11. Architectural, Mechanical, and Electrical Components (Simplified and Systematic Rehabilitation)

11.1 Scope

This chapter establishes rehabilitation criteria for architectural, mechanical, and electrical components and systems that are permanently installed in buildings, or are an integral part of a building system, including their supports and attachments. These components are collectively referred to as “nonstructural components.” Contents introduced into buildings by owners or occupants are not within the scope of the *Guidelines.*

Guidance for rehabilitating existing nonstructural components is included within this chapter, while new nonstructural components shall conform to the materials, detailing, and construction requirements for similar elements in new buildings.

Nonstructural components in historic buildings may be highly significant, especially if they are original to the building or innovative for their age. Guidance for their seismic rehabilitation should be sought from the State Historic Preservation Officer or other historic preservation specialist, and from specialized publications. Equally important are other nonseismic considerations, such as accessibility for the disabled, fire protection, and hazardous materials considerations (especially asbestos-containing nonstructural materials). The variety of such nonseismic factors is so great as to make it impossible to treat them in detail in this document.

The assessment process necessary to make a final determination of which nonstructural components are to be rehabilitated is not part of the *Guidelines*, but the subject is touched on briefly in Section 11.3, and the *Commentary* to this chapter provides an outline of an assessment procedure.

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

- A list of nonstructural components subject to Life Safety requirements of these *Guidelines*
- Rehabilitation requirements related to Seismic Zone and Life Safety Performance Level
- Identification of the required Analysis 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 these *Guidelines*; an extensive discussion in the *Commentary* reviews the issues involved if this topic is selected for consideration.

Section 11.5 offers a brief discussion of 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. Another set of equations sets out the Analytical Procedures for determining drift ratios and relative displacements. The general requirements for prescriptive procedures are also set out.

Section 11.8 notes the general ways in which nonstructural rehabilitation is carried out, with a more extended discussion in the *Commentary.*

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:

- Definition and scope
- Component behavior and rehabilitation concepts
- Acceptance criteria
- Evaluation requirements

Methods of rehabilitation are discussed in more detail in the *Commentary* for each component.

11.2 Procedural Steps

Once the general philosophy of Section 11.1 is understood, its use can be reduced to the following steps, conducted within the framework of a nonstructural hazard mitigation plan (discussed in the *Commentary*, Section C11.3.2).

1. Determine the Performance Level or Range desired.

2. Refer to Table 11-1 to determine for each nonstructural component the applicability of Life Safety or Immediate Occupancy requirements related to seismic zone, and required method of analysis.

3. Refer to Sections 11.9, 11.10, and 11.11 for acceptance criteria for each nonstructural component.

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

COMPONENT		High Seismicity		Moderate Seismicity		Low Seismicity		Analysis Method
		LS	IO	LS	IO	LS	IO	
A. ARCHITECTURAL								
1.	**Exterior Skin**							
	Adhered Veneer	Yes	Yes	Yes	Yes	No	Yes	F/D
	Anchored Veneer	Yes	Yes	Yes	Yes	No	Yes	F/D
	Glass Blocks	Yes	Yes	Yes	Yes	No	Yes	F/D
	Prefabricated Panels	Yes	Yes	Yes	Yes	Yes	Yes	F/D
	Glazing Systems	Yes	Yes	Yes	Yes	Yes	Yes	F/D
2.	**Partitions**							
	Heavy	Yes	Yes	Yes	Yes	No	Yes	F/D
	Light	No	Yes	No	Yes	No	Yes	F/D
3.	**Interior Veneers**							
	Stone, Including Marble	Yes	Yes	Yes	Yes	No	Yes	F/D
	Ceramic Tile	Yes	Yes	No	Yes	No	Yes	F/D
4.	**Ceilings**							
	a. Directly Applied to Structure	No[13]	Yes	No[13]	Yes	No	Yes	F
	b. Dropped. Furred, Gypsum Board	No	Yes	No	Yes	No	Yes	F
	c. Suspended Lath and Plaster	Yes	Yes	Yes	Yes	No	Yes	F
	d. Suspended Integrated Ceiling	No[11]	Yes	No[11]	Yes	No[11]	Yes	PR
5.	**Parapets and Appendages**	Yes	Yes	Yes	Yes	Yes	Yes	F[1]
6.	**Canopies and Marquees**	Yes	Yes	Yes	Yes	Yes	Yes	F
7.	**Chimneys and Stacks**	Yes	Yes	Yes	Yes	No	Yes	F[2]
8.	**Stairs**	Yes	Yes	Yes	Yes	Yes	Yes	*

Notes and definitions provided on page 11-4

Table 11-1 Nonstructural Components: Applicability of Life Safety and Immediate Occupancy Requirements and Methods of Analysis (continued)

		High Seismicity		Moderate Seismicity		Low Seismicity		
COMPONENT		**LS**	**IO**	**LS**	**IO**	**LS**	**IO**	**Analysis Method**
B. MECHANICAL EQUIPMENT								
1.	**Mechanical Equipment**							
	Boilers and Furnaces	Yes	Yes	Yes	Yes	Yes	Yes	F
	General Mfg. and Process Machinery	No[3]	Yes	No	Yes	No	Yes	F
	HVAC Equipment, Vibration-Isolated	No[3]	Yes	No	Yes	No	Yes	F
	HVAC Equipment, Non-Vibration-Isolated	No[3]	Yes	No	Yes	No	Yes	F
	HVAC Equipment, Mounted In-Line with Ductwork	No[3]	Yes	No	Yes	No	Yes	PR
2.	**Storage Vessels and Water Heaters**							
	Structurally Supported Vessels (Category 1)	No[3]	Yes	No	Yes	No	Yes	Note 4
	Flat Bottom Vessels (Category 2)	No[3]	Yes	No	Yes	No	Yes	Note 5
3.	**Pressure Piping**	Yes	Yes	No	Yes	No	Yes	Note 5
4.	**Fire Suppression Piping**	Yes	Yes	No	Yes	No	Yes	PR
5.	**Fluid Piping, not Fire Suppression**							
	Hazardous Materials	Yes	Yes	Yes	Yes	Yes	Yes	PR/F/D
	Nonhazardous Materials	No	Yes	No	Yes	No	Yes	PR/F/D
6.	**Ductwork**	No[6]	Yes	No[6]	Yes	No	Yes	PR
C. ELECTRICAL AND COMMUNICATIONS								
1.	**Electrical and Communications Equipment**	No[7]	Yes	No[7]	Yes	No	Yes	F
2.	**Electrical and Communications Distribution Equipment**	No[8]	Yes	No[8]	Yes	No	Yes	PR
3.	**Light Fixtures**							
	Recessed	No	No	No	No	No	No	
	Surface Mounted	No	No	No	No	No	No	
	Integrated Ceiling	Yes	Yes	Yes	Yes	No	Yes	PR
	Pendant	No[9]	Yes	No[9]	Yes	No	Yes	F

Notes and definitions provided on page 11-4

Table 11-1 Nonstructural Components: Applicability of Life Safety and Immediate Occupancy Requirements and Methods of Analysis (continued)

COMPONENT		High Seismicity		Moderate Seismicity		Low Seismicity		Analysis Method
		LS	IO	LS	IO	LS	IO	
D. FURNISHINGS AND INTERIOR EQUIPMENT								
1.	**Storage Racks**	Yes[10]	Yes	Yes[10]	Yes	No	Yes	F
2.	**Bookcases**	Yes	Yes	Yes	Yes	No	Yes	F
3.	**Computer Access Floors**	No	Yes	No	Yes	No	Yes	PR/FD
4.	**Hazardous Materials Storage**	Yes	Yes	No[12]	Yes	No[12]	Yes	PR
5.	**Computer and Communication Racks**	No	Yes	No	Yes	No	Yes	PR/F/D
6.	**Elevators**	Yes	Yes	Yes	Yes	No	Yes	F/D
7.	**Conveyors**	No	Yes	No	Yes	No	Yes	F/D

1. Unreinforced masonry parapets not over 4 ft in height may be rehabilitated to Prescriptive Design Concept.
2. Residential masonry chimneys may be rehabilitated to Prescriptive Design Concept.
3. Rehabilitation required to Life Safety Performance Level when:
   Equipment type A or B, or vessel, 6 ft or over in height
   Equipment type C
   Equipment forming part of an emergency power system
   Gas-fired equipment in occupied or unoccupied space
4. Residential water heaters with capacity less than 100 gal may be rehabilitated by Prescriptive Procedure. Other vessels to meet force provisions of Section 11.7.3 or 11.7.4.
5. Vessels or piping systems may be rehabilitated according to Prescriptive Standards. Large systems or vessels shall meet force provisions of Section 11.7.3 or 11.7.4; piping also shall meet drift provisions of Section 11.7.5.
6. Rehabilitation required when ductwork 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.
7. Rehabilitation required to Life Safety Performance Level when:
   Equipment is 6 ft or over in height
   Equipment weighs over 20 lbs.
   Equipment forms part of an emergency power and/or communication system
8. Rehabilitation required to Life Safety Performance Level when equipment forms part of an emergency lighting, power, and/or communication system
9. Rehabilitation required to Life Safety Performance Level when fixture weight per support exceeds 20 lbs.
10. Rehabilitation not required for storage racks in essentially unoccupied space.
11. Rehabilitation required to Life Safety Performance Level when panels exceed 2 lb/sq. ft and for Enhanced Rehabilitation Objectives.
12. Rehabilitation required where material is in close proximity to occupancy, and leakage can cause immediate life safety threat.
13. Rehabilitation required to achieve Life Safety Performance Level for poorly attached large areas (over 10 sq. ft) of plaster ceilings on metal or wood lath.

Key:

LS Life Safety Performance Level
IO Immediate Occupancy Performance Level
PR Prescriptive Procedure acceptable
F Analytical Procedure: force analysis, Section 11.7.3 or 11.7.4
F/D Analytical Procedure: force and relative displacement analysis, Sections 11.7.4 and 11.7.5
* Rehabilitate as required for individual components

4. Use equations in Section 11.7 to conduct any necessary analysis.
5. Develop any necessary design solutions to meet the force requirements, the deformation criteria, and any prescriptive requirements. For capacities of

nonstructural components and their connections refer to Chapters 5 through 8, or derive capacity values in a manner consistent with those chapters.

11.3 Historical and Component Evaluation Considerations

11.3.1 Historical Perspective

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 quite clear that damage to nonstructural elements could result in serious casualties, severe building functional impairment, and major economic losses even when the structural damage was not significant (Lagorio, 1990).

The architectural, mechanical, and electrical components and systems of a historic building may be very significant, especially if they are original to the building, very old, or innovative. An assessment of their significance by an appropriate professional—such as an architectural historian, historical preservation architect, or historian of engineering and technology—may be necessary. Historic buildings may also have 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.

Readers are referred to the *Commentary* to this section for further discussion and a chronology of the introduction of nonstructural considerations into seismic codes.

11.3.2 Component Evaluation

Procedures for detailed assessment to decide which existing nonstructural components should be rehabilitated are not part of these *Guidelines*. However, there is a brief discussion under “Evaluation Needs” in each component section. To achieve the Basic Safety Objective (BSO), nonstructural components as listed in Table 11-1 must meet the Life Safety Performance Level for specified ground motion, as defined in Chapter 2. In other cases—such as when the Limited Safety Performance Range applies—there may be more latitude in the selection of components for rehabilitation. A suggested procedure for the detailed evaluation of existing nonstructural components—with cost-effectiveness and a ranking of importance in mind—is outlined in the *Commentary*, Section C11.3.2.

11.4 Rehabilitation Objectives, Performance Levels, and Performance Ranges

The nonstructural Rehabilitation Objective may be the same as for the structural rehabilitation, or may differ, except for the BSO, in which case structural and nonstructural requirements specified in the *Guidelines* must be met.

These *Guidelines* are 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 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 even if only nonstructural components are to be rehabilitated, to properly take into account loads on nonstructural components generated by inertial forces or imposed deformations.

11.4.1 Performance Levels for Nonstructural Components

Four Nonstructural Performance Levels and three Structural Performance Levels are described in Chapter 2 of the *Guidelines*. For nonstructural components, the Collapse Prevention Performance Level does not, in general, apply, since most nonstructural damage resulting from a building at the Collapse Prevention damage state is regarded as acceptable. (Rehabilitation of parapets and heavy appendages is required, however, for conformance with the Collapse Prevention Building Performance Level.) The four defined Performance Levels applying to nonstructural components are:

- **Hazards Reduced Performance Level.** This represents a post-earthquake damage level in which extensive damage has occurred to nonstructural components but large or heavy items—such as parapets, cladding, plaster ceilings, or storage racks—posing a falling hazard to many people are prevented from falling.

- **Life Safety Performance Level**. This Performance Level is intended primarily to prevent nonstructural falling hazards that can directly cause injury. Excluded from the Life Safety Performance Level are specific criteria relating to post-earthquake nonstructural performance, such as egress, alarm and communications systems, fire protection systems, and other functional issues. The issue of egress protection, although not specifically addressed, is substantially taken care of by rehabilitation of relevant nonstructural components to the Life Safety Performance Level.

  Acceptance Criteria for the Life Safety Performance Level are provided in the sections on each nonstructural equipment category.

  Post-earthquake functional concerns are addressed within the Damage Control Performance Range and by the Immediate Occupancy Performance Level.

- **Immediate Occupancy Performance Level.** To attain this Performance Level, conformance with requirements for the Life Safety Performance Level must be met, together with the requirements for Immediate Occupancy where applicable.

Acceptance criteria for the Immediate Occupancy Performance Level are provided only in the sections on each nonstructural component category.

- **Operational Performance Level.** A theoretical Building Performance Level beyond Immediate Occupancy, this level depends on the continuing functioning of all utilities and systems, and, often, of other sensitive equipment. Specific criteria for nonstructural components for this Performance Level are not provided in these *Guidelines* because the critical components and systems are building-specific, and operational capability may be dependent on equipment over which the design team has no authority.

The procedure for attaining an Operational Performance Level is to use the criteria for Immediate Occupancy and develop additional criteria based on a detailed evaluation of the specific building relative to the operational functions to be maintained.

Tables 2-6 through 2-8 summarize nonstructural damage states in relation to Performance Levels.

11.4.2 Performance Ranges for Nonstructural Components

Including the Hazards Reduced Performance Level, below the Life Safety Nonstructural Performance Level, there are nonstructural rehabilitation damage states that will fall below or above the Life Safety Level. For example, it is possible to exceed the Life Safety Level but fall short of Immediate Occupancy, or exceed Immediate Occupancy but not meet Operational Performance Level requirements. Performance in excess of the Operational Performance Level is also conceivable, though unlikely. While the ranges may be conceptually referred to as Enhanced or Limited (relative to Life Safety), such ranges are not formally defined by the *Guidelines* for nonstructural components, nor are requirements specified.

