Chapter 12
SEISMIC DESIGN REQUIREMENTS FOR BUILDING STRUCTURES

12.1 STRUCTURAL DESIGN BASIS

12.1.1 Basic Requirements. The seismic analysis and design procedures to be used in the design of building structures and their components shall be as prescribed in this section. The building structure shall include complete lateral and vertical force-resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within the prescribed limits of deformation and strength demand. The design ground motions shall be assumed to occur along any horizontal direction of a building structure. The adequacy of the structural systems shall be demonstrated through the construction of a mathematical model and evaluation of this model for the effects of design ground motions. The design seismic forces, and their distribution over the height of the building structure, shall be established in accordance with one of the applicable procedures indicated in Section 12.6 and the corresponding internal forces and deformations in the members of the structure shall be determined. An approved alternative procedure shall not be used to establish the seismic forces and their distribution unless the corresponding internal forces and deformations in the members are determined using a model consistent with the procedure adopted.

EXCEPTION: As an alternative, the simplified design procedures of Section 12.14 is permitted to be used in lieu of the requirements of Sections 12.1 through 12.12, subject to all of the limitations contained in Section 12.14.

12.1.2 Member Design, Connection Design, and Deformation Limit. Individual members, including those not part of the seismic force–resisting system, shall be provided with adequate strength to resist the shears, axial forces, and moments determined in accordance with this standard, and connections shall develop the strength of the connected members or the forces indicated in Section 12.1.1. The deformation of the structure shall not exceed the prescribed limits where the structure is subjected to the design seismic forces.

12.1.3 Continuous Load Path and Interconnection. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance. All parts of the structure between separation joints shall be interconnected to form a continuous path to the seismic force–resisting system, and the connections shall be capable of transmitting the seismic force (F_p) induced by the parts being connected. Any smaller portion of the structure shall be tied to the remainder of the structure with elements having a design strength capable of transmitting a seismic force of 0.133 times the short period design spectral response acceleration parameter, S_{DS}, times the weight of the smaller portion or 5 percent of the portion's weight, whichever is greater. This connection force does not apply to the overall design of the seismic force–resisting system. Connection design forces need not exceed the maximum forces that the structural system can deliver to the connection.

12.1.4 Connection to Supports. A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder, or truss either directly to its supporting elements, or to slabs designed to act as diaphragms. Where the connection is through a diaphragm, then the member's supporting element must also be connected to the diaphragm. The connection shall have a minimum design strength of 5 percent of the dead plus live load reaction.

12.1.5 Foundation Design. The foundation shall be designed to resist the forces developed and accommodate the movements imparted to the structure by the design ground motions. The dynamic nature of the forces, the expected ground motion, the design basis for strength and energy dissipation capacity of the structure, and the dynamic properties of the soil shall be included in the determination of the foundation design criteria. The design and construction of foundations shall comply with Section 12.13.

12.1.6 Material Design and Detailing Requirements. Structural elements including foundation elements shall conform to the material design and detailing requirements set forth in Chapter 14.

12.2 STRUCTURAL SYSTEM SELECTION

12.2.1 Selection and Limitations. The basic lateral and vertical seismic force–resisting system shall conform to one of the types indicated in Table 12.2-1 or a combination of systems as permitted in Sections 12.2.2, 12.2.3, and 12.2.4. Each type is subdivided by the types of vertical elements used to resist lateral seismic forces. The structural system used shall be in accordance with the seismic design category and height limitations indicated in Table 12.2-1. The appropriate response modification coefficient, R, system overstrength factor, Ω_0, and the deflection amplification factor, C_d, indicated in Table 12.2-1 shall be used in determining the base shear, element design forces, and design story drift.

The selected seismic force-resisting system shall be designed and detailed in accordance with the specific requirements for the system per the applicable reference document and the additional requirements set forth in Chapter 14.

Seismic force–resisting systems that are not contained in Table 12.2-1 are permitted if analytical and test data are submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to the structural systems listed in Table 12.2-1 for equivalent response modification coefficient, R, system overstrength coefficient, Ω_0, and deflection amplification factor, C_d, values.

12.2.2 Combinations of Framing Systems in Different Directions. Different seismic force–resisting systems are permitted to be used to resist seismic forces along each of the two orthogonal axes of the structure. Where different systems are used, the respective R, C_d, and Ω_0 coefficients shall apply to each system, including the limitations on system use contained in Table 12.2-1.

12.2.3 Combinations of Framing Systems in the Same Direction. Where different seismic force–resisting systems are used in combination to resist seismic forces in the same direction of structural response, other than those combinations considered as

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS

Seismic Force–Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	System Overstrength Factor, $\Omega_0{}^g$	Deflection Amplification Factor, $C_d{}^b$	Structural System Limitations and Building Height (ft) Limit^c				
					Seismic Design Category				
					B	C	D^d	E^d	F^e
A. BEARING WALL SYSTEMS									
1. Special reinforced concrete shear walls	14.2 and 14.2.3.6	5	2½	5	NL	NL	160	160	100
2. Ordinary reinforced concrete shear walls	14.2 and 14.2.3.4	4	2½	4	NL	NL	NP	NP	NP
3. Detailed plain concrete shear walls	14.2 and 14.2.3.2	2	2½	2	NL	NP	NP	NP	NP
4. Ordinary plain concrete shear walls	14.2 and 14.2.3.1	1½	2½	1½	NL	NP	NP	NP	NP
5. Intermediate precast shear walls	14.2 and 14.2.3.5	4	2½	4	NL	NL	40^k	40^k	40^k
6. Ordinary precast shear walls	14.2 and 14.2.3.3	3	2½	3	NL	NP	NP	NP	NP
7. Special reinforced masonry shear walls	14.4 and 14.4.3	5	2½	3½	NL	NL	160	160	100
8. Intermediate reinforced masonry shear walls	14.4 and 14.4.3	3½	2½	2¼	NL	NL	NP	NP	NP
9. Ordinary reinforced masonry shear walls	14.4	2	2½	1¾	NL	160	NP	NP	NP
10. Detailed plain masonry shear walls	14.4	2	2½	1¾	NL	NP	NP	NP	NP
11. Ordinary plain masonry shear walls	14.4	1½	2½	1¼	NL	NP	NP	NP	NP
12. Prestressed masonry shear walls	14.4	1½	2½	1¾	NL	NP	NP	NP	NP
13. Light-framed walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1, 14.1.4.2, and 14.5	6½	3	4	NL	NL	65	65	65
14. Light-framed walls with shear panels of all other materials	14.1, 14.1.4.2, and 14.5	2	2½	2	NL	NL	35	NP	NP
15. Light-framed wall systems using flat strap bracing	14.1, 14.1.4.2, and 14.5	4	2	3½	NL	NL	65	65	65
B. BUILDING FRAME SYSTEMS									
1. Steel eccentrically braced frames, moment resisting connections at columns away from links	14.1	8	2	4	NL	NL	160	160	100
2. Steel eccentrically braced frames, non-moment-resisting, connections at columns away from links	14.1	7	2	4	NL	NL	160	160	100
3. Special steel concentrically braced frames	14.1	6	2	5	NL	NL	160	160	100
4. Ordinary steel concentrically braced frames	14.1	3¼	2	3¼	NL	NL	35^j	35^j	NP^j
5. Special reinforced concrete shear walls	14.2 and 14.2.3.6	6	2½	5	NL	NL	160	160	100
6. Ordinary reinforced concrete shear walls	14.2 and 14.2.3.4	5	2½	4½	NL	NL	NP	NP	NP
7. Detailed plain concrete shear walls	14.2 and 14.2.3.2	2	2½	2	NL	NP	NP	NP	NP
8. Ordinary plain concrete shear walls	14.2 and 14.2.3.1	1½	2½	1½	NL	NP	NP	NP	NP
9. Intermediate precast shear walls	14.2 and 14.2.3.5	5	2½	4½	NL	NL	40^k	40^k	40^k
10. Ordinary precast shear walls	14.2 and 14.2.3.3	4	2½	4	NL	NP	NP	NP	NP
11. Composite steel and concrete eccentrically braced frames	14.3	8	2	4	NL	NL	160	160	100
12. Composite steel and concrete concentrically braced frames	14.3	5	2	4½	NL	NL	160	160	100
13. Ordinary composite steel and concrete braced frames	14.3	3	2	3	NL	NL	NP	NP	NP
14. Composite steel plate shear walls	14.3	6½	2½	5½	NL	NL	160	160	100
15. Special composite reinforced concrete shear walls with steel elements	14.3	6	2½	5	NL	NL	160	160	100
16. Ordinary composite reinforced concrete shear walls with steel elements	14.3	5	2½	4½	NL	NL	NP	NP	NP
17. Special reinforced masonry shear walls	14.4	5½	2½	4	NL	NL	160	160	100
18. Intermediate reinforced masonry shear walