



2009 NEHRP Recommended Seismic Provisions: Training and Instructional Materials

FEMA P-752 CD / June 2013



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Design for Nonstructural Components

*Robert Bachman, S.E., John Gillengerten, S.E.,
and Susan Dowty, S.E.*

Nonstructural Components

Architectural, Mechanical and Electrical Components supported by or located within buildings or other structures

In 2009 *NEHRP Recommended Provisions*:

- Part 1, Provisions
Modifications to ASCE 7-05 Chapter 13, Seismic Design Requirements for Nonstructural Elements

In ASCE 7-05:

- Chapter 13 – Seismic Design Requirements for Nonstructural Components
- Section 12.11.2 Anchorage of Concrete and Masonry Structural Walls

2009 NEHRP Provisions, Part 1

Modification #1 to ASCE 7-05 Chapter 13

ASCE 7-05 Section 13.6.5.5, Item 6f:
Revise 6f as follows:

Attachments into concrete utilize nonexpanding insets,
power actuated fasteners, or cast iron embedments.
Attachments into concrete utilize anchors that have not
been prequalified for seismic applications in
accordance with ACI 355.2

**Please note that this section has been
completely rewritten in ASCE 7-10.**

2009 NEHRP Provisions, Part 1

Modification #2 to ASCE 7-05 Chapter 13

Delete ASCE 7-05 Sections 13.6.8.2 and 13.6.8.3 and replace with the following:

13.6.8.2 Fire Protection Sprinkler Systems.

Fire protections sprinkler systems designed and constructed in accordance with NFPA 13 shall be deemed to meet the other requirements of this section.

ASCE 7-05 Chapter 13

Nonstructural Components

ASCE 7-05 Section	Title
13.1	General
13.2	General Design Requirements
13.3	Seismic Demands on Nonstructural Components
13.4	Nonstructural Component Anchorage
13.5	Architectural Component
13.6	Mechanical and Electrical Components

Architectural Components (Table 13.5-1)

Nonstructural walls & partitions

Parapets & chimneys

Exterior nonstructural wall elements & connections

Veneer

Penthouses

Ceilings

Cabinets

Access floors

Signs

Billboards

Appendages

Glazing



Mechanical Components (Table 13.6-1)

Boilers and furnaces

HVAC

Piping systems

Engines

Turbines

Fans

Furnaces

Chillers

Elevators

Escalators



OSHPD/FDD

Electrical Components (Table 13.6-1)

Conduits
Bus ducts
Cable trays
Lighting fixtures
Motors
Generators
Communication eqmt
Inverters
Transformers
Motor control centers
Switch gear



Nonstructural Limits of Applicability

- ASCE 7-05 – Applies throughout the United States with following exceptions:
 1. Mechanical and electrical components in structures assigned to SDC A and B
 2. Mechanical and electrical components in structures assigned to SDC C if $I_p = 1.0$
 3. Architectural components in structures assigned to SDC A
 4. Architectural components in structures assigned to SDC B if $I_p = 1.0$ (except certain parapets)
- Other exceptions for light items, piping and ductwork in structures assigned to SDC D-F

There is a important errata regarding this section.

http://www.asce.org/uploadedFiles/sei/Books_and_Journals/erratasheet7-05.pdf



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 9

Nonstructural Demands

- Equivalent Static Forces – F_p Equation
 1. F_p Equation 13.3-1 is independent of building structural properties.
 2. F_p Equation 13.3-4 is dependent on building structural properties.

Both F_p equations are subject to the maximum and minimum values of F_p provided in Equations 13.3-2 and 13.3-3.

- Relative Displacements for Displacement-Sensitive Components (ASCE 7-05 Section 13.3.2)
 1. Anticipated Relative Displacements at Design Earthquake Level (D_p).
 2. ASCE 7-05 provides explicit equations and options for determining using building structural properties.

Nonstructural Force Demand

$$F_p = \frac{0.4a_p S_{DS}}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) W_p \quad \text{.....ASCE 7-05 – Equation 13.3-1}$$

$$F_{p(max)} = 1.6 S_{DS} I_p W_p \quad \text{.....ASCE 7-05 – Equation 13.3-2}$$

$$F_{p(min)} = 0.3 S_{DS} I_p W_p \quad \text{.....ASCE 7-05 – Equation 13.3-3}$$

Nonstructural Importance Factor - I_p

- ASCE 7-05 has assigned Nonstructural Component Importance Factor, I_p
- The values of I_p is either 1.0 or 1.5
- In ASCE 7-05, the value of I_p is based on
 1. Requirement of the component to function after a DBE or
 2. Occupancy Category of the structure or facility
- In ASCE 7-05, nonstructural components/systems which are assigned an $I_p = 1.5$ are called *Designated Seismic Systems*.

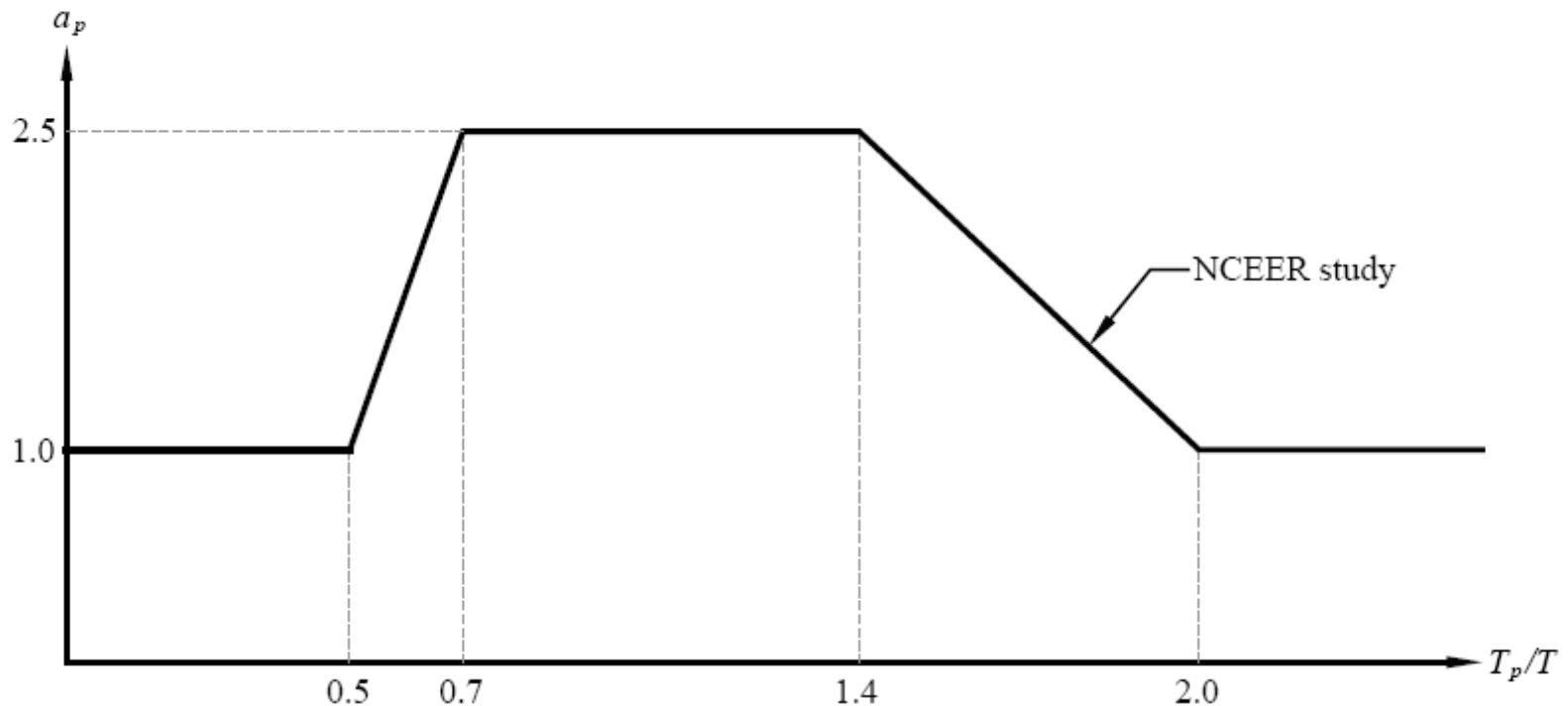
Nonstructural Component Factors

a_p and R_p

- ASCE 7-05 has a_p and R_p factors assigned in tables that are used in F_p equation.
- a_p values range from 1.0 to 2.5 and values of a_p can be taken as less than 2.5 based on dynamic analysis.
- R_p values range from 1.0 to 12.0.
- The values of R_p can be assigned based on the ductility and deformability capacity.

Component Amplification Factor

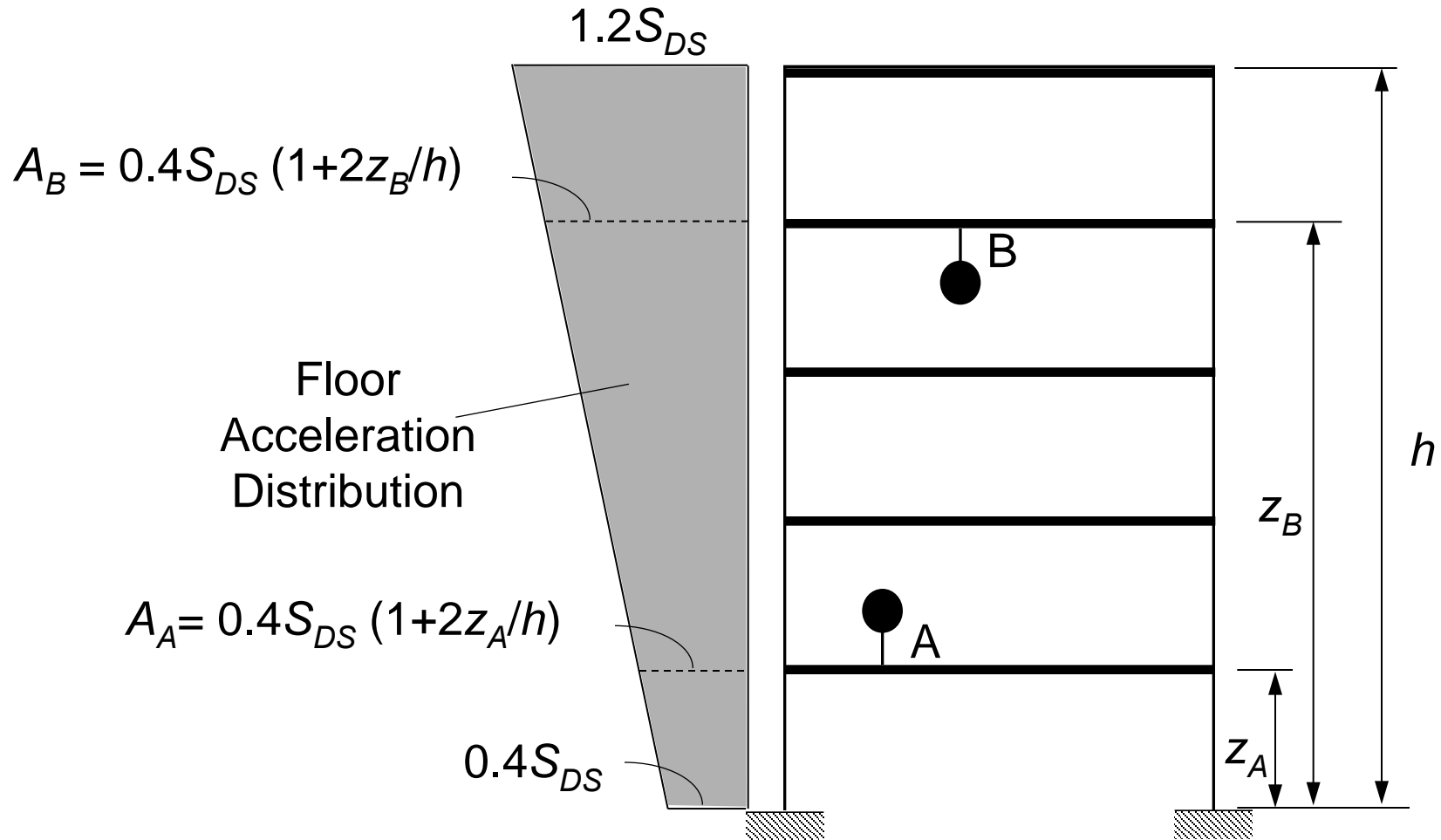
a_p



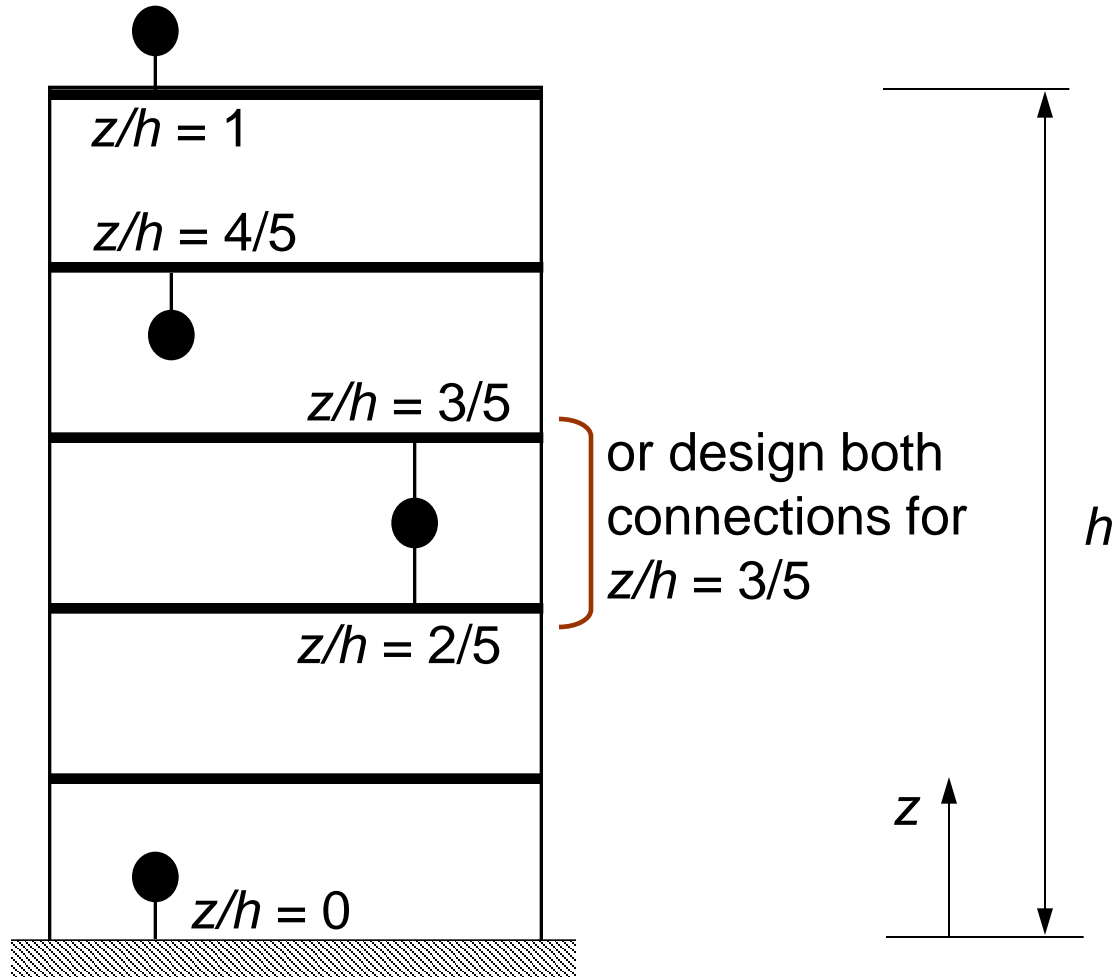
a_p and R_p values for Selected Architectural Components

Architectural Component	a_p R_p	
	a_p	R_p
Cantilever Parapets	2.5	2.5
Exterior Nonstructural Walls and Elements (e.g. precast cladding)	1.0	2.5
Partitions	1.0	2.5
Ceilings	1.0	2.5
Penthouses (not an extension)	2.5	3.5
Signs and Billboards	2.5	2.5
Access Floors (special)	1.0	2.5
Storage Cabinets	1.0	2.5

Explanation of $0.4S_{DS}(1 + 2z/h)$



Explanation of z/h



Alternative to F_p Equation 13.3-1

$$F_p = \frac{a_i a_p W_p}{\left(\frac{R_p}{I_p} \right)} A_x \quad \text{.....ASCE 7-05 – Equation 13.3-4}$$

a_i = acceleration at level i from modal analysis per Section 12.9
with $R = 1.0$

A_x = torsional amplification factor per Eq. 12.8-14

Upper and lower limits of F_p per Eqs. 13.3-2 and 13.3-3 apply

ASCE 7-05 Nonstructural Relative Displacement Demand for Design Earthquake Motions

- Required for anchorage of nonstructural components (ASCE 7-05 Section 13.4.1)
- Required for architectural components themselves which pose a life safety hazard including exterior wall elements and glazing. (ASCE 7-05 Section 13.5.2)
- Required for mechanical and electrical components themselves where I_p is greater than 1.0. (ASCE 7-05 Section 13.6.3)
- Except for glazing – no specific acceptance criteria is provided.

Load Combinations

- In ASCE 7-05 Section 12.4, strength and allowable stress design load combinations are provided.
- In ASCE 7-05 Section 12.4, there are E_h and E_v loads. E_h is defined as F_p for nonstructural components and E_v is defined as $0.2 S_{DS}D$.
- In ASCE 7-05, the redundancy factor, ρ , is specified as 1.0 for nonstructural components. (ASCE 7-05 Section 12.3.4.1, Item 3)
- In ASCE 7-05, Ω_o is not specified and load combinations with Ω_o are not used with nonstructural components (including penthouses)
- Other allowable stress design methods are addressed in ASCE 7-05 Section 13.1.7.

Anchorage of Nonstructural Components

ASCE 7-05 Section 13.4.2 Anchors in Concrete or Masonry

- All anchor forces based on R_p of 1.5 unless:
 - Anchorage governed by ductile steel element or
 - Post installed for seismic applications per ACI 355.2 or
 - Anchors design in accordance with ACI 318-05, App. D
- Additional 1.3 factor or maximum transferable force
- Per footnote b to ASCE 7-05 Table 13.6-1: for vibration isolated equipment, use $(2)(F_p)$ if gap > 0.25"
- Load path analysis to primary structure must be performed.