11.4.3 Regional Seismicity and Nonstructural Components

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

11.4.4 Means of Egress: Escape and Rescue

Emergency post-earthquake access into and out of buildings is one of the aspects of nonstructural performance that may be selected for consideration in the Damage Control Performance Range. Because the Damage Control Performance Range is not specifically defined by requirements in the *Guidelines*, emergency escape and rescue criteria are not included within the *Guidelines*.

Preservation of egress is accomplished primarily by ensuring that the most hazardous nonstructural elements are replaced or rehabilitated. The items listed in Table 11-1 for achieving the Life Safety 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 FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (pp. 91–92, and pp. A-20) (BSSC, 1992b).

- Walls around stairs, elevator enclosures, and corridors are not hollow clay tile or unreinforced masonry.
- Stair enclosures do not contain any piping or equipment except as required for life safety.
- Veneers, cornices, and other ornamentation above building exits are well anchored to the structural system.
- 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.

- 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
- 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
- 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
- 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
- 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 Performance Level requirement. The last condition is very difficult to remove 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.

Refer to the *Commentary* for this section for further discussion of egress, escape, and rescue issues.

11.5 Structural-Nonstructural Interaction

11.5.1 Response Modification

In cases where a nonstructural component directly modifies the strength or stiffness of the building structural elements, or its mass affects the building loads, its characteristics should be considered in the structural analysis of the building. Particular care should be taken to identify masonry infill that could reduce the effective length of adjacent columns.

11.5.2 Base Isolation

Nonstructural components that cross the isolation interface in a base-isolated structure should be designed to accommodate the total maximum displacement of the isolator.

11.6 Acceptance Criteria for Acceleration-Sensitive and Deformation-Sensitive Components

11.6.1 Acceleration-Sensitive Components

Acceleration-sensitive components shall meet the force requirements derived from equations in Section 11.7. Acceleration-sensitive components are discussed, where necessary, in each component section (Sections 11.9, 11.10, and 11.11). 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 steps for application of acceleration-sensitive acceptance criteria are as follows:

1. Determination of the Rehabilitation Objective and associated Performance Level (see Table 11-1 for

the applicability of requirements keyed to the Life Safety Performance Level)

2. Determination of the seismicity—Low, Moderate, or High—as defined in Section 2.6.3

3. Application of design forces to the existing or modified component (Section 11.7), if the Analytical Procedure is required by Table 11-1; or, if the Prescriptive Procedure is acceptable according to Table 11-1, comparison of the existing component with required characteristics as defined in a reference or standard

4. Verification that the component can meet the acceptance criteria for the applicable Performance Level (see each specific component section, Sections 11.9, 11.10, and 11.11).

11.6.2 Deformation-Sensitive Components

Deformation-sensitive components shall meet the general acceptance criteria of this section, as well as additional requirements listed for specific components. The steps for application of deformation-sensitive acceptance criteria are:

1. Determination of the Rehabilitation Objective and associated Performance Level (see Table 11-1 for the applicability of requirements keyed to Performance Level) shall be made.

2. Determination of the seismicity—Low, Moderate, or High—as defined in Section 2.6.3, shall be made.

3. Determination of the deformation and associated drift ratio of the structural component(s) to which the deformation-sensitive nonstructural component is attached (see structural Analysis Procedures of preceding sections) shall be made.

4. Analysis shall be made of the nonstructural component's response to the deformation of the structure, including a consideration of the transfer of loads through the particular connection details of the nonstructural component, or comparison of the existing component with required characteristics as defined in a reference or standard, if the Prescriptive Procedure is acceptable according to Table 11-1.

5. Verification shall be made that the component can meet the acceptance criteria for the applicable Performance Level (see each specific component section, Sections 11.9, 11.10 and 11.11). In lieu of application of the specific acceptance criteria listed for each component, the following requirements may be used:

Life Safety Performance Level. The component meets deformation-sensitive acceptance criteria if the drift ratio at that story level is 0.01 or less. (This alternative will require consideration of glazing or other components that can hazardously fail at lesser drift ratios—depending on installation details—or components that can undergo greater distortion without hazardous failure resulting—for example, typical gypsum board partitions. This alternative may be appropriate only where the Prescriptive Procedure is allowed [though calculations are required here because the structure's drift must be known].)

Use of Drift Ratio Values as Acceptance Criteria. The data on drift ratio values related to damage states is 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 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 an absolute acceptance criterion that might require costly redesign of the structural rehabilitation. For further discussion, see the *Commentary* for this section.

11.6.3 Acceleration- and Deformation-Sensitive Components

Some components are both acceleration- and deformation-sensitive. They must be analyzed for conformance to acceptance criteria for both forms of response.

11.7 Analytical and Prescriptive Procedures

11.7.1 Application of Analytical and Prescriptive Procedures

There are two nonstructural rehabilitation procedures:

- Prescriptive Procedure
- Analytical Procedure

There are three analysis methods for calculating forces within the Analytical Procedure.

- Equation 11-1, a simple conservative default equation, may be used.
- Equations 11-2 and 11-3 offer more complete equivalent lateral force equations. In addition, Equations 11-4 and 11-5 should be used when drift is a consideration.
- Results from any structural analysis method allowed for the building's rehabilitation may be used, as long as Performance Level criteria, response modification factors, and other considerations are treated consistently. The Analytical Procedure is always acceptable; the Prescriptive Procedure is acceptable for the combinations of seismicity, Performance Level, and component listed in Table 11-1.

11.7.2 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.

Where a Prescriptive Procedure is allowed, the specific prescriptive references are given in the section on the individual component, Sections 11.9, 11.10, and 11.11.

11.7.3 Analytical Procedure: Default Equation

Seismic forces shall be determined in accordance with Equation 11-1:

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

where

F_p = Seismic design force applied horizontally at the component's center of gravity and distributed relative to the component's mass distribution

S_{XS} = Spectral response acceleration at short periods for any hazard level

I_p = Component performance factor that is either 1.0 for Life Safety Performance Level or 1.5 for Immediate Occupancy Performance Level

W_p = Component operating weight

11.7.4 Analytical Procedure: General Equation

Alternatively, seismic forces shall be determined in accordance with Equations 11-2 and 11-3

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

Note: F_p calculated from Equation 11-2 need not exceed F_p calculated from Equation 11-1.

$$F_p \text{ (minimum)} = 0.3\, S_{XS}\, I_p\, W_p \qquad (11\text{-}3)$$

where

a_p = Component amplification factor, related to rigidity of component that varies from 1.00 to 2.50 (select appropriate value from Table 11-2)

F_p = Seismic design force applied horizontally at the component's center of gravity and distributed relative to the component's mass distribution

S_{XS} = Spectral response acceleration at short periods for any hazard level

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

I_p = Component performance factor that is either 1.0 for Life Safety Performance Level or 1.5 for Immediate Occupancy Performance Level

R_p = Component response modification factor, related to ductility of anchorage that varies from 1.25 to 6.0 (select appropriate value from Table 11-2)

W_p = Component operating weight

x = Elevation in structure of component relative to grade elevation

11.7.5 Drift Ratios and Relative Displacements

Drift ratios (D_r) shall be determined in accordance with the following equations:

For two connection points on the same building or structural system, use

$$D_r = (\delta_{xA} - \delta_{yA}) / (X - Y) \quad (11\text{-}4)$$

Relative displacements (D_p) shall be determined in accordance with the following equation:

For relative displacement of two connection points on separate buildings or structural systems, use

$$D_p = |\delta_{xA}| + |\delta_{xB}| \quad (11\text{-}5)$$

where

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

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

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

δ_{yA} = 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

The effects of seismic relative displacements shall be considered in combination with displacements caused by other loads, as appropriate.

