.

11.11.2 Bookcases

11.11.2.1 Definition and Scope

Bookcases constructed of wood or metal, in excess of four feet high, shall meet the requirements of this section.

11.11.2.2 Component Behavior and Rehabilitation Methods

Bookcases shall be considered acceleration-sensitive.

Bookcases not conforming to the acceptance criteria of Section 11.11.2.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.2.2 Component Behavior and Rehabilitation Methods

Bookcases may deform or overturn due to inadequate bracing or attachment to floors or adjacent walls, columns, or other structural members. Rehabilitation is usually accomplished by the addition of metal cross bracing to the rear of the bookcase to improve its internal resistance to racking forces, and by bracing the bookcase both in- and out-of-plane to the adjacent structure or walls to prevent overturning and racking.

11.11.2.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.2.3.1 Life Safety Nonstructural Performance Level

Bookcases shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.11.2.3.2 Immediate Occupancy Nonstructural Performance Level

Bookcases shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.11.2.4 Evaluation Requirements

The loading, type, and condition of bookcases, their connection to support structures, and type and stability of supporting structure shall be considered in the evaluation.

11.11.3 Computer Access Floors

11.11.3.1 Definition and Scope

Computer access floors shall include panelized, elevated floor systems designed to facilitate access to wiring, fiber optics, and other services associated with computers and other electronic components.

C11.11.3.1 Definition and Scope

Access floors vary in height but generally are less than three feet above the supporting structural floor. The systems include structural legs, horizontal panel supports, and panels.

11.11.3.2 Component Behavior and Rehabilitation Methods

Computer access floors shall be considered both acceleration- and deformation-sensitive.

Computer access floors not conforming to the acceptance criteria of Section 11.11.3.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.3.2 Component Behavior and Rehabilitation Methods

Computer access floors may displace laterally or buckle vertically under seismic loads. Rehabilitation of access floors usually includes a combination of improved attachment of computer and communication racks through the access floor panels to the supporting steel structure or to the underlying floor system, while improving the lateral-load-carrying capacity of the steel stanchion system by installing braces or improving the connection of the stanchion base to the supporting floor, or both.

Rehabilitation should be designed in accordance with concepts described in FEMA 74. The weight of the floor system, as well as supported equipment, should be included in the analysis.

11.11.3.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.3.3.1 Life Safety Nonstructural Performance Level

Computer access floors need not be rehabilitated for the Life Safety Nonstructural Performance Level.

11.11.3.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, prescriptive requirements of Section 11.7.2 shall be met. If the Analytical Procedure is selected based on Table 11-1, computer access floors shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.11.3.4 Evaluation Requirements

Buckling and racking of access floor supports, connection to the support structure, and the effects of mounted equipment shall be considered in the evaluation.

C11.11.3.4 Evaluation Requirements

Possible future equipment should also be considered in the evaluation.

11.11.4 Hazardous Materials Storage

11.11.4.1 Definition and Scope

Hazardous materials storage shall include permanently installed containers-freestanding, on supports, or stored on countertops or shelves-that hold materials defined to be hazardous by the National Institute for Occupational Safety and Health, including the following types:

1. Propane gas tanks.
2. Compressed gas vessels.
3. Dry or liquid chemical storage containers.

Large nonbuilding structures, such as large tanks found in heavy industry or power plants, floating-roof oil storage tanks, and large (greater than ten feet long) propane tanks at propane manufacturing or distribution plants need not meet the requirements of this section.

11.11.4.2 Component Behavior and Rehabilitation Methods

Hazardous materials storage shall be considered acceleration-sensitive.

Hazardous materials storage not conforming to the acceptance criteria of Section 11.11.4.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.4.2 Component Behavior and Rehabilitation Methods

Upset of the storage container may release the hazardous material. Failure occurs because of buckling and overturning of supports and/or inadequate bracing. Rehabilitation consists of strengthening and increasing supports or adding bracing designed according to concepts described in FEMA 74 and FEMA 172.

11.11.4.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.4.3.1 Life Safety Nonstructural Performance Level

Hazardous materials storage shall meet prescriptive requirements in accordance with Section 11.7.2.

11.11.4.3.2 Immediate Occupancy Nonstructural Performance Level

Hazardous materials storage shall meet prescriptive requirements for essential facilities in accordance with Section 11.7.2.

11.11.4.4 Evaluation Requirements

The location and types of hazardous materials, container materials, manner of bracing, internal lateral resistance, and the effect of hazardous material spills shall be considered in the evaluation.

11.11.5 Computer and Communication Racks

11.11.5.1 Definition and Scope

Computer and communication racks shall include free-standing rack systems in excess of four feet in height designed to support computer and other electronic equipment. Equipment stored on computer and communication racks need not meet the requirements of this section.