Design and Detailing Requirements of Architectural Components

ASCE 7-05 Section 13.5

- Specific demands for exterior nonstructural wall elements and connections (13.5.3)
- Suspending Ceilings – CISCA, ASTM C635 and ASTM C636 (13.5.6)
- Access Floors (13.5.7)
- Tall Partitions – independent bracing (13.5.8)
- Glazing – Drift capacity AAMA 501.6 (13.5.9)

Design and Detail Requirements for Mechanical and Electrical Equipment

ASCE 7-05 Section 13.6:

- Sprinkler systems – NFPA 13-2007 (by NEHRP Provisions Modification #1)
- Escalators and Elevators – ASME A17.1 (2004)
- Vessels – ASME BPVC (2001)
- Piping – ASME B31
- HVAC Ducting – (SMACNA not specifically referenced)
- Lighting fixtures – Prescriptive detail requirements
- Many specific prescriptive details for mechanical and electrical Equipment – Section 13.6.5.5

Special Certification Requirements for Certain Designated Seismic Systems ($I_p=1.5$)

- In ASCE 7-05 Section 13.2.2 - Seismic qualification required for
 1. Active mechanical and electrical equipment that are required to function following a DBE
 2. Components containing hazardous contents
- Qualification to demonstrate functionality after being subject to a DBE to be determined by one of the following:
 1. Shake table testing – ICC-ES AC-156 , 2004
 2. Experience Data
 3. Analysis (extremely difficult for active equipment)
- Certification required by supplier indicating compliance

Special Certification

Q: Where in the standard and code?

A: ASCE 7-05 Section 13.2.2 & 2009 IBC Section 1708.5

Q: Applies to what?

A: SDC C-F mech & elec equipment with $I_p > 1^*$ and SDC C-F components with hazardous contents with $I_p > 1^*$

Q: Requires what?

A: Special Certification

*Designated seismic system is defined in ASCE 7-05 Section 11.2 ($I_p > 1.0$)

Special Certification

For mechanical and electrical equipment.....
show that equipment remains operable following design
earthquake by:

- Shake table testing in accordance with ASCE 7-05
Section 13.2.5 OR
- Experience data in accordance with ASCE 7-05
Section 13.2.6

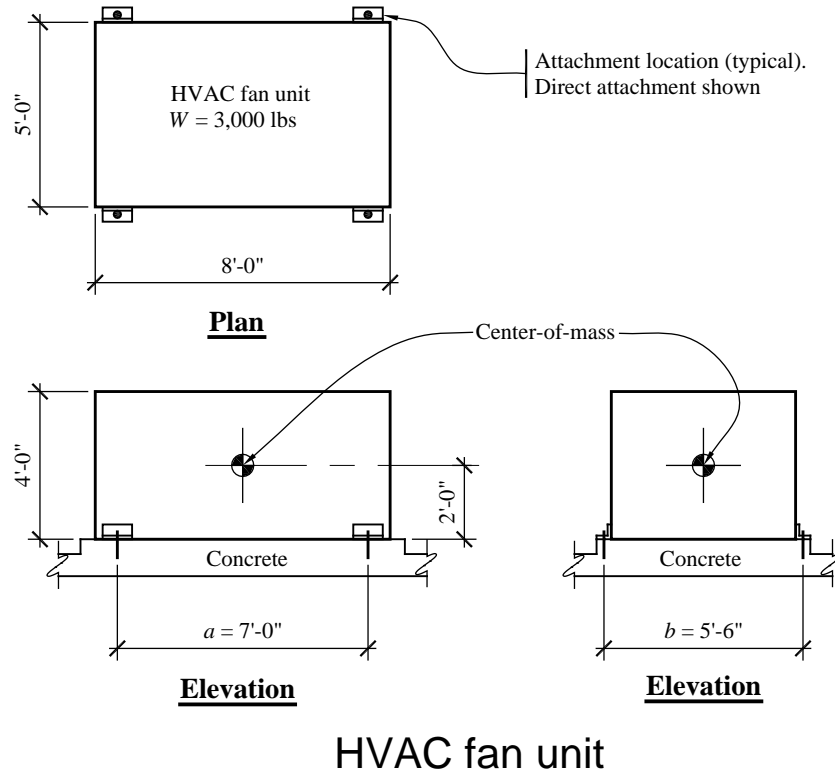
Special Certification

For components with hazardous contents.....
show that containment is maintained following design
earthquake by:

- Shake table testing in accordance with Section 13.2.5
OR
- Experience data in accordance with Section 13.2.6 OR
- Analysis

HVAC Fan Unit Support Design Example

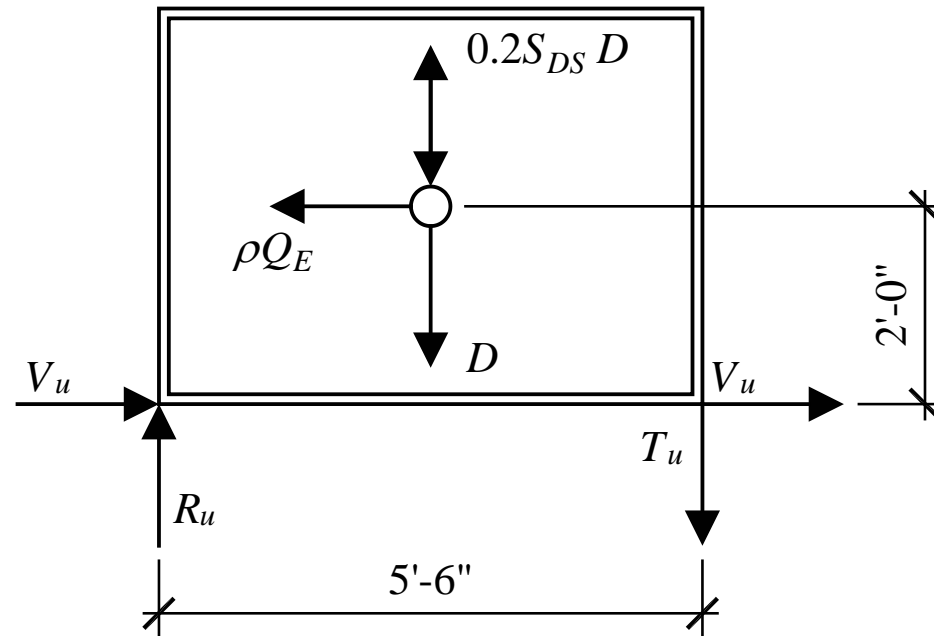
The component is located at the roof level of a five-story office building, near a significant active fault in Los Angeles, California. The building is assigned to Occupancy Category II.



Seismic Design Parameters and Coefficients

- $S_{DS} = 1.487$ (for the selected location and site class)
Seismic Design Category = D (*Standard Table 11.6-1*)
- $W_p = 3,000$ lb (given)
- $a_p = 2.5$ for both direct attachment and spring isolated (*Standard Table 13.6-1*)
- $R_p = 6.0$ for HVAC fans, directly attached (not vibration isolated) (*Standard Table 13.6-1*)
- $R_p = 2.0$ for spring isolated components with restraints (*Standard Table 13.6-1*)
- $R_p = 1.5$ for anchors in concrete or masonry unless criteria of *Standard Section 13.4.2* are satisfied
- $I_p = 1.0$ (*Standard Sec. 13.1.3*)
 $z/h = 1.0$ (for roof-mounted equipment)

Determine Prescribed Seismic Forces



Free-body diagram for seismic force analysis

Determine Prescribed Seismic Forces

- $F_p = \frac{0.4 \times 2.5 \times 1.487 \times (3,000 \text{ lb})}{(6.0/1.0)} (1 + 2 \times 1) = 2,231 \text{ lb}$ (Standard Eq. 13.3-1)
- $F_{pmax} = 1.6 \times 1.487 \times 1.0 \times 3,000 = 7,138 \text{ lb}$ (Standard Eq. 13.3-2)
- $F_{pmin} = 0.3 \times 1.487 \times 1.0 \times 3,000 = 1,338 \text{ lb}$ (Standard Eq. 13.3-3)

Since F_p is greater than F_{pmin} and less than F_{pmax} , the value determined from Equation 13.3-1 applies.

- $E_h = \rho Q_E$ (Standard Eq. 12.4-3)
- $E_v = 0.2 S_{DS} D$ (Standard Eq. 12.4-4)

where:

- Q_E (due to horizontal application of F_p) = 2,231 lb (Standard Sec. 12.4.2-1)
- $\rho = 1.0$ (HVAC units are nonstructural components) (Standard Sec. 13.3.1)
- D = dead load effect (due to vertical load application)

Determine Prescribed Seismic Forces

Substituting, one obtains:

- $E_h = \rho Q_E = (1.0)(2,231 \text{ lb}) = 2,231 \text{ lb}$ (horizontal earthquake effect)
- $E_v = 0.2 S_{DS} D = (0.2)(1.487)(3,000 \text{ lb}) = 892 \text{ lb}$ (vertical earthquake effect)
- $(1.2 + 0.2 S_{DS}) D + \rho Q_E + L + 0.2 S$ (*Standard Basic Load Combination 5*)
- $(0.9 - 0.2 S_{DS}) D + \rho Q_E + 1.6 H$ (*Standard Basic Load Combination 7*)
- $U = (1.2 + 0.2 S_{DS}) D + \rho Q_E$
- $V_u = \frac{1.0(2,231 \text{ lb})}{4 \text{ bolts}} = 558 \text{ lb/bolt}$
- $T_u = \frac{(1.2 - 0.2 \times 1.487) \times (3,000 \text{ lb}) \times 2.75 \text{ ft} - 1.0 \times 2,231 \times 2 \text{ ft}}{(5.5 \text{ ft})(2 \text{ bolts})} = 299 \text{ lb/bolt}$ (no tension)

Determine Prescribed Seismic Forces

- $U = (0.9 - 0.2S_{DS}) D + \rho Q_E$
- $V_u = \frac{1.0(2,231\text{lb})}{4\text{bolts}} = 558 \text{ lb/bolt}$
- $T_u = \frac{(0.9 - 0.2 \times 1.487) \times (3,000\text{lb}) \times 2.75\text{ft} - 1.0 \times 2,231 \times 2\text{ft}}{(5.5\text{ft})(2\text{bolts})} = 46 \text{ lb/bolt (no tension)}$

Questions?





Design for Nonstructural Components

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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 1

This unit is only a brief introduction to the subject of earthquake resistant design of nonbuilding structures. It was originally developed by Jim Harris from two primary sources: the content of the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* and two slide collections of the Earthquake Engineering Research Institute: the “Annotated Slide Collection” and the “EERI Northridge Earthquake of January 1994 Collection.” This unit has been updated by J. G. (Greg) Soules P.E., S.E.

The images here are all taken from the 1994 Northridge event: failed transformers in an electric power distribution substation (Sylmar), fire and flood from breaks in buried gas and water mains (Balboa Blvd, Granada Hills), and demolition of damaged highway interchange structures (Gavin Canyon undercrossing, Interstate 5).

Nonstructural Components

Architectural, Mechanical and Electrical
Components supported by or located within
buildings or other structures

In 2009 *NEHRP Recommended Provisions*:

- Part 1, Provisions
Modifications to ASCE 7-05 Chapter 13, Seismic
Design Requirements for Nonstructural Elements

In ASCE 7-05:

- Chapter 13 – Seismic Design Requirements for
Nonstructural Components
- Section 12.11.2 Anchorage of Concrete and
Masonry Structural Walls



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 2

Architectural, mechanical and electrical components are commonly referred to as “nonstructural components.”

2009 NEHRP Recommended Provisions are incorporated in ASCE 7-10.

No longer complete provisions as were found in previous NEHRP Recommended Provisions. Instead modifications are provided to ASCE 7-05 Chapter 13, Seismic Design Requirements for Nonstructural Elements

Chapter 13 of ASCE 7-05 also references other Chapters of ASCE 7 for its provisions. For example, it references Chapter 11 for ground motions. Of special interest is the reference to Section 12.11.2 Anchorage of Concrete and Masonry Structural Walls. It references Section 12.11.2 for the application connection requirements of nonstructural concrete and masonry walls for buildings with flexible diaphragms.

The reason Section 12.11.2 is listed is because code users are often confused about what design forces should be applied to structural walls out-of-plane and this is the section that Ch. 13 refers the user to for concrete and masonry walls.

2009 NEHRP Provisions, Part 1

Modification #1 to ASCE 7-05 Chapter 13

ASCE 7-05 Section 13.6.5.5, Item 6f:

Revise 6f as follows:

Attachments into concrete utilize nonexpanding insets, power actuated fasteners, or cast iron embedments.

Attachments into concrete utilize anchors that have not been prequalified for seismic applications in accordance with ACI 355.2

Please note that this section has been completely rewritten in ASCE 7-10.



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 3

The previous language in Item 6f was intended to identify anchor types that would be considered nonductile. The previous requirement has been superseded by requirements for qualification that include checks for ductility and good performance in earthquake conditions.