11.7.6 Other Procedures

Other procedures are available that require determination of the maximum acceleration of the building at each component support and the maximum relative displacements between supports common to an individual component.

Linear Procedures can be used to calculate the maximum acceleration of each component support and the inter-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.

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 *Seismic Design of Buildings* (Department of the Army, Navy, and Air Force, 1986).

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

Recent research (Drake and Bachman, 1995) has shown that the Analytical Procedures in Sections 11.7.3 and 11.7.4, which are based on the 1997 *NEHRP Provisions for New Buildings* (BSSC, 1997) Analytical Procedures, provide a reasonable upper bound for the seismic forces on nonstructural components.

Therefore, the other complex analytical procedures outlined above to develop roof and floor spectra are not required to evaluate and rehabilitate the typical nonstructural components discussed in this chapter. Use of the Analytical Procedures in Sections 11.7.3 and 11.7.4 is recommended.

Table 11-2 Nonstructural Component Amplification and Response Modification Factors

COMPONENT		a_p[1]	R_p[2]
A.	**ARCHITECTURAL**		
1.	**Exterior Skin**		
	Adhered Veneer	1	4
	Anchored Veneer	1	3[3]
	Glass Block	1	2
	Prefabricated Panels	1	3[3]
	Glazing Systems	1	2
2.	**Partitions**		
	Heavy	1	1.5
	Light	1	3
3.	**Interior Veneers**		
	Stone, Including Marble	1	1.5
	Ceramic Tile	1	1.5
4.	**Ceilings**		
	a. Directly Applied to Structure	1	1.5
	b. Dropped, Furred Gypsum Board	1	1.5
	c. Suspended Lath and Plaster	1	1.5
	d. Suspended Integrated Ceiling	1	1.5
5.	**Parapets and Appendages**	2.5	1.25
6.	**Canopies and Marquees**	2.5	1.5
7.	**Chimneys and Stacks**	2.5	1.25
8.	**Stairs**	1	3
B.	**MECHANICAL EQUIPMENT**		
1.	**Mechanical Equipment**		
	Boilers and Furnaces	1	3
	General Mfg. and Process Machinery	1	3
	HVAC Equipment, Vibration-Isolated	2.5	3
	HVAC Equipment, Non-Vibration-Isolated	1	3
	HVAC Equipment, Mounted In-Line with Ductwork	1	3
2.	**Storage Vessels and Water Heaters**		
	Vessels on Legs (Category 1)	2.5	1.5
	Flat Bottom Vessels (Category 2)	2.5	3
3.	**High-Pressure Piping**	2.5	4
4.	**Fire Suppression Piping**	2.5	4

Table 11-2 Nonstructural Component Amplification and Response Modification Factors (continued)

COMPONENT		a_p[1]	R_p[2]
5.	**Fluid Piping, not Fire Suppression**		
	Hazardous Materials	2.5	1
	Nonhazardous Materials	2.5	4
6	**Ductwork**	1	3
C.	**ELECTRICAL AND COMMUNICATIONS EQUIPMENT**		
1.	**Electrical and Communications Equipment**	1	3
2.	**Electrical and Communications Distribution Equipment**	2.5	5
3.	**Light Fixtures**		
	Recessed	1	1.5
	Surface Mounted	1	1.5
	Integrated Ceiling	1	1.5
	Pendant	1	1.5
D.	**FURNISHINGS AND INTERIOR EQUIPMENT**		
1.	**Storage Racks**[4]	2.5	4
2.	**Bookcases**	1	3
3.	**Computer Access Floors**	1	3
4.	**Hazardous Materials Storage**	2.5	1
5.	**Computer and Communications Racks**	2.5	6
6.	**Elevators**	1	3
7.	**Conveyors**	2.5	3

1. A lower value for a_p may be justified by detailed dynamic analysis. The value for a_p shall be not less than 1. The value of $a_p = 1$ is for equipment generally regarded as rigid and rigidly attached. The value of $a_p = 2.5$ is for equipment generally regarded as flexible and flexibly attached. See the definitions (Section 11.12) for explanations of “Component, rigid” and “Component, flexible.” Where flexible diaphragms provide lateral support for walls and partitions, the value of a_p shall be increased to 2.0 for the center one-half of the span.
2. $R_p = 1.5$ for anchorage design where component anchorage is provided by expansion anchor bolts, shallow chemical anchors, or shallow (nonductile) cast-in-place anchors, or where the component is constructed of nonductile materials. Shallow anchors are those with an embedment length-to-bolt diameter ratio of less than eight.
3. Applies when attachment is ductile material and design, otherwise 1.5.
4. Storage racks over six feet in height shall be designed in accordance with the provisions of Section 11.11.1.

11.8 Rehabilitation Concepts

Nonstructural rehabilitation is accomplished through replacement, strengthening, repair, bracing, or attachment. These methods are discussed in more depth in the *Commentary* to this section.

11.9 Architectural Components: Definition, Behavior, and Acceptance Criteria

11.9.1 Exterior Wall Elements

11.9.1.1 Adhered Veneer

A. Definition and Scope

Adhered veneer includes thin exterior finish materials secured to a backing material by adhesives. The backing may be masonry, concrete, cement plaster, or a structural framework material. The four main categories of adhered veneer are:

1. Tile, masonry, stone, terra cotta, or other similar materials not over one inch thick
2. Glass mosaic units not over 2" x 2" x 3/8" thick
3. Ceramic tile
4. Exterior plaster (stucco)

B. Component Behavior and Rehabilitation Concepts

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.

Calculation of the drift of the structure to which the nonstructural component is attached is necessary to establish conformance with drift acceptance criteria related to Performance Level. 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.

C. Acceptance Criteria

Life Safety Performance Level. Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting in-plane drift ratio is 0.03.

Immediate Occupancy Performance Level. Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting in-plane drift ratio is 0.01.

D. Evaluation Requirements

Adhered veneer must be evaluated by visual observation, as well as tapping to discern looseness or cracking that may be present. If found, this may indicate either defective bonding to the substrate or excessive flexibility of the supporting structure.

11.9.1.2 Anchored Veneer

A. Definition and Scope

Anchored veneer includes masonry or stone units that are attached to the supporting structure by mechanical means. The three main categories of anchored veneer are:

1. Masonry and stone units not over five inches nominal thickness
2. Stone units from five inches to ten inches nominal thickness
3. Stone slab units not over two inches nominal thickness

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

B. Component Behavior and Rehabilitation Concepts

Anchored veneer is both acceleration- and deformation-sensitive. Heavy units may be dislodged by direct acceleration, which distorts or fractures the mechanical connections. Deformation 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.

Drift analysis is necessary to establish conformance with drift acceptance criteria related to Performance Level. Nonconformance requires limiting structural drift, or special detailing to isolate substrate from structure to permit drift. Defective connections must be replaced.

C. Acceptance Criteria

Life Safety Performance Level. Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and relative displacement to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.02.

