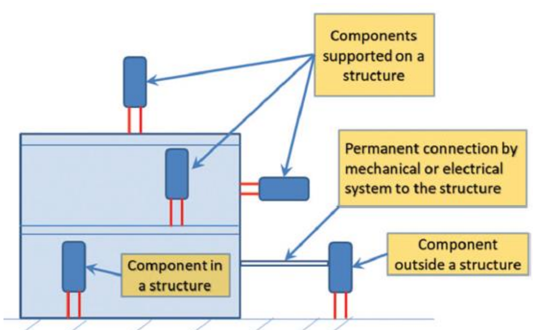
SEISMIC DESIGN GUIDE FOR ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS FOR RC I TO IV STRUCTURES

This guide addresses the seismic design requirements for nonstructural components in structures assigned to Risk Category (RC) I through IV, as defined in Table 2-2 of UFC 3-301-01.

UFC 3-301-01 Chapter 3 provides supplemental requirements for applying the ASCE 7-22, *Minimum Design Loads for Buildings and Other Structures*, structural and nonstructural component provisions to conventional DoD building design by listing required modifications for specific ASCE 7-22 sections. Where conflicts between the 2024 IBC or ASCE 7-22 and this UFC arise, this UFC controls.

Chapter 13 of ASCE 7-22 defines minimum design criteria for architectural, mechanical, electrical, and other nonstructural systems and components, recognizing structure use, occupant load, the need for operational continuity, and the interrelation of structural, architectural, mechanical, electrical, and other nonstructural components. The nonstructural components in these structures are designed for design earthquake ground motions, as defined in ASCE 7-22 Section 11.2, and are usually represented by the Design Response Spectrum in ASCE 7-22 Section 11.4.5. In contrast to structures, which are implicitly designed for a low probability of collapse when subjected to risk-targeted maximum considered earthquake (MCE_R) ground motions, there are no implicit performance goals associated with the MCE_R for nonstructural components. Note that unless specified, all the Section and Table numbers in this design guide refer to ASCE 7-22.

The requirements for seismic design of nonstructural components apply to the nonstructural component and its supports and attachments, regardless of whether it is within or supported by a building or nonbuilding structure, or if it is outside of a structure.



Possible locations of nonstructural components.
(Source: ASCE 7-22 Commentary)

STEP 1 — Check if the Nonstructural Component is Exempted from Design Requirements in Chapter 13

The following applies to a particular nonstructural component that is housed in or supported by a structure or is outside that structure but is permanently connected to it by a mechanical or electrical system.

Step 1a – Determine the Seismic Design Category (SDC) for the structure.

Structures must be assigned a seismic design category in accordance with Section 11.6.

ASCE 7-22 Table 11.6-1. Seismic Design Category Based on Short-Period Response Acceleration Parameter.

Value of S_{DS}	Risk Category	
	I or II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \le S_{DS} < 0.33$	B	C
$0.33 \le S_{DS} < 0.50$	C	D
$0.50 \le S_{DS}$	D	D

ASCE 7-22 Table 11.6-2. Seismic Design Category Based on 1 s Period Response Acceleration Parameter.

Value of S_{DS}	Risk Category	
	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \le S_{D1} < 0.133$	B	C
$0.133 \le S_{D1} < 0.20$	C	D
$0.20 \le S_{D1}$	D	

Step 1b – Determine the Seismic Design Category (SDC) for the nonstructural component.

A nonstructural component shall be assigned to the same seismic design category as:

1. The structure that it occupies or is supported by, or
2. The structure to which it is permanently connected by mechanical or electrical systems, or
3. For parts of an egress system, the structure it serves.

If an egress system serves more than one structure, the highest SDC of the structures served must be used.

Step 1c – Determine the Risk Category of the structure

Determine the Risk Category the structure in accordance with UFC 3-301-01, Table 2-2.

Step 1d – Determine Component Importance Factor, I_p

I_p is 1.0 for all components except when any of the following conditions apply, in which case I_p must be taken as 1.5.

1. The component is required to function for life-safety purposes after an earthquake, including the fire protection sprinkler systems and egress stairways.
2. The component conveys, supports, or otherwise contains toxic, highly toxic, or explosive substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction (AHJ) and is sufficient to pose a threat to the public if released.
3. The component is in or supported by a Risk Category IV structure or permanently connected by mechanical or electrical systems to a Risk Category IV structure, and the component is required for the continued operation of a structure designated an Essential Facility, or its failure would impair the continued operation of a structure designated an Essential Facility.
4. The component conveys, supports, or otherwise contains hazardous substances and is attached to a structure or portion thereof classified by the AHJ as a hazardous occupancy.

Step 1e – Check if any of the exemptions listed in Table 13.1-1 apply to the component.