C11.11.5.1 Definition and Scope

Racks may be supported on either structural or access floors and may or may not be attached directly to these supports.

11.11.5.2 Component Behavior and Rehabilitation Methods

Computer and communication racks shall be considered acceleration-sensitive.

Computer communication racks not conforming to the acceptance criteria of Section 11.11.5.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.5.2 Component Behavior and Rehabilitation Methods

Computer and communication racks may fail internally-through inadequate bracing or moment-resisting capacity-or externally, by overturning caused by absence or failure of floor attachments.

Rehabilitation is usually accomplished by the addition of bracing to the rear and side panels of the racks, and/or by improving the connection of the rack to the supporting floor using concepts shown in FEMA 74 or FEMA 172.

11.11.5.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.5.3.1 Life Safety Nonstructural Performance Level

Computer and communication racks need not be rehabilitated for the Life Safety Nonstructural Performance Level.

11.11.5.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, computer and communication racks shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, computer and communication racks shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.11.5.4 Evaluation Requirements

Buckling or racking failure of rack components, their connection to support structures, and type and stability of the supporting structure shall be considered in the evaluation. The effect of rack failure on equipment shall also be considered.

11.11.6 Elevators

11.11.6.1 Definition and Scope

Elevators shall include cabs and shafts, as well as all equipment and equipment rooms associated with elevator operation, such as hoists, counterweights, cables, and controllers.

11.11.6.2 Component Behavior and Rehabilitation Methods

Components of elevators shall be considered acceleration-sensitive. Shafts and hoistway rails, which rise through multiple floors, shall be considered both acceleration- and deformation-sensitive.

Elevator components not conforming to the acceptance criteria of Section 11.11.6.2 shall be rehabilitated in accordance with Section 11.8.

C11.11.6.2 Component Behavior and Rehabilitation Methods

Components of elevators may become dislodged or derailed. Shaft walls and the construction of machinery room walls are often not engineered and must be considered in a way similar to that for other partitions. Shaft walls that are of unreinforced masonry or hollow tile must be considered with special care, since failure of these components violates Life Safety Nonstructural Performance Level criteria.

Elevator machinery may be subject to the same damage as other heavy floor-mounted equipment. Electrical power loss renders elevators inoperable.

Rehabilitation measures include a variety of techniques taken from specific component sections for partitions, controllers, and machinery. Rehabilitation specific to elevator operation can include seismic shutoffs, cable restrainers, and counterweight retainers; such measures should be in accordance with ASME A17.1.

11.11.6.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.6.3.1 Life Safety Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, elevator components shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, elevator components shall be capable of resisting seismic design forces computed in accordance with Section 11.7.3 or 11.7.4.

11.11.6.3.2 Immediate Occupancy Nonstructural Performance Level

If the Prescriptive Procedure is selected based on Table 11-1, elevator components shall meet the prescriptive requirements of Section 11.7.2. If the Analytical Procedure is selected based on Table 11-1, elevator components shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4.

11.11.6.4 Evaluation Requirements

The construction of elevator shafts shall be considered in the evaluation.

C11.11.6.4 Evaluation Requirements

The possibility of displacement or derailment of hoistway counterweights and cables should be considered, as should the anchorage of elevator machinery.

11.11.7 Conveyors

11.11.7.1 Definition and Scope

Conveyors shall include material conveyors, including all machinery and controllers necessary to operation.

11.11.7.2 Component Behavior and Rehabilitation Methods

Conveyors shall be considered both acceleration- and deformation-sensitive.

Conveyors not conforming to the acceptance criteria of Section 11.11.7.3 shall be rehabilitated in accordance with Section 11.8.

C11.11.7.2 Component Behavior and Rehabilitation Methods

Conveyor machinery may be subject to the same damage as other heavy floor-mounted equipment. In addition, deformation of adjoining building materials may render the conveyor inoperable. Electrical power loss renders the conveyor inoperable.

Rehabilitation of the conveyor involves prescriptive procedures using special skills provided by the conveyor manufacturer.

11.11.7.3 Acceptance Criteria

Acceptance criteria shall be applied in accordance with Section 11.3.2.

11.11.7.3.1 Life Safety Nonstructural Performance Level

Conveyors need not be rehabilitated for the Life Safety Nonstructural Performance Level.

11.11.7.3.2 Immediate Occupancy Nonstructural Performance Level

If the Analytical Procedure is selected based on Table 11-1, conveyors shall be capable of resisting seismic design forces computed in accordance with Section 11.7.4. If the Prescriptive Procedure is selected based on Table 11-1, conveyors shall meet prescriptive standards in accordance with Section 11.7.2.

11.11.7.4 Evaluation Requirements

The stability of machinery shall be considered in the evaluation.