Immediate Occupancy Performance Level. Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

D. Evaluation Requirements

The stone units must have adequate stability, joint detailing, and maintenance to prevent moisture penetration from weather that could destroy the anchors. The anchors must be visually evaluated and, based on the engineer’s judgment, tested to establish capacity to sustain design forces and deformations.

11.9.1.3 Glass Block Units and Other Nonstructural Masonry

A. Definition and Scope

This category includes glass block, and other units that are self-supporting for static vertical loads, held together by mortar, and structurally detached from the surrounding structure.

B. Component Behavior and Rehabilitation Concepts

These units 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.

For small wall areas (less than 144 square feet or 15 feet in any dimension), rehabilitation can be accomplished by restoration, using the Prescriptive Procedure based on the *Uniform Building Code*, 1994, Section 2110 (ICBO, 1994). For larger areas, the Analytical Procedure must be used to establish forces and drifts against which the design must be measured. Nonconformance with deformation criteria requires limiting structural drift, or special detailing to isolate the glass block wall from the surrounding structure to permit drift. 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 acceptance criteria.

C. Acceptance Criteria

Life Safety Performance Level. Compliance is provided by design of the glass block wall and its enclosing framing, to meet both the in-plane and out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.02.

Immediate Occupancy Performance Level . Compliance is provided by design of the glass block wall and its enclosing framing, to meet both the in-plane and out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

D. Evaluation Requirements

The Prescriptive Procedure referred to above will serve as the criteria against which the wall must be evaluated.

11.9.1.4 Prefabricated Panels

A. Definition and Scope

This category consists of prefabricated panels that are installed with adequate structural strength within themselves and their connections to resist wind, seismic, and other forces. These panels are generally attached around their perimeters to the primary structural system. The three typical types of prefabricated panels are the following:

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

B. Component Behavior and Rehabilitation Concepts

Prefabricated panels are both acceleration- and deformation-sensitive. Lightweight units may be damaged by racking; heavy units may be dislodged by direct acceleration, which distorts or fractures the mechanical connections. Excessive deformation of the supporting structure—most likely if it is a frame—may result in the units 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 Performance Level. Nonconformance requires limiting structural drift, or special detailing to isolate panels from structure to permit drift; this generally requires panel removal. Defective connections must be replaced.

C. Acceptance Criteria

Life Safety Performance Level. Compliance is provided by design of the panel and connections to meet the in-plane and out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.02.

Immediate Occupancy Performance Level. Compliance is provided by design of the panel and connections to meet the in-plane and out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

D. Evaluation Requirements

The attachment of prefabricated panels to the structure must be evaluated for in- and out-of-plane forces and for in-plane displacement. Connections must be visually inspected and, based on the engineer’s judgment, testing to establish capacity to sustain design forces and loads.

11.9.1.5 Glazing Systems

A. Definition and Scope

Glazing systems consist of assemblies of walls that are made up from structural subframes attached to the main structure. The subframes may be assembled in the field, or prefabricated in sections and assembled in the field. Five typical categories of glazing system are:

1. Stick curtainwall systems, assembled on site
2. Unitized curtain wall systems, assembled from prefabricated units
3. Sloped glazing and skylights—may be prefabricated units or assembled on site
4. “Storefront” type glazing, assembled on site
5. Structural glazing in which the glass is attached to its supporting framework on two or four sides with adhesive silicone without mechanical restraint

Within each of these categories, there are three basic types of glazed openings:

1. Marine glazing (mostly factory built), in which the glass is clasped in a “U” rubber or vinyl gasket and then surrounded by a screwed-together aluminum frame (i.e., sliding doors and windows)
2. “Wet” glazing, in which the glass is held into the frame with silicone or other sealant compound or is attached to the frame with silicone as in structural glazing
3. “Dry” glazing, in which the glass is held into the frame with either putty, a rubber/vinyl bead, or wood/metal stops

B. Component Behavior and Rehabilitation Concepts

Glazing systems are predominantly deformation-sensitive, but may also become displaced or detached by large acceleration forces. Failures predominantly stem from the third method of glazing (“dry” glazing), and generally occur by the glass shattering due to in-plane displacements, or glass falling out of its supporting frame due to out-of-plane forces, often combined with loss of edge blocks and sealant strips caused by racking.

Drift analysis is 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 permit drift; this would require removal of the glazing system and replacement with an alternative design. Glazing with insufficient edge bite or insufficient resilience and clearance from the metal framing must be reglazed.

C. Acceptance Criteria

Life Safety Performance Level. Compliance is provided by design of the glazing system and its supporting structure to meet the force provisions of Section 11.7.3 or 11.7.4 for out-of-plane forces, and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.02.

Immediate Occupancy Performance Level.
Compliance is provided by design of the glazing system and its supporting structure to meet the force provisions of Section 11.7.3 or 11.7.4 for out-of-plane forces, and to meet the relative displacement in-plane drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

D. Evaluation Requirements

Glazed walls must be evaluated visually to determine the details of glass support, mullion configuration, sealant (wet or dry), and connectors.

11.9.2 Partitions

11.9.2.1 Definition and Scope

Partitions are vertical non-load-bearing interior elements that provide space division. They 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.

Heavy partitions are constructed of masonry materials such as hollow clay tile or concrete block, or are assemblies that weigh five pounds per square foot or more.

Light partitions are constructed of metal or wood studs surfaced with lath and plaster, gypsum board, wood, or other facing materials, and weigh less than five pounds per square foot.

Glazed partitions that span from floor to ceiling or to the underside of floor or roof above are subject to the requirements of Section 11.9.1.5.

Modular office furnishings that include movable partitions are considered as contents rather than partitions, and as such are not within the *Guidelines*' scope.

Heavy partitions—whether infill or freestanding—constructed of masonry materials, such as hollow clay tile or concrete block, are subject to the requirements of Chapter 7.

11.9.2.2 Component Behavior and Rehabilitation Concepts

Partitions are both acceleration- and deformation-sensitive. 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 zones 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. Refer to the *Commentary* for discussion on rehabilitation of lightweight partitions used as fire walls.

11.9.2.3 Acceptance Criteria

Life Safety Performance Level
Heavy Partitions. Compliance is provided by design of the partitions to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the in-plane relative displacement provisions of Section 11.7.5. The limiting drift ratio is 0.01.

Light Partitions. No requirements.

Immediate Occupancy Performance Level
Heavy Partitions. Compliance is provided by design of the partitions to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the in-plane relative displacement drift provisions of Section 11.7.5. The limiting drift ratio is 0.005.

Light Partitions. Compliance is provided by design of the partitions to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4 and to meet the in-plane relative displacement drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

11.9.2.4 Evaluation Requirements

Partitions must be evaluated to ascertain the type of material. 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 are thin decorative-finish materials applied to interior walls and partitions. These provisions apply to veneers mounted four feet or more above the floor.

11.9.3.2 Component Behavior and Rehabilitation Concepts

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 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

Life Safety Performance Level. Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4, and to meet the in-plane relative displacement drift provisions of Section 11.7.5. The limiting drift ratio is 0.02.

Immediate Occupancy Performance Level.
Compliance is provided by design of the attachment to the backing to meet the out-of-plane force provisions of Section 11.7.3 or 11.7.4, and to meet the in-plane relative displacement drift provisions of Section 11.7.5. The limiting drift ratio is 0.01.

11.9.3.4 Evaluation Requirements

The backup wall or other support and the attachment to that support must be considered, as well as the condition of the veneer itself.