SDC of the Nonstructural Component	Nonstructural Components Exempt from the Requirements of this Chapter
All SDCs	• Furniture (except storage cabinets, as noted in Table 13.5-1) • Temporary components that remain in place for 180 days or less • Mobile units and equipment including components that are moved from one point in the structure to another during ordinary use
A	• All components

SDC of the Nonstructural Component	Nonstructural Components Exempt from the Requirements of this Chapter
B	• Architectural Components, other than parapets, provided that the component Importance Factor, I_p, is equal to 1.0 • Mechanical and Electrical Components
C	• Mechanical and Electrical Components, provided that either ▪ The component Importance Factor, I_p, is equal to 1.0 and the component is positively attached to the structure; or ▪ The component weighs 20 lb (89 N) or less
D, E, F	• Mechanical and electrical components positively attached to the structure, provided that ▪ For discrete mechanical and electrical components, the component weighs 400 lb (1,779 N) or less, the center of mass is located 4 ft (1.22 m) or less above the adjacent floor level, flexible connections are provided between the component and associated ductwork, piping, and conduit, and the component Importance Factor, I_p, is equal to 1.0; or ▪ For discrete mechanical and electrical components, the component weighs 20 lb (89 N) or less; or ▪ For distribution systems, the component Importance Factor, I_p, is equal to 1.0 and the operating weight of the system is 5 lb/ft (73 N/m) or less. • Distribution systems included in the exceptions for conduit, cable tray, and raceways in Section 13.6.5, duct systems in 13.6.6, and piping and tubing systems in 13.6.7.3. Where in-line components, such as valves, in-line suspended pumps, and mixing boxes require independent support, they shall be addressed as discrete components and shall be braced considering the tributary contribution of the attached distribution system.

STEP 2 DESIGN BASIS

Step 2a – Determine effective seismic weight, W, of the supporting structure

W is the weight of the structure plus that of any contents that could, with a high degree of probability, be attached to the structure at the time of the earthquake. In addition to the dead load of the structure, ASCE 7-22 Section 12.7.2 requires that the following loads be included in the effective seismic weight, W:

Description	Include Seismic Weight
Areas of storage (other than public garages and open parking structures)	25 percent of floor live load (not needed where the inclusion of storage loads adds no more than 5% of the seismic weight at that level)
Buildings with partitions	10 psf or actual weight, whichever is greater
Buildings with roofs designed for snow	Where flat roof snow loads are greater than 45 psf, 15 percent of the uniform design snow load, regardless of actual roof slope
Permanent equipment	100 percent of operating weight
Buildings with roof gardens	100 percent of the weight of landscaping and other materials
Buildings containing fluids and bulk material	Weight of fluids and bulk material expected to be present during normal use.

Step 2b – Weight of the nonstructural component < 20% of combined effective seismic weight of the supporting structure and the nonstructural component.

Go to Step 3.

Step 2c – Weight of the nonstructural component ≥ 20% of the combined effective seismic weight of the supporting structure and the nonstructural component.

1. Determine the fundamental period, T_p, of the nonstructural component, including its supports and attachment to the structure

$$T_p = 2\pi\sqrt{\frac{W_p}{K_p g}}$$

where
W_p= Component operating weight,
K_p= Combined stiffness of the component, supports, and attachments, determined in terms of load per unit defection at the center of gravity of the component.

Alternatively, T_p can be determined from experimental test data or by a properly substantiated analysis.

Component period is used to classify components as rigid (T_p ≤ 0.06 s) or flexible (T_p > 0.06 s).

2. Determine the fundamental period of the supporting structure, T (including the lumped weight of the nonstructural component)

3. If $T_p/T < 0.5$ or $T_p/T > 2$, the supporting structure shall be designed in accordance with the requirements of Chapter 12 or Section 15.5, as appropriate. For design of nonstructural components go to Step 3.

Otherwise, go to Step 2d.

Step 2d – Perform structural analysis of the combined system

Perform structural analysis of the combined system accounting for stiffness, boundary conditions, material properties, and other structural characteristics of both the nonstructural component and the supporting structure. The nonstructural component and its attachments and the supporting structure must be designed for forces and displacements in accordance with Chapter 12 for nonstructural components in building structures or in accordance with Section 15.5 for nonstructural components in nonbuilding structures. The R-value for the combined system must be taken as the lesser of: 0.40$\left[\frac{C_{AR}}{R_{po}}\right]$ of the nonstructural component or the R-value of the supporting structure.

The nonstructural component and its attachments should be designed for forces and displacements resulting from the combined analysis. For other design criteria, Chapter 13 should be followed.

STEP 3 GENERAL DESIGN REQUIREMENTS FOR NONSTRUCTURAL COMPONENTS

Architectural, mechanical, and electrical components, their supports, and attachments must comply with the sections referenced in Table 13.2-1.

ASCE 7-22 Table 13.2-1. Applicable Requirements for Architectural, Mechanical, and Electrical Components: Supports and Attachments.

Nonstructural Components, their Supports, and Attachments	General Design Requirements (Section 13.2)	Force and Displacement Requirements (Section 13.3)	Attachment Requirements (Section 13.4)	Architectural Component Requirements (Section 13.5)	Mechanical and Electrical Component Requirements (Section 13.6)
Architectural components and supports and attachments for those components	X	X	X	X	

Nonstructural Components, their Supports, and Attachments	General Design Requirements (Section 13.2)	Force and Displacement Requirements (Section 13.3)	Attachment Requirements (Section 13.4)	Architectural Component Requirements (Section 13.5)	Mechanical and Electrical Component Requirements (Section 13.6)
Mechanical and electrical components	X	X	X		X
Supports and attachments for mechanical and electrical components	X	X	X		X

The applicable requirements must be satisfied by one of the following:

1. Project-specific design and documentation submitted for approval to the Authority Having Jurisdiction (AHJ) after review and acceptance by a registered design professional; or

2. Submittal of the manufacturer's certification that the component is seismically qualified by at least one of the following:

a) Analysis, or
b) Testing in accordance with Section 13.2.6
c) Experience data in accordance with Section 13.2.7

As an alternative to the analytical requirements of Sections 13.3 through 13.6, testing and experience data can be used to determine the seismic capacity of components and their supports and attachments.