This section has been completely revised in ASCE 7-10. ASCE 7-10 requires design for seismic forces in accordance with Section 13.3 in general and provides exceptions where this is not required. Note that the ASCE 7-05 language required design only where specific conditions were met.

2009 NEHRP Provisions, Part 1

Modification #2 to ASCE 7-05 Chapter 13

Delete ASCE 7-05 Sections 13.6.8.2 and 13.6.8.3 and replace with the following:

13.6.8.2 Fire Protection Sprinkler Systems.

Fire protection sprinkler systems designed and constructed in accordance with NFPA 13 shall be deemed to meet the other requirements of this section.



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 4

NFPA 13-2007 applies to SDC C-F. The lateral design procedures of NFPA 13-2007 have been revised for consistency with the ASCE 7-05 design approach while retaining traditional sprinkler system design concepts. Using conservative upper bound values of the various design parameters, a single lateral force coefficient, C_p , was developed. It is a function of the mapped short period response parameter, S_s . Stresses in the pipe and connections are controlled by limiting the maximum reaction at bracing points as a function of pipe diameter.

In SDC C, the prescriptive requirements of NFPA 13-2007, using a default lateral force of 50 percent of the weight of the water-filled pipe, provide a conservative design, although application of the NFPA sway bracing calculation may produce a lower design lateral force.

ASCE 7-05 Chapter 13 Nonstructural Components

ASCE 7-05 Section	Title
13.1	General
13.2	General Design Requirements
13.3	Seismic Demands on Nonstructural Components
13.4	Nonstructural Component Anchorage
13.5	Architectural Component
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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 5

This slide is essentially a table of contents of ASCE 7-05 Chapter 13.

Architectural Components (Table 13.5-1)

Nonstructural walls & partitions
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Exterior nonstructural wall elements & connections
Veneer
Penthouses
Ceilings
Cabinets
Access floors
Signs
Billboards
Appendages
Glazing



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 6

The requirements are intended to apply only to permanently attached components – not to furnishings, temporary items, or mobile units. Furnishings such as tables, chairs, and desks may shift but generally pose minimal hazards provided they do not obstruct emergency egress routes. Storage cabinets, tall bookshelves, and other items of significant mass do not fall into this category and should be anchored or braced in accordance with this chapter.

Mechanical Components (Table 13.6-1)

Boilers and furnaces
HVAC
Piping systems
Engines
Turbines
Fans
Furnaces
Chillers
Elevators
Escalators



OSHDP/FDD



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 7

For both mechanical and electrical components, the focus is on anchorage unless $I_p = 1.5$.

Electrical Components (Table 13.6-1)

Conduits
Bus ducts
Cable trays
Lighting fixtures
Motors
Generators
Communication eqmt
Inverters
Transformers
Motor control centers
Switch gear



Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 8

For both mechanical and electrical components, the focus is on anchorage unless $I_p = 1.5$.

Nonstructural Limits of Applicability

- ASCE 7-05 – Applies throughout the United States with following exceptions:
 1. Mechanical and electrical components in structures assigned to SDC A and B
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 4. Architectural components in structures assigned to SDC B if $I_p = 1.0$ (except certain parapets)
- Other exceptions for light items, piping and ductwork in structures assigned to SDC D-F

There is a important errata regarding this section.

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Nonstructural Components - 9

Chapter 13 does not apply to SDC A due to its very low level of seismic hazard; see ASCE 7-05 Section 11.7 and Section C11.7.

The exceptions applicable to other seismic design categories are based on SDC and Importance Factor.

Sprinkler systems are assigned an Importance Factor of 1.5 in accordance with Section 13.1.3, Item 1.

With the exception of parapets supported by bearing walls or shear walls, all components in SDC B are exempt due to the low level of seismic risk. Parapets are not exempt because experience has shown these items can fail and pose a significant falling hazard even at low shaking levels.

Mechanical and electrical components in Seismic Design Category C with an importance factor (I_p) equal to 1.0 are exempt because they are subject to low levels of seismic hazard, they do not contain hazardous substances, and their function is not required to maintain life safety following an earthquake. Small components with I_p in SDC D, E, and F also are exempt since they do not contain hazardous substances and are not large enough to pose a life-safety hazard if they fall, slide, or topple. Failures of unbraced distribution systems at or near the point of connection to nonstructural components have been observed in past earthquakes. For this reason, flexible connections such as expansion loops, braided hose, or expansion joints are required to allow for the larger relative displacements associated with unbraced components. Note that the stiffness of flexible connections may be sensitive to internal pressure and length of the connection.

Nonstructural Demands

- Equivalent Static Forces – F_p Equation
 1. F_p Equation 13.3-1 is independent of building structural properties.
 2. F_p Equation 13.3-4 is dependent on building structural properties.Both F_p equations are subject to the maximum and minimum values of F_p provided in Equations 13.3-2 and 13.3-3.
- Relative Displacements for Displacement-Sensitive Components (ASCE 7-05 Section 13.3.2)
 1. Anticipated Relative Displacements at Design Earthquake Level (D_p).
 2. ASCE 7-05 provides explicit equations and options for determining using building structural properties.



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 10

There are two types of demands on nonstructural components: forces and relative displacements between points of attachment. The forces are associated with the acceleration response of the structure at the points of attachment. Nonstructural demands are based on design earthquake level motions and MCE motions are not considered.

Equation 13.3-1 is intentionally conservative to cover the wide range of building structural systems, heights, etc.

Nonstructural Force Demand

$$F_p = \frac{0.4a_p S_{DS}}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) W_p \quad \text{.....ASCE 7-05 – Equation 13.3-1}$$

$$F_{p(max)} = 1.6 S_{DS} I_p W_p \quad \text{.....ASCE 7-05 – Equation 13.3-2}$$

$$F_{p(min)} = 0.3 S_{DS} I_p W_p \quad \text{.....ASCE 7-05 – Equation 13.3-3}$$



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 11

The seismic design force for a component depends on:

The weight of the component, W_p

The component importance factor, I_p

The component response modification factor, R_p

The component amplification factor, a_p

The component acceleration at point of attachment to the structure, z

F_p forces are typically larger than those used for the design of the building.