11.9.4 Ceilings

11.9.4.1 Definition and Scope

Ceilings are horizontal and sloping assemblies of materials attached to or suspended from the building structure, or separately supported. Ceilings in an exterior location are referred to as soffits; these provisions also apply to them. Ceilings are mainly of the following types:

Category a. Surface-applied or furred with materials such as wood or metal furring acoustical tile, gypsum board, plaster, or metal panel ceiling materials, which are applied directly to wood joists, concrete slabs, or steel decking with mechanical fasteners or adhesives

Category b. Short dropped gypsum board sections attached to wood or metal furring supported by carrier members

Category c. Suspended metal lath and plaster

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

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 Concepts

Ceiling systems are both acceleration- and deformation-sensitive. 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, with 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 to prescriptive design standards such as the CISCA recommendations appropriate to the seismic zone (CISCA, 1990, 1991).

11.9.4.3 Acceptance Criteria

Life Safety Performance Level. There are no requirements for ceiling Categories a, b, and d, except as noted in the footnotes to Table 11-1. Where rehabilitation is required for ceiling Categories a and b, strengthening to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance. For ceiling Category c, rehabilitation must also comply with relative displacement provisions of Section 11.7.5. Where rehabilitation is required for ceiling Category d, rehabilitation by the Prescriptive Procedure provides compliance.

Immediate Occupancy Performance Level. For ceiling Categories a and b, strengthening to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance. For ceiling Category c, rehabilitation must also comply with relative displacement provisions of Section 11.7.5. For ceiling Category d, rehabilitation by the Prescriptive Procedure provides compliance.

11.9.4.4 Evaluation Requirements

The condition of the ceiling finish material and 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 must be evaluated.

11.9.5 Parapets and Appendages

11.9.5.1 Definition and Scope

Parapets and appendages include exterior nonstructural features that project above or away from a building. They include sculpture and ornament in addition to concrete, masonry, or terra cotta parapets. The following parapets and appendages are within the scope of these requirements:

- Unreinforced masonry parapets more than one and a half times as high as they are thick
- Reinforced masonry parapets more than three times as high as they are wide
- Cornices or ledges constructed of stone, terra cotta, or brick, unless supported by steel or reinforced concrete structure
- Other appendages, such as flagpoles and signs, that are similar to the above in size, weight, or potential consequence of failure

11.9.5.2 Component Behavior and Rehabilitation Concepts

Parapets and appendages are acceleration-sensitive in the out-of-plane direction. 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 (FEMA, 1994) and FEMA 172 (BSSC, 1992a), with detailing to conform to accepted engineering practice. Braces for parapets should be spaced at a maximum of eight feet on center, and, when the parapet construction is discontinuous, a continuous backing element 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

Life Safety Performance Level. Compliance is provided by strengthening and bracing to a prescriptive concept with engineering evaluation or design to meet the force provisions of Section 11.7.3 or 11.7.4.

Immediate Occupancy Performance Level.
Compliance is similar to that for the Life Safety Performance Level.

11.9.5.4 Evaluation Requirements

Evaluation of masonry parapets should consider the condition of mortar and masonry, connection to supports, type and stability of the supporting structure, and horizontal continuity of the parapet coping.

11.9.6 Canopies and Marquees

11.9.6.1 Definition and Scope

Canopies are projections from an exterior wall to provide weather protection. They may be extensions of the horizontal building structure, or independent structures that are sometimes also tied to the building. Marquees are free-standing structures, often constructed of metal and glass, providing weather protection. Canopies and marquees included within the scope of this document are those that project over exits or exterior walkways, and those with sufficient mass to generate significant seismic forces. Specifically excluded are canvas or other fabric projections.

11.9.6.2 Component Behavior and Rehabilitation Concepts

Canopies and marquees are acceleration-sensitive. Their variety of design 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

Life Safety Performance Level. Compliance is provided by design to meet the force provisions of Section 11.7.3 or 11.7.4. Consider both horizontal and vertical accelerations.

Immediate Occupancy Performance Level. Compliance is similar to that for the Life Safety Performance Level.

11.9.6.4 Evaluation Requirements

Evaluation should consider buckling in bracing, connection to supports, and type and stability of the supporting structure.

11.9.7 Chimneys and Stacks

11.9.7.1 Definition and Scope

Chimneys and stacks that are cantilevered above building roofs are included within the scope of this document. Light metal residential chimneys, whether enclosed within other structures or not, are not included.

11.9.7.2 Component Behavior and Rehabilitation Concepts

Chimneys and stacks are acceleration-sensitive, and 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 (FEMA, 1994).

11.9.7.3 Acceptance Criteria

Life Safety Performance Level. Compliance is provided by strengthening and bracing to a prescriptive concept with engineering evaluation or design to meet the force provisions of Section 11.7.3 or 11.7.4.

Immediate Occupancy Performance Level. Compliance is similar to that for the Life Safety Performance Level.

11.9.7.4 Evaluation Requirements

Evaluation of masonry chimneys should consider the condition of mortar and masonry, connection to adjacent structure, and type and stability of foundations.

Concrete should be evaluated for spalling and exposed reinforcement; steel should be evaluated for corrosion.

11.9.8 Stairs and Stair Enclosures

11.9.8.1 Definition and Scope

Stairs included within the scope of this document are defined as 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 Concepts.

Stairs include a variety of separate components that can be either acceleration- or deformation-sensitive. 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

Life Safety Performance Level. Stairs shall meet the force provisions of Section 11.7.3 or 11.7.4 and relative displacement provisions of Section 11.7.5. Other elements of the stair assemblage shall meet the Life Safety acceptance criteria for applicable sections of this chapter.

Immediate Occupancy Performance Level. Stairs shall meet the force provisions of Section 11.7.3 or 11.7.4 and relative displacement provisions of Section 11.7.5. Other elements of the stair assemblage shall meet the applicable Immediate Occupancy acceptance criteria for applicable sections of this chapter.

11.9.8.4 Evaluation Requirements

Evaluation of individual stair elements should consider 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.

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 that is used for the operation of the building, and is therefore an integral part of it, is included within the scope of the *Guidelines*. Included are:

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 when design loads, as required by the *Guidelines*, 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 not included in one of the three categories above

These categories of equipment include, but are not limited to:

- Boilers and furnaces
- Conveyors (nonpersonnel)
- HVAC system equipment, vibration-isolated
- HVAC system equipment, non-vibration-isolated
- HVAC system equipment mounted in-line with ductwork

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 Concepts

Mechanical equipment is acceleration-sensitive. 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 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.

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

Seismic forces can be established by analysis using the default Equation 11-1. Equipment weighing over 400 pounds and located on the third floor or above (or on an equivalent-height roof) should be analyzed using Equations 11-2 and 11-3.

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

Life Safety Performance Level. Equipment anchorage should meet the force provisions of Section 11.7.3 or 11.7.4.

Immediate Occupancy Performance Level.
Compliance criteria are similar to those for the Life Safety Performance Level.

11.10.1.4 Evaluation Requirements

Equipment must be analyzed to establish acceleration-induced forces, and visually evaluated for the existence of satisfactory supports, hold-downs, and bracing. 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

This section includes all vessels that contain fluids used for building operation. 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.