Seismic qualification by testing must be based on a nationally recognized testing procedure acceptable to the AHJ. Seismic qualification by experience data must be based on nationally recognized procedures acceptable to the AHJ.

UFC 3-301-01 Section 13.2.3 endorses the following nationally recognized testing procedures:

1. The requirements of the International Code Council Evaluations Service (ICC-ES), *Acceptance Criteria for Seismic Qualification by Shake-Table Testing of Nonstructural Components*, ICC-ES AC156, November 2020.
2. The CERL *Equipment Fragility and Protection Procedure* (CEFAPP), USACERL Technical Report 97/58, Wilcoski, J., Gambill, J.B., and Smith, S.J., March 1997. The test motions, test plan, and results of this method require peer review.
3. For power substation equipment only, Institute of Electrical and Electronics Engineers (IEEE), *Recommended Practices for Seismic Design of Substations*, IEEE 693-2018.

The substantiated seismic capacities from the above alternative procedures must be equal to or greater than the seismic force and displacement demands determined in accordance with Section 13.3.1 and 13.3.2.

STEP 4 — Determine Horizontal Seismic Design Force, F_p

The horizontal seismic design force, F_p, to be applied at the component's center of gravity and distributed relative to the component's mass distribution, can be determined by either of the following methods:

1. Using Equation 13.3-1

$$0.3\, S_{DS} I_p W_p \le F_p = 0.4 S_{DS} I_p W_p \left[\frac{H_f}{R_\mu}\right]\left[\frac{C_{AR}}{R_{po}}\right] \le 1.6 S_{DS} I_p W_p$$

The parameters in the equation are determined in Steps 4a through 4f.

2. Using Nonlinear Response History Analysis (NRHA) procedures of Chapter 16, 17, or 18. Where dynamic properties of nonstructural component are not explicitly modeled in the analysis, the seismic design force, F_P, must be calculated as

$$0.3\, S_{DS} I_p W_p \le F_p = I_p W_p a_i \left[\frac{C_{AR}}{R_{po}}\right] \le 1.6 S_{DS} I_p W_p$$

where a_i is the maximum acceleration at level i obtained from the NRHA at Design Earthquake ground motion. NRHA must be performed for at least seven ground motions. When the supporting structure is designed using NRHA, the entire suite of ground motions used to design the structure should be used to determine a_i. The value of a_i should be taken as the mean of the maximum values of accelerations at the center of mass of the support level, obtained from analysis for each of the ground motions in the suite.

The directions of F_p used must be those that produce the most critical load effects on the component, the component supports, and attachments. Alternatively, it is permitted to use the more severe of the following two load cases:

- Case 1: A combination of 100% of F_p in any one horizontal direction and 30% of F_p in a perpendicular horizontal direction applied simultaneously.
- Case 2: The combination from Case 1 rotated 90 degrees.

Step 4a – Determine design spectral response acceleration at short periods, S_{DS}

S_{DS}, must be taken as 2/3 of the spectral acceleration at a period of 0.2 sec from the multi-period 5%-damped MCE$_R$ response spectrum from the USGS Seismic Design Geodatabase for the applicable site class. Alternatively, ASCE Hazard Tool (https://ascehazardtool.org/) can be used to find the value of S_{DS} for the desired site class at a given location.

Step 4b – Determine the Component Importance Factor, I_p

Already determined in Step 1d.

Step 4c – Calculate the component operating weight, W_p

Operating weight is the total weight of a component when it is in use, including the weights of such things as an operator, fuel, and any additional equipment or tools required for its operation.

Step 4d – Determine the factor for force amplification as a function of height in the structure, H_f

For nonstructural components supported at or below grade plane, H_f is 1.0.

For nonstructural components supported above the grade plane, H_f can be determined by either of the following equations:

$$H_f = 1 + a_1\left(\frac{z}{h}\right) + a_2\left(\frac{z}{h}\right)^{10}$$

$$H_f = 1 + 2.5\left(\frac{z}{h}\right)$$

where

$a_1 = 1/T_a \le 2.5$;

$a_2 = [1 - (0.4/T_a)^2] \ge 0$;

z = Height above the base of the structure to the point of attachment of the component. For items at or below the base, z must be taken as 0. The value of z/h need not exceed 1.0;

h = Average roof height of structure with respect to the base; and

T_a= Lowest approximate fundamental period of the supporting building or nonbuilding structure in either orthogonal direction. For structures with combinations of seismic force-resisting systems (SFRSs), the SFRS that produces the lowest value of T_a must be used.

For buildings T_a can be determined using Equation 12.8-8

$$T_a = C_t h_n^x$$

where h_n is the structural height as defined in ASCE 7-22 Section 11.2, and the parameters C_t and x are determined from ASCE 7-22 Table 12.8-2.

ASCE 7-22 Table 12.8-2. Values of Approximate Period Parameters C_t and x.

Structure Type	C_t	x
Moment-resisting frame systems in which the frames resist 100% of the required seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting where subjected to seismic forces:		
Steel moment-resisting frames	0.028 (0.0724)*	0.8
Concrete moment-resisting frames	0.016 (0.0466)*	0.9
Steel eccentrically braced frames in accordance with Table 12.2-1, line B1 or D1	0.03 (0.0731)*	0.75
Steel buckling-restrained braced frames	0.03 (0.0731)*	0.75
All other structural systems	0.02 (0.0488)*	0.75

*SI equivalents in parentheses.

Where the SFRS is unknown, T_a can be determined using the approximate period parameters for "All other structural systems."

For nonbuilding structures, T_a can be taken as:

a) The period of nonbuilding structure determined from analysis.
b) The period determined using Equation 15.4-6

$$T = 2\pi\sqrt{\frac{\sum_{i=1}^{n} w_i \delta_i^2}{g\sum_{i=1}^{n} f_i \delta_i}}$$

where f_i represents the lateral force in the i^{th} level and δ_i is the elastic deflection for the i^{th} level, calculated for the applied lateral forces, f_i.
c) The approximate fundamental period, T_a, determined by Equation 12.8-8 using the approximate period parameters for "All other structural systems."

Step 4e – Determine Structure Ductility Reduction Factor, R_μ

$$R_\mu = \left[\frac{1.1R}{I_e\Omega_0}\right]^{\frac{1}{2}} \geq 1.3$$

where
I_e = Seismic Importance Factor. The seismic importance factor is related to the Risk Category and is given in Table 1.5-2. A Risk Category I or II structure is assigned I_e = 1.0; a Risk Category III structure is assigned I_e = 1.25; and a Risk Category IV structure is assigned I_e = 1.5.
R = Response modification factor for the building or nonbuilding structure supporting the component, from Table 12.2-1, 15.4-1, or 15.4-2.
Ω_o = Overstrength factor for the building or nonbuilding structure supporting the component, from Table 12.2-1, 15.4-1, or 15.4-2.

Note that for components supported at or below grade, R_μ should be taken as 1.0. If the SFRS of the building or nonbuilding structure is not known or is not listed in Table 12.2-1, 15.4-1, or 15.4-2, then R_μ can be taken as 1.3 unless the seismic design parameters for the unlisted SRFS have been approved by the AHJ.

For a supporting structure containing combinations of SFRSs in different directions, the R_μ of the structure should be based on the SFRS resulting in the lowest value.

Step 4f – Determine Component Resonance Ductility Factor, C_{AR} and Component Strength Factor, R_{po}

C_{AR} and R_{po} for architectural components are provided in Table 13.5-1 and for mechanical components are provided in Table 13.6-1.

C_{AR} for mechanical and electrical equipment mounted on equipment support structures or platforms must not be less than component resonance ductility factor used for the equipment support structure or platform.

STEP 5 Determine Vertical Seismic Design Force

The component, including its supports and attachments, must be designed for a concurrent vertical seismic design force, $E_v = 0.2S_{DS}D$, where D is the effect of dead load.

EXCEPTION: The concurrent vertical seismic force need not be considered for lay-in access floor panels and lay-in ceiling panels.

STEP 6 Determine Seismic Relative Displacements, D_{pI}

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

$$D_{pI} = D_p I_e$$

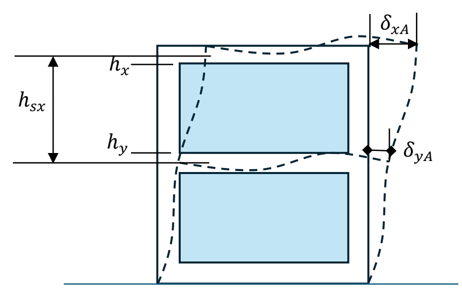
The value of D_p relies on whether the component is attached to a single structure or if it's connected to two separate structures.

Displacements within Structures

For two connection points on the same structure A or the same structural system, one at a height h_x and the other at a height h_y

$$D_p = \delta_{xA} - \delta_{yA}$$

δ_{xA} = Deflection at building level x of structure A
δ_{yA} = Deflection at building level y of structure A



Structure A

δ_x is the design earthquake displacement at level x

$$\delta_x = \frac{C_d\delta_{e,x}}{I_e} + \delta_{di,x}$$

C_d = Deflection amplification factor from Table 12.2-1;
$\delta_{e,x}$ = Elastic displacement at level x computed under design earthquake forces, including the effects of accidental torsion and torsional amplification as applicable; and
$\delta_{di,x}$ = Displacement due to diaphragm deformation at level x corresponding to the design earthquake, caused by diaphragm design forces from Section 12.10.

Alternatively, D_p can be determined using linear dynamic procedures specified in Section 12.9: Modal Response Spectrum Analysis (MRSA) and Linear Response History Analysis (LRHA). For structures where the story drift associated with the Design Earthquake Displacement does not exceed the allowable drift defined in Table 12.12-1, D_p is not required to be taken as greater than

$$D_p = \frac{(h_x - h_y)\Delta_{aA}}{h_{sx}}$$

where Δ_{aA} is the allowable story drift for structure A, and h_{sx} is the story height used in the definition of the allowable drift, Δ_a.

ASCE 7-22 Table 12.12-1. Allowable Story Drift, Δ_a

Structure	Risk Category		
	I or II	III	IV
Structures, other than masonry shear wall structures, four stories or less above the base as defined in Section 11.2, with interior walls, partitions, and ceilings that have been designed to accommodate the drifts associated with the Design Earthquake Displacements	$0.025h_{sx}$[a]	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures[b]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

[a] There shall be no drift limit for single-story structures in which the interior walls, partitions, and ceilings have been designed to accommodate story drifts associated with the Design Earthquake Displacement. The structural separation requirement of Section 12.12.3 is not waived.

[b] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support that are so constructed that moment transfer between shear walls (coupling) is negligible.

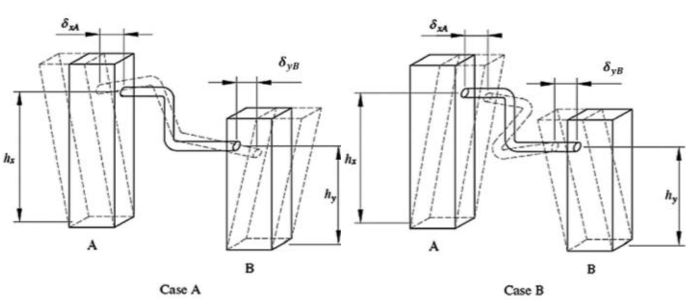
Displacements between Structures

For two connection points on separate structures A and B or separate structural systems, one at height h_x, and the other at a height h_y, D_p must be determined as

$$D_p = |\delta_{xA}| + |\delta_{yB}| \le \left[\frac{h_x \Delta_{aA}}{h_{sx}} + \frac{h_y \Delta_{aB}}{h_{sy}}\right]^*$$

*the limit applies only to structures where story drifts associated with Design Earthquake Displacement do not exceed the allowable story drift.

A component or system connected to two structures must accommodate horizontal movements in any direction, as illustrated in Figure below.



Displacement between structures.

(Source: ASCE 7-22 Commentary)

STEP 7 LOAD COMBINATIONS

Sections 12.4.2 and 12.4.3 address the determination of the combined seismic load effect, E, and seismic load effect including overstrength, E_m. E is the combined effect of horizontal (Section 12.4.2.1) and vertical (Section 12.4.2.2) earthquake-induced forces. For nonstructural components it can be quantified by the following equation:

ρ = 1 for nonstructural components

$$E = \rho F_p \pm 0.2S_{DS}D = F_p \pm 0.2S_{DS}D$$

Effect of Horizontal Seismic Design Forces, determined in Step 4

Vertical Seismic Design Forces, determined in Step 5

E_m is the maximum seismic load effect and is required for the design of certain elements critical to the seismic load paths.

$$E_m = \Omega_{op} F_p \pm 0.2S_{DS}D$$

Ω_{op} is the component overstrength factor listed in Tables 13.5-1 and 13.6-1. $\Omega_{op}F_p$ represents the actual forces that may be experienced by a nonstructural component, its attachments or supports as a result of the design-level ground motion. E_m is used in the additive and the counteractive load combinations the same way as E.

For masonry and concrete anchors where nonductile anchorage in concrete and masonry is used, the anchorage overstrength factor, Ω_{op}, given in Tables 13.5-1 and 13.6-1 must be used.

Nonstructural components, including their supports and attachments, must comply with Section 1.3, and designed for load combinations of either Section 2.3 (strength design) or 2.4 (allowable stress design), as appropriate.

Where the effects of nonseismic loads on nonstructural components exceed those due to F_p, the nonseismic load effects must govern the strength design, but the detailing requirements and limitations prescribed in Section 13.5 and 13.6 must still apply.

STEP 8 DESIGN OF COMPONENT ANCHORAGE AND ATTACHMENT

The design force in the attachment must be determined based on the forces and displacements calculated for the component in Steps 4 through 7. The determination of forces in attachments must take into account the expected conditions of installation, including eccentricities and prying effects. Where there are multiple attachments at one location, the design force from the component must be distributed to the attachments taking into account the stiffness and ductility of the component, the component supports, the attachments, the structure, and the ability to redistribute loads to other attachments in the group.

A continuous load path of sufficient strength and stiffness between the component and supporting structure must be provided. Local elements of the structure, including connections, must be designed and constructed for the effects of component forces where they control the design of these elements.

Component attachments must be bolted, welded, or otherwise positively fastened without depending on frictional resistance produced by effects of gravity.

Anchors in Concrete

Anchors in concrete must be designed in accordance with Chapter 17 of ACI 318-19. Where nonductile anchorage to concrete is used to satisfy ACI 318-19 Section 17.10.5.3 (d), the anchorage overstrength factor, Ω_{op}, given in Tables 13.5-1 and 13.6-1 must be used.

In structures assigned to SDC C or higher, post-installed mechanical anchors in concrete are required to be prequalified for seismic applications in accordance with ACI 355.2 or other approved qualification procedures. Post-installed adhesive anchors in concrete in structures assigned to SDC C, D, E, or F are required to be prequalified for seismic applications in accordance with ACI 355.4 or other approved qualification procedures.

Anchors in Masonry

Anchors in masonry must be designed in accordance with TMS 402-22. Additionally, at least one of the following must be satisfied in structures assigned to SDC C or higher.

a. Anchors in tension are designed to be governed by the tensile strength of a ductile steel element.
b. Anchors are designed for the maximum load that can be transmitted to the anchors from a ductile attachment, considering both material overstrength and strain hardening of the attachment.
c. Anchors are designed for the maximum load that can be transmitted to the anchors by a non-yielding attachment.
d. Anchors are designed for the maximum load obtained from design load combinations that include F_p, where the effect of horizontal seismic design force, F_p, is multiplied by Ω_{op} as given in ASCE 7-22 Tables 13.5-1 and 13.6-1.

In structures assigned to SDC C or higher, post-installed anchors in masonry are required to be prequalified for seismic applications in accordance with approved qualification procedures.

Use of Power-Actuated Fasteners must comply with the requirements of Section 13.4.5

Use of Friction Clips must comply with the requirements of Section 13.4.6

STEP 8 Requirements for Mechanical and Electrical Component Supports

Mechanical and electrical component supports include structural members, braces, frames, skirts, legs, saddles, pedestals, cables, guys, stays, snubbers, tethers, and elements forged or cast as a part of the component. Section 13.6.4 outlines design and detailing requirements of mechanical and electrical component supports, as well as equipment support structures and platforms. Here is a summary of the requirements:

1. If supports designed in accordance with ASME B31, NFPA 13, or MSS SP-58 are used, they must be designed by load rating (i.e., testing) or for calculated seismic design forces in Steps 4 and 5.
2. The supports must be designed to accommodate seismic relative displacements calculated in Step 6.
3. The means by which the supports are attached to the component must be designed for seismic forces and relative displacements. The local region of the support attachment point must be evaluated for the effect of load transfer on the component wall.
4. Materials for support and means of attachment must be in conformance with nationally recognized standards.
5. Seismic supports must be constructed to maintain engagement. Reinforcement (e.g., stiffeners or Belleville washers) is required for bolted connections through sheet metal equipment housings. Weak-axis bending of cold-formed steel supports requires specific evaluation. Components on vibration isolators need appropriate restraints and materials to limit impact loads.
6. Equipment support structures and platforms must be designed for seismic forces and relative displacements determined in Steps 4 through 6. The selected seismic force-resisting system (SFRS) for equipment structures and platforms should conform to the types in Table 12.2-1 or 15.4-1, with detailed design according to specific requirements of Section 13.6.4.6.
7. Distribution system supports are assigned a component resonance ductility factor, C_{AR}, from Table 13.6-1, based on the type of support system. Seismic loads for distribution system supports and trapeze assemblies must be based on the weight of the distribution system tributary to the supports, including fittings and in-line components.

For buildings that are assigned to RC IV, guidance on the design of lighting fixtures is found in Section C-3.4 of UFC 3-301-01.

STEP 9 Consequential Damage – Seismic Interaction Effects

The functional and physical interrelationship of components, their supports, and their effects on each other must be considered so that the failure of an essential or nonessential architectural, mechanical, or electrical component shall not cause the failure of an essential architectural, mechanical, or electrical component. Where not otherwise established by analysis or test, required clearances for sprinkler system drops and sprigs must not be less than those specified in Section 13.2.4.1.

STEP 10 Requirements for Architectural Components

All architectural components, and their supports and attachments, must be designed for seismic forces calculated in Step 4, applied at center of mass of the component.

Architectural components that could pose life-safety hazard must be designed to accommodate the seismic relative displacement calculated in Step 6. They must be designed considering vertical deflection caused by joint rotation of cantilever structural members.

Transverse or out-of-plane bending of a component or system must not exceed the out-of-plane deflection capability of the component or system.

Strength and ductility requirements for architectural components

Type of Component	Strength and Ductility Requirements
Suspended components or components supported by chains **Section 13.5.1**	Need not satisfy seismic force and relative displacement requirements if they meet all of the following criteria: • The components are designed for a gravity load of 1.4 times the operating weight with a simultaneous lateral load of 1.4 times the operating weight. The lateral load should be applied in the direction that results in the most load effect. • Seismic interaction effects are considered (Step 9) • Connection allows for 360-degree range of motion in horizontal plane.
Exterior Nonstructural Wall Elements and Connections **Section 13.5.3**	• In addition to seismic relative displacement, the component must accommodate movements due to temperature changes. • Connections and panel joints must allow for D_{pI}, or 0.5 in. (13 mm), whichever is greater. • Connections with threaded steel rods or bolts: ○ Threaded rods or bolts must be made of low-carbon or stainless steel. Cold-worked carbon steel rods must meet or exceed ASTM F1554 Grade 36 requirements. Grade 55 rods are also permitted if they meet Supplement 1 (of ASTM F1554) requirements. ○ Threaded rods in connections accommodating drift through sliding mechanisms in slotted or oversized holes must have length(clear distance between nuts or threaded bolts)-to-diameter

Type of Component	Strength and Ductility Requirements
	ratios of 4 or less, with slots or holes proportioned to accommodate full design story drift in each direction. Nuts must be finger-tight, with measures to prevent loosening. ○ Connections accommodating story drift by bending of threaded rods must satisfy $$\frac{\left(\frac{L\text{ (clear length as above)}}{d\text{ (rod diameter)}}\right)}{D_{pI}} \geq 6\left(\frac{1}{\text{in.}}\right)$$ • The connecting member itself shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds. • Forces should be calculated for the connecting system which includes the connections between the wall panels or elements and the structure, and the interconnections between wall panels or elements. • Flat straps used for anchorage must be attached or hooked around reinforcing steel or terminated such that they transfer the forces to reinforcing steel.
Glass in glazed curtain walls, glazed storefronts, and glazed partitions **Sections 13.5.6, 13.5.9**	Glass in glazed curtain walls, glazed storefronts, and glazed partitions shall meet the relative displacement requirement of Equation 13.5-2: $$\Delta_{fallout} \geq 1.25\, D_p$$ ASCE 7-22 Equation 13.5-2 or 0.5 in., whichever is greater, where $\Delta_{fallout}$ is the seismic relative displacement (drift) at which the glass fallout from the curtain wall occurs, which must be determined in accordance with AAMA 501.6 or by engineering analysis. D_p is the relative displacement over the height of the glass component under consideration. Glass need not comply with the above requirement if it meets one of the three exceptions listed in Section 13.5.9.1. Glazing Sealants, when used, must conform to the requirements of the standards listed in Table 13.5-2.
Suspended Ceilings	Follow ASCE 7-22 Section 13.5.6 and UFC 3-301-01 Section 13.5.6. Additional guidance on suspended ceiling design is provided in Section C-2.2.8 of UFC 3-301-01.
Access Floors	Follow ASCE 7-22 Section 13.5.7. Access floor components that have $I_p > 1.0$ must meet the requirements of Special Access floors (Section 13.5.7.2). Additional requirements concerning certification is provided in UFC 3-301-01 Section 13.5.7.
Partitions	Section 13.5.8 provides requirements for lateral bracing of partitions tied to the ceiling or exceeding 6 ft (1.8 m) in height. Such bracing should be independent of ceiling lateral force bracing and spaced to limit horizontal deflection at the partition head, aligning with ceiling deflection requirements. However, there are exceptions to this requirement.
Egress Stairs and Ramps	Egress stairs and ramps that are not part of the seismic force-resisting system (SFRS) of the structure to which they are attached must be detailed to accommodate D_{pI} defined in Section 13.3.2, including diaphragm deformation, in accordance with Section 13.5.10.
Penthouses and Rooftop Structures	Penthouses and rooftop structures must be designed in accordance with Section 13.5.11, except for those framed by an extension of the building frame, which should be designed according to Chapter 12 requirements. Section 13.5.11.1 provides requirements for seismic force-resisting systems for penthouses and rooftop structures.
Bridges, Cranes, and Monorails	Structural supports for crane systems in buildings or structures assigned to SDC C with I_p greater than 1.0 or in structures assigned to SDC D, E, and F should be designed for F_p with $\left[\frac{C_{AR}}{R_{po}}\right] = 1$. Crane rail connections must be designed for the forces resulting from $\left[\frac{C_{AR}}{R_{po}}\right] = 1.15$. Refer to UFC 3-301-01 Section 13.6.14 for more requirements. Further guidance on the design of these systems can be found in Section C-3.5 of UFC 3-301-01.

STEP 11 Requirements for Mechanical and Electrical Components

Dynamic effects of the components, their contents, and their supports and attachments should be considered. Where such effects are pronounced, the interaction between the components and the supporting structure, including other mechanical and electrical components must also be evaluated.

Strength and ductility requirements for mechanical and electrical components

Type of Component	Strength and Ductility Requirements
Mechanical Components	
Components that have I_p determined in Step 1d greater than 1.0	• Components that are vulnerable to impact or are made of nonductile materials or where the ductility may decrease due to service conditions must not experience seismic impact. • The possibility of loads imposed on components by attached utility or service lines, caused by differential movement of support points on separate structures, must be evaluated. • Piping or HVACR ductwork components attached to structures that could displace relative to one another or where such components cross isolation interface for isolated structures must be designed to accommodate seismic relative displacements.
HCACR equipment	HVACR equipment qualified in accordance with the requirements of Chapters 1 through 10 of ANSI/AHRI Standard 1270 (I-P) or ANSI/AHRI Standard 1271 is deemed to meet the special certification requirements for designated systems, provided the requirements in Section 13.6.2.1 are met.
HVACR ductwork	HVACR and other duct systems not designed to carry toxic, highly toxic, or flammable gases or not used for smoke control need not be designed for seismic forces and relative displacements if they meet the exceptions in Section 13.6.6
Piping systems	Piping and tubing systems must comply with the requirements of Section 13.6.7. Piping systems that satisfy the exceptions in Section 13.6.7.3 need not be designed for seismic forces. Note these exceptions do not apply to elevator system piping.

Type of Component	Strength and Ductility Requirements
	ASME pressure piping systems must satisfy the requirements of Section 13.6.7.1. Fire protection sprinkler piping must satisfy the requirements of Section 13.6.7.2. Elevator system piping must satisfy the requirements of Section 13.6.11.
Boilers and Vessels	Boilers and Pressure Vessels can be designed either for seismic forces and displacements in Sections 13.3.1 and 13.3.2 or in accordance with ASME BPVC. For more requirements refer to Section 13.6.10.
Elevators	Refer to Section 13.6.11 and UFC 3-301-01 Section 13.6.11.3.
Rooftop Solar Panels	UFC 3-301-01 Section 13.6.12 deletes the exception in ASCE 7-22 Section 13.6.12 related to ballasted solar panels. Ballasted systems are specifically disallowed by UFC 3-110-03, *Roofing.*
All other mechanical components	Refer to Section 13.6.13.
Electrical Components	
Components that have I_p determined in Step 1d greater than 1.0	These components must be designed for the seismic forces and relative displacements determined in Steps 4 through 6 and satisfy the additional requirements given in Section 13.6.3.
Light fixtures, lighted signs, and ceiling fans not connected to ducts or piping, supported by chains or suspended from the structure	These components need not be designed for seismic forces and relative displacements determined in Steps 4 through 6 if they meet all of the following criteria: • The components are designed for a gravity load of 1.4 times the operating weight with a simultaneous lateral load of 1.4 times the operating weight. The lateral load should be applied in the direction that results in the most critical load effect. • Seismic interaction effects are considered (Step 9) • Connection allows for 360-degree range of motion in the horizontal plane.
Utility and service lines	Utility and service lines must have the flexibility to accommodate the differential movement between moving structures or portions that they are connected to. The possible interruption of utility lines in designated seismic systems of RC IV structures must be considered. Underground utilities need specific attention. For more requirements refer to Section 13.6.9
Distribution Systems: Conduit, Cable Tray, and Raceways	Cable trays and raceways shall be designed for seismic forces and seismic relative displacements determined in Steps 4 through 6. Design for the seismic forces and relative displacements shall not be required for raceways with I_p = 1.0, where: • flexible connections or other assemblies are provided between the cable tray or raceway and associated components to accommodate the relative displacement, • the cable tray or raceway is positively attached to the structure, and • one of the requirements of Exception 1 to Section 13.6.5 is met. Conduit greater than 2.5 in. (64 mm) trade size and attached to panels, cabinets, or other equipment subject to seismic relative displacement, D_{pI} , shall be provided with flexible connections or designed for seismic forces and seismic relative displacements determined in Steps 4 through 6. Design for the seismic forces and relative displacements shall not be required for conduit, regardless of the value of I_p, where the conduit is less than 2.5 in. However, across seismic joints, deign for displacements shall be required for conduit, cable trays, and raceways with I_p = 1.5 without consideration of conduit size.
Other electrical components	Refer to Section 13.6.13