Nonstructural Importance Factor - I_p

- ASCE 7-05 has assigned Nonstructural Component Importance Factor, I_p
- The values of I_p is either 1.0 or 1.5
- In ASCE 7-05, the value of I_p is based on
 1. Requirement of the component to function after a DBE or
 2. Occupancy Category of the structure or facility
- In ASCE 7-05, nonstructural components/systems which are assigned an $I_p = 1.5$ are called *Designated Seismic Systems*.



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 12

For $I_p = 1.0$, the following behaviors are anticipated:

1. Minor earthquake ground motions – minimal damage; not likely to affect functionality.
2. Moderate earthquake ground motions – some damage that may affect functionality
3. Design earthquake ground motions – major damage but significant falling hazards are avoided; likely loss of functionality

Components with $I_p = 1.5$, they are expected to remain in place, sustain limited damage, and, when necessary, function following design earthquake level motions.

Nonstructural Component Factors a_p and R_p

- ASCE 7-05 has a_p and R_p factors assigned in tables that are used in F_p equation.
- a_p values range from 1.0 to 2.5 and values of a_p can be taken as less than 2.5 based on dynamic analysis.
- R_p values range from 1.0 to 12.0.
- The values of R_p can be assigned based on the ductility and deformability capacity.



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Instructional Material Complementing FEMA P-751, Design Examples

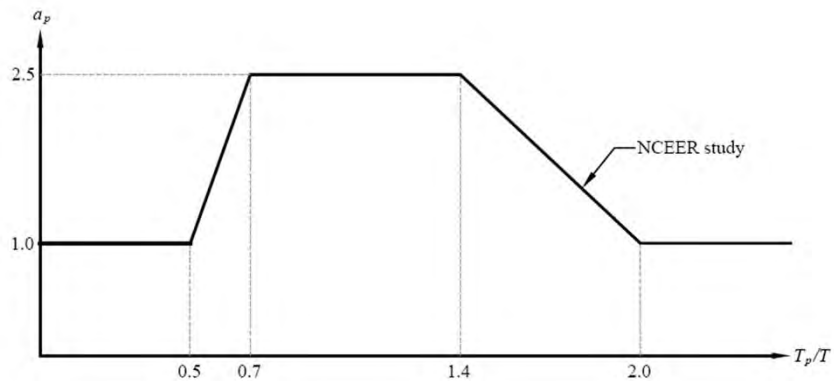
Nonstructural Components - 13

a_p values represent the dynamic amplification of component response as a function of the fundamental periods of the structure and component. a_p values are based on component behavior that is assumed to be either rigid or flexible. Where the fundamental period of the component is less than 0.06 seconds, dynamic amplification is not expected and the component is considered rigid and a_p is equal to 1.

R_p values represent the energy absorption capability of a component and its attachments and is dependent on both overstrength and deformability.

Component Amplification Factor

a_p



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Instructional Material Complementing FEMA P-751, Design Examples

Nonstructural Components - 14

The tabulation of assumed a_p values is not meant to preclude more precise determination of the component amplification factor where the fundamental periods of both structure and component are available. The NCEER formulation shown in Figure C13.3-1 may be used to compute a_p as a function of T_p/T . This works if the building structure does not have significant higher modes of vibration.

a_p and R_p values for Selected Architectural Components

Architectural Component	a_p	R_p
Cantilever Parapets	2.5	2.5
Exterior Nonstructural Walls and Elements (e.g. precast cladding)	1.0	2.5
Partitions	1.0	2.5
Ceilings	1.0	2.5
Penthouses (not an extension)	2.5	3.5
Signs and Billboards	2.5	2.5
Access Floors (special)	1.0	2.5
Storage Cabinets	1.0	2.5



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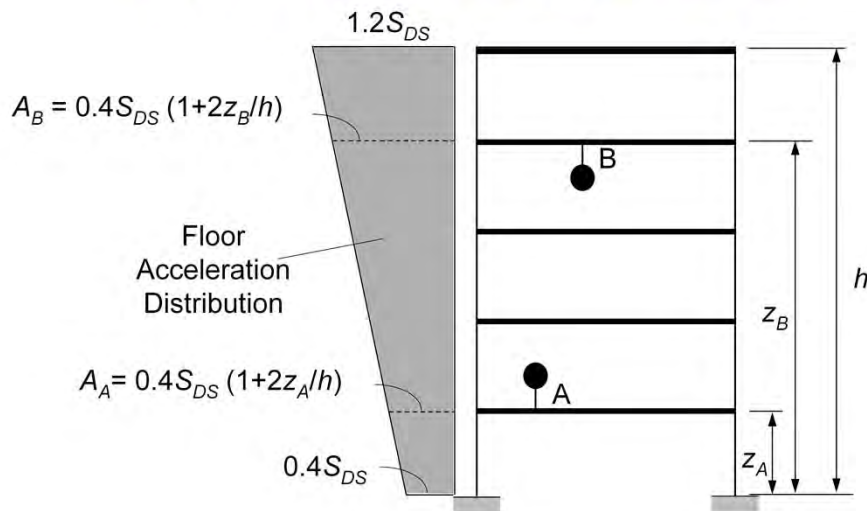


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Nonstructural Components - 15

This is a partial list of a_p and R_p values for architectural nonstructural component values from ASCE 7-05 Table 13.5-1.

Explanation of $0.4S_{DS}(1 + 2z/h)$



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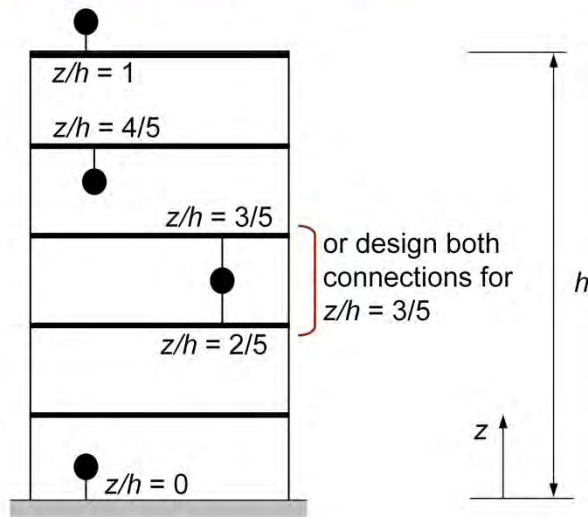


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Nonstructural Components - 16

Equation 13.3-1 represents a trapezoidal distribution of floor accelerations within a structure, varying linearly from the acceleration at the ground (taken as $0.4S_{DS}$) to the acceleration at the roof (taken as $1.2S_{DS}$). The ground acceleration ($0.4S_{DS}$) is intended to be the same acceleration used as design input for the structure itself, including site effects. The roof acceleration is established as three times the input ground acceleration based on examination of recorded in-structure acceleration data for short and moderate height structures in response to large California earthquakes.

Explanation of z/h



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Nonstructural Components - 17

In this example, floors are equally spaced with a story height of $h/5$.

Alternative to F_p Equation 13.3-1

$$F_p = \frac{a_i a_p W_p}{\left(\frac{R_p}{I_p} \right)} A_x \quad \text{.....ASCE 7-05 – Equation 13.3-4}$$

a_i = acceleration at level i from modal analysis per Section 12.9
with $R = 1.0$

A_x = torsional amplification factor per Eq. 12.8-14

Upper and lower limits of F_p per Eqs. 13.3-2 and 13.3-3 apply



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Nonstructural Components - 18

Equation 13.3-4 permits an alternate determination of the component design force based on the dynamic properties of the structure.

It requires a modal analysis of the structure be performed satisfying modal analysis procedures described in Chapter 12 of ASCE 7-05 including scaling of results assuming $R = 1$. Significant nonstructural items can be included in the modal analysis model. If the nonstructural item is included the value of a_p can also be determined in the analysis. However a_p cannot be taken as less than 1.0. Use of this equation can sometimes lead to significantly lower F_p values than Equation 13.3-1 especially in the middle and upper levels of moment frame building with 3 or more stories but requires much more computational effort, which often is impractical.

ASCE 7-05 Nonstructural Relative Displacement Demand for Design Earthquake Motions

- Required for anchorage of nonstructural components (ASCE 7-05 Section 13.4.1)
- Required for architectural components themselves which pose a life safety hazard including exterior wall elements and glazing. (ASCE 7-05 Section 13.5.2)
- Required for mechanical and electrical components themselves where I_p is greater than 1.0. (ASCE 7-05 Section 13.6.3)
- Except for glazing – no specific acceptance criteria is provided.



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Nonstructural Components - 19

Glazing acceptance criteria is set forth in ASCE 7-05 Section 13.9.

Load Combinations

- In ASCE 7-05 Section 12.4, strength and allowable stress design load combinations are provided.
- In ASCE 7-05 Section 12.4, there are E_h and E_v loads. E_h is defined as F_p for nonstructural components and E_v is defined as $0.2 S_{DS} D$.
- In ASCE 7-05, the redundancy factor, ρ , is specified as 1.0 for nonstructural components. (ASCE 7-05 Section 12.3.4.1, Item 3)
- In ASCE 7-05, Ω_o is not specified and load combinations with Ω_o are not used with nonstructural components (including penthouses)
- Other allowable stress design methods are addressed in ASCE 7-05 Section 13.1.7.



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Nonstructural Components - 20

F_p is required to be combined with other loads as set forth in ASCE 7-05 Section 12.4. To use Section 12.4, there are certain items that need to be defined and these include E_h , E_v , ρ and Ω_o .

Anchorage of Nonstructural Components

ASCE 7-05 Section 13.4.2 Anchors in Concrete or Masonry

- All anchor forces based on R_p of 1.5 unless:
 - Anchorage governed by ductile steel element or
 - Post installed for seismic applications per ACI 355.2 or
 - Anchors design in accordance with ACI 318-05, App. D
- Additional 1.3 factor or maximum transferable force
- Per footnote b to ASCE 7-05 Table 13.6-1: for vibration isolated equipment, use $(2)(F_p)$ if gap > 0.25"
- Load path analysis to primary structure must be performed.



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Nonstructural Components - 21

The goal of this section is to ensure that anchors exhibit ductile behavior or provide a specified degree of excess strength. For masonry, the capacity of anchors is rarely governed by steel capacity and failure in the masonry is nonductile and there R_p of 1.5 will most likely be required to be used in design. There are further improvements that have been made to this section in ASCE 7-10.

Design and Detailing Requirements of Architectural Components

ASCE 7-05 Section 13.5

- Specific demands for exterior nonstructural wall elements and connections (13.5.3)
- Suspending Ceilings – CISCA, ASTM C635 and ASTM C636 (13.5.6)
- Access Floors (13.5.7)
- Tall Partitions – independent bracing (13.5.8)
- Glazing – Drift capacity AAMA 501.6 (13.5.9)



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Nonstructural Components - 22

The requirements of Section 13.5 are intended to reduce property damage and life-safety hazards posed by architectural components due to loss of stability or integrity. Architectural components may pose a direct falling hazard to building occupants or to people outside the building (as in the case of parapets, exterior cladding, and glazing). Failure or displacement of interior components (such as partitions and ceiling systems in exits and stairwells) may block egress.

Design and Detail Requirements for Mechanical and Electrical Equipment

ASCE 7-05 Section 13.6:

- Sprinkler systems – NFPA 13-2007 (by NEHRP Provisions Modification #1)
- Escalators and Elevators – ASME A17.1 (2004)
- Vessels – ASME BPVC (2001)
- Piping – ASME B31
- HVAC Ducting – (SMACNA not specifically referenced)
- Lighting fixtures – Prescriptive detail requirements
- Many specific prescriptive details for mechanical and electrical Equipment – Section 13.6.5.5



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Nonstructural Components - 23

This is a list of mechanical and electrical equipment that have specific detailing requirements, many of which can be found in the applicable referenced standard.

Special Certification Requirements for Certain Designated Seismic Systems ($I_p=1.5$)

- In ASCE 7-05 Section 13.2.2 - Seismic qualification required for
 1. Active mechanical and electrical equipment that are required to function following a DBE
 2. Components containing hazardous contents
- Qualification to demonstrate functionality after being subject to a DBE to be determined by one of the following:
 1. Shake table testing – ICC-ES AC-156 , 2004
 2. Experience Data
 3. Analysis (extremely difficult for active equipment)
- Certification required by supplier indicating compliance



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Nonstructural Components - 24

While the goal of design for most nonstructural components is to prevent detachment or toppling that would pose a hazard to life safety, designated seismic systems (with $I_p = 1.5$) are intended to meet higher performance goals. In some cases, failure of mechanical or electrical equipment itself poses a significant hazard. This section addresses the design and certification of designated seismic system components and their supports and attachments. Examples of designated seismic systems include fire protection piping, uninterruptible power supplies for hospitals, and certain vessels or piping that contain highly toxic or explosive substances.