Vessels are classified into two categories:

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

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

11.10.2.2 Component Behavior and Rehabilitation Concepts

Tanks and vessels are acceleration-sensitive. 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 shown in FEMA 74 (FEMA, 1994) or FEMA 172 (BSSC, 1992a). 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 STD 650-93 or API-90 by the American Petroleum Institute (API, 1993), for vessels containing petroleum products or other chemicals, or AINSI/AWWA D100-96 (AWS D5 2-96) by the American Water Works Association (AWWA, 1996), for water vessels.

11.10.2.3 Acceptance Criteria

Life Safety Performance Level.
Category 1 equipment. Refer to Table 11-1 for applicability. Design and support to meet the force provisions of Section 11.7.3 or 11.7.4 will provide compliance.

Category 2 equipment. Design in accordance with a recognized prescriptive standard and to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance.

Immediate Occupancy Performance Level.
Compliance criteria are similar to those for Life Safety.

11.10.2.4 Evaluation Requirements

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

This section includes all piping that carries fluids which, in their vapor stage, exhibit a pressure of 15 psi, gauge, or higher, except fire suppression piping.

11.10.3.2 Component Behavior and Rehabilitation Concepts

Piping is predominantly acceleration-sensitive, but piping that runs between floors or seismic joints may be deformation-sensitive. The most common failure is joint failure, caused by inadequate support or bracing.

Rehabilitation is accomplished by prescriptive design approaches to support and bracing. The prescriptive requirements of *NFPA-13* (NFPA, 1996) should be used. Piping systems should be evaluated for compliance with the latest edition of ASME/ANSI B31.9 and other B31 standards where applicable. For large critical piping systems, the building official or responsible engineer must establish forces and evaluate supports.

11.10.3.3 Acceptance Criteria

Life Safety Performance Level. Design in accordance with a recognized prescriptive standard, and to meet force provisions of Section 11.7.3 or 11.7.4 and displacement provisions of Section 11.7.5, will provide compliance.

Immediate Occupancy Performance Level. Compliance criteria are similar to those for Life Safety.

11.10.3.4 Evaluation Requirements

High-pressure piping shall be tested in accordance with the ASME/ANSI standards mentioned above. In addition to other tests, lines shall be hydrostatically tested to 150% of the maximum anticipated pressure of the system.

11.10.4 Fire Suppression Piping

11.10.4.1 Definition and Scope

Fire suppression piping includes 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 down to approximately two pounds per foot.

11.10.4.2 Component Behavior and Rehabilitation Concepts

Piping is predominantly acceleration-sensitive, but piping that runs between floors or seismic joints may be deformation-sensitive. The most common failure 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* (NFPA, 1996) should be used.

11.10.4.3 Acceptance Criteria

Life Safety Performance Level. Design in accordance with a recognized prescriptive standard to meet force provisions of Section 11.7.3 or 11.7.4. provides compliance.

Immediate Occupancy Performance Level. Compliance criteria are similar to those for Life Safety.

11.10.4.4 Evaluation Requirements

Fire suppression piping must be evaluated for adequate support, flexibility, protection at seismic movement joints, and freedom from impact from adjoining materials at the sprinkler heads. 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

This section includes all piping, other than pressure piping or fire suppression lines, that transfers fluids under pressure by gravity, or is open to the atmosphere. This includes drainage and ventilation piping; hot, cold, and chilled water piping; and piping carrying liquids, as well as fuel gas lines, used in industrial, medical, laboratory, and other occupancies. There are two categories of fluids, based on potential damage or hazard to personnel:

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, as defined in NFPA 325-94, 49-94, 491M-91, and 704-90.

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

11.10.5.2 Component Behavior and Rehabilitation Concepts

Piping is predominantly acceleration-sensitive, but piping that runs between floors or expansion or seismic joints may be deformation-sensitive. 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 (MSS, 1993); the piping systems themselves should be designed to meet the force provisions of Sections 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 (MSS, 1993) 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.

11.10.5.3 Acceptance Criteria

Life Safety Performance Level
Category 1 piping systems. Design to meet prescriptive standards, the force provisions of Section 11.7.3 or 11.7.4, and the relative displacement provisions of Section 11.7.5, provides compliance.

Category 2 piping systems. Design to meet prescriptive standards provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety. Prescriptive standards should be met for essential facilities.

11.10.5.4 Evaluation Requirements

Piping must be evaluated for adequate support, flexibility, and protection at seismic movement joints. 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. Piping must be protected by adequate insulation from detrimental heat effects.

11.10.6 Ductwork

11.10.6.1 Definition and Scope

This section includes HVAC and special exhaust ductwork systems. Seismic restraints are not required for ductwork that is not conveying hazardous materials, and that meets either of the following conditions.

- HVAC ducts are suspended from hangers 12 inches or less in length from the top of the duct to the supporting structure. The hangers should be designed and placed in such a way as to avoid significant bending of the hangers.
- HVAC ducts have a cross-sectional area of less than six square feet.

11.10.6.2 Component Behavior and Rehabilitation Concepts

Ducts are predominantly acceleration-sensitive, but when ductwork runs between floors or across expansion or seismic joints it may be deformation-sensitive.

Damage 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, per SMACNA Duct Construction Standards (SMACNA, 1980, 1985).

11.10.6.3 Acceptance Criteria

Life Safety Performance Level. Design to meet prescriptive standards provides compliance.

Immediate Occupancy Performance Level.
Compliance criteria are similar to those for Life Safety. Prescriptive standards should be for essential facilities.

11.10.6.4 Evaluation Requirements

These components must be evaluated by visual means to ascertain their compliance with the conditions defined in Section 11.10.6.1.

11.10.7 Electrical and Communications Equipment

11.10.7.1 Definition and Scope

This section includes 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.

The following equipment is subject to these *Guidelines*:

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 when design loads, as required by the *Guidelines*, 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 not falling into one of the three categories above

11.10.7.2 Component Behavior and Rehabilitation Concepts

Electrical equipment is acceleration-sensitive. 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 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

Life Safety Performance Level. Design to meet the force provisions of Section 11.7.3 or 11.7.4 provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety.

11.10.7.4 Evaluation Requirements

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

This includes all electrical and communications transmission lines, conduit, and cables, and their supports.

11.10.8.2 Component Behavior and Rehabilitation Concepts

Electrical distribution equipment is predominantly acceleration-sensitive, but wiring or conduit that runs between floors or expansion or seismic joints may be deformation-sensitive. Failure occurs most commonly by inadequate support or bracing, deformation of the attached structure, or impact from adjoining materials.

Rehabilitation is accomplished by strengthening support and bracing using the prescriptive methods contained in SMACNA standards (SMACNA, 1980, 1985).

11.10.8.3 Acceptance Criteria

Life Safety Performance Level. Design to meet prescriptive standards provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety. Prescriptive standards should be for essential facilities.

11.10.8.4 Evaluation Requirements

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

11.10.9 Light Fixtures

11.10.9.1 Definition and Scope

This section includes lighting fixtures in the following categories:

Category 1. Recessed in ceilings

Category 2. Surface mounted to ceilings or walls

Category 3. Supported within a suspended ceiling system (integrated ceiling)

Category 4. Suspended from ceilings or structure (pendant or chain)

11.10.9.2 Component Behavior and Rehabilitation Concepts

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 (FEMA, 1994). Rehabilitation of Category 4 components involves strengthening of attachment and ensuring freedom to swing without impacting adjoining materials.

11.10.9.3 Acceptance Criteria

Life Safety Performance Level
Categories 1 and 2. There are no specific acceptance criteria, but secure connection to ceiling or wall must be assured.

Category 3. Systems bracing and support to meet prescriptive requirements provides compliance.