STEP 12 Special Certification Requirements for Designated Seismic Systems

Designated Seismic Systems: These are nonstructural components that require design in accordance with Chapter 13 and for which the component importance factor, I_p, is greater than 1.0.

Designated seismic systems assigned to SDC C and above should be certified as follows:

Active mechanical and electrical equipment	• Active mechanical and electrical equipment that must remain operable following the design earthquake ground motion shall be certified by the manufacturer as operable.
	• Active parts and energized components:
	  ○ must be certified exclusively on the basis of approved shake table testing using a nationally recognized testing standard such as ICC-ES 156, or
	  ○ must be shown to be inherently rugged by comparison with similar seismically qualified components. Evidence of such comparison must be reviewed and accepted by a registered design professional and then submitted to the AHJ for approval.
	• Cannot be certified through analysis.

Nonactive components	• Analysis can be used to certify these components and the seismic demand in Step 4 should be calculated for $\left[\frac{C_{AR}}{R_{po}}\right]$=2.5. • For components with period, $T_p \leq 0.06$ secs, as calculated in Step 2c, $\left[\frac{C_{AR}}{R_{po}}\right]$ can be taken as 1.0. • R_μ must be taken as 1.3 for components located above the grade plane.
Components with hazardous substances and assigned a component Importance Factor, I_p, of 1.5	These components must be certified as maintaining containment following design earthquake ground motion by: • Analysis, or • Approved shake table testing, or • Experience data. Evidence demonstrating compliance with this requirement must be reviewed and accepted by a registered design professional and submitted to the AHJ for approval.

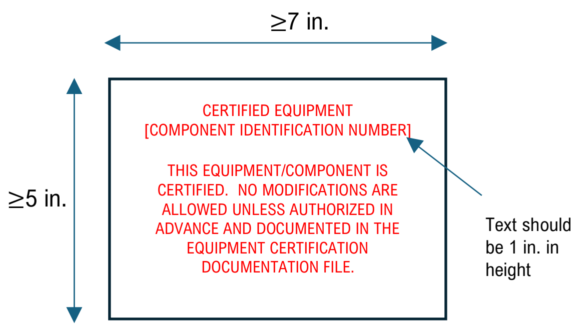
UFC 3-301-01 Section 13.2.3 provides more certification requirements. This section adds the following requirements to ASCE 7-22 Section 13.2.3.

13.2.3.1 - Component Certification and Operations & Maintenance (O&M) Manual

For any electrical or mechanical component required by ASCE 7-22 Section 13.2.3 to be certified, evidence demonstrating compliance with the requirement must be maintained in a file identified as "Equipment Certification Documentation." This file must be a part of the Operations & Maintenance (O&M) Manual that is turned over to the AHJ. The project specifications must require the O&M Manual to state that replaced or modified components need to be certified per the original certification criteria.

13.2.3.2 - Component Identification Nameplate

Any electrical or mechanical component required by ASCE 7-22 Section 13.2.3 to be certified is required to bear permanent marking or nameplates constructed of a durable heat- and water-resistant material. Nameplates must be mechanically attached to such nonstructural components and placed on each component for clear identification.



The nameplate cannot be less than 5 in. x 7 in. with red letters 1 in. in height on a white background, stating "Certified Equipment." The following statement is required to be on the nameplate: "This equipment/component is certified. No modifications are allowed unless authorized in advance and documented in the Equipment Certification Documentation file." The nameplate needs to also contain the component identification number in accordance with the drawings/specifications and the O&M manuals.

STEP 13 — CONSTRUCTION DOCUMENTS

Where design of nonstructural components or their supports and attachments is required by Table 13.2-1, such design shall be shown in construction documents prepared by a registered design professional for use by the owner, Authorities Having Jurisdiction, contractors, and inspectors.

ABBREVIATIONS

AAMA	American Architectural Manufacturers Association
ACI	American Concrete Institute
AHJ	Authority Having Jurisdiction
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPVC	Boilers and Pressure Vessels
CEFAPP	CERL Equipment Fragility and Protection Procedure
CERL	Construction Engineering Research Laboratory
DoD	Department of Defense
DOE	Department of Energy
IBC	International Building Code
ICC	International Code Council
ICC-ES	International Code Council - Evaluation Services
IEEE	Institute of Electrical and Electronics Engineers
MCE_R	Risk-Targeted Maximum Considered Earthquake
MSS	Manufacturers Standardization Society
NFPA	National Fire Protection Association
RC	Risk Category
SDC	Seismic Design Category
SFRS	Seismic Force-Resisting System
O&M	Operations & Maintenance
TMS	The Masonry Society
UFC	Unified Facilities Criteria
USACERL	U.S. Army Construction Engineering Research Laboratory