Category 4. Fixtures weighing over 20 pounds should have adequate articulating or ductile connections to the building, and be free to swing without impacting adjoining materials.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety. Prescriptive standards should be met for essential facilities.

11.10.9.4 Evaluation Requirements

Fixtures must be visually evaluated to determine the adequacy of supports and, for Category 3 fixtures, the existence of adequate independent support.

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 include systems, usually constructed of metal, for the purpose of holding materials either permanently or temporarily. 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 when the Life Safety Performance Level is selected.

11.11.1.2 Component Behavior and Rehabilitation Concepts

Storage racks are acceleration-sensitive, and 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

Life Safety Performance Level. Design to meet the force provisions of Section 11.7.3 or 11.7.4 provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety.

11.11.1.4 Evaluation Requirements

Evaluation should consider buckling or racking failure of rack elements, connection to support structures, and type and stability of supporting structure.

11.11.2 Bookcases

11.11.2.1 Definition and Scope

Bookcases, constructed of wood or metal, in excess of four feet high should be considered.

11.11.2.2 Component Behavior and Rehabilitation Concepts

Bookcases are acceleration-sensitive, and 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

Life Safety Performance Level. Design to meet the force provisions of Section 11.7.3 or 11.7.4 provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for Life Safety.

11.11.2.4 Evaluation Requirements

Evaluation should consider the loading, type, and condition of bookcases, their connection to support structures, and type and stability of supporting structure.

11.11.3 Computer Access Floors

11.11.3.1 Definition and Scope

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

These components are both acceleration- and deformation-sensitive. They 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 (FEMA, 1994). The weight of the floor system, as well as supported equipment, should be included in the analysis.

11.11.3.3 Acceptance Criteria

Life Safety Performance Level. Not applicable.

Immediate Occupancy Performance Level. Design to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance, together with design to approved prescriptive standards.

11.11.3.4 Evaluation Requirements

Evaluation should consider buckling and racking of access floor supports, and connection to the support structure. The effects of mounted equipment, including possible future equipment, should also be considered.

11.11.4 Hazardous Materials Storage

11.11.4.1 Definition and Scope

For the purpose of this section, hazardous materials storage shall be defined as permanently installed containers—either 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:

- Propane gas tanks
- Compressed gas vessels
- 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 manufacture or distribution plants are not within the scope of these *Guidelines.*

11.11.4.2 Component Behavior and Rehabilitation Concepts

These components are acceleration-sensitive; 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 or adding bracing designed according to concepts described in FEMA 74 (FEMA, 1994) and FEMA 172 (BSSC, 1992a).

11.11.4.3 Acceptance Criteria

Life Safety Performance Level. Design to approved prescriptive concepts provides compliance.

Immediate Occupancy Performance Level. Acceptance criteria are similar to those for the Life Safety Performance Level. Prescriptive standards should be met for essential facilities.

11.11.4.4 Evaluation Requirements

Evaluation should consider the location and types of hazardous materials, container materials, manner of bracing, internal lateral resistance, and the effect of hazardous material spills.

11.11.5 Computer and Communication Racks

11.11.5.1 Definition and Scope

Computer and communication racks are large, free-standing rack systems designed to support computer and other electronic equipment. Racks may be supported on either structural or access floors and may or may not be attached directly to these supports. The equipment itself is not included in this definition. All computer and communication racks are included within the scope of this section.

11.11.5.2 Component Behavior and Rehabilitation Concepts

These components are acceleration-sensitive, and 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 (FEMA, 1994) or FEMA 172 (BSSC, 1992a).

11.11.5.3 Acceptance Criteria

Life Safety Performance Level. Not applicable.

Immediate Occupancy Performance Level. Design to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance, together with design to approved prescriptive standards.

11.11.5.4 Evaluation Requirements

Evaluation should consider buckling or racking failure of rack elements, their connection to support structures, and type and stability of the supporting structure. The effect of rack failure on equipment should also be considered.

11.11.6 Elevators

11.11.6.1 Definition and Scope

Elevators 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 Concepts

Most elements of elevators are acceleration-sensitive, and can become dislodged or derailed. Shafts and hoistway rails, which rise through a number of floors, may also be deformation-sensitive. 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 elements violates Life Safety 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 (ASME, 1996).

11.11.6.3 Acceptance Criteria

Life Safety Performance Level. Design to meet force provisions of Section 11.7.3 or 11.7.4 provides compliance, together with design to approved prescriptive standards.

Immediate Occupancy Performance Level. Rehabilitation criteria are similar to those for Life Safety.

11.11.6.4 Evaluation Requirements

Evaluation should consider the construction of elevator shafts consistent with the requirements of applicable sections of the *Guidelines*. 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 are defined as material conveyors only for the purposes of this section, including all machinery and controllers necessary to operation.

11.11.7.2 Component Behavior and Rehabilitation Concepts

Conveyors are both acceleration- and deformation-sensitive. 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

Life Safety Performance Level. Not applicable.

Immediate Occupancy Performance Level. Design to meet force provisions of Section 11.7.3 or 11.7.4 and displacement provisions of Section 11.7.5, together with special prescriptive concepts, provides compliance.

11.11.7.4 Evaluation Requirements

Evaluation should consider the stability of machinery consistent with the requirements of applicable sections of these *Guidelines*.

11.12 Definitions

Acceleration-sensitive nonstructural component: A nonstructural component sensitive to and subject to damage from inertial loading. Once inertial loads are generated within the component, the deformation of the component may be significant; this is separate from the issue of deformation imposed on the component by structural deflections (see deformation-sensitive nonstructural components).

Component, flexible: A component, including its attachments, having a fundamental period greater than 0.06 seconds.

Component, rigid: A component, including its attachments, having a fundamental period less than or equal to 0.06 seconds.

Contents: Movable items within the building introduced by the owner or occupants.

Deformation-sensitive nonstructural component: A nonstructural component sensitive to deformation imposed on it by the drift or deformation of the structure, including deflection or deformation of diaphragms.

Flexible connections: Connections between components that permit rotational and/or translational movement without degradation of performance. Examples include universal joints, bellows expansion joints, and flexible metal hose.

Nonstructural component: An architectural, mechanical, plumbing, or electrical component, or item of interior equipment and furnishing, permanently installed in the building, as listed in Table 11-1.

Storage racks: Industrial pallet racks, movable shelf racks, and stacker racks made of cold-formed or hot-rolled structural members. Does not include other types of racks such as drive-in and drive-through racks, cantilever wall-hung racks, portable racks, or racks made of materials other than steel.

11.13 Symbols

D_p Relative seismic displacement that the component must be designed to accommodate

D_r Drift ratio

F_p Seismic design force applied horizontally at the component's center of gravity and distributed according to the component's mass distribution

R_p Component response modification factor, related to ductility of anchorage that varies from 1.25 to 6.0 (select appropriate value from Table 11-2)

S_{XS} Spectral response acceleration at short periods for any hazard level and any damping, g

W_p Component operating weight

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

a_p Component amplification factor, related to rigidity of component, that varies from 1.00 to 2.50 (select appropriate value from Table 11-2)

h Average roof elevation of structure, relative to grade elevation

x Elevation in structure of component relative to grade elevation

δ_{xA} Deflection at building level x of Building A, determined by an elastic analysis as defined in Chapter 3

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

δ_{xB} Deflection at building level x of Building B, determined by an elastic analysis as defined in Chapter 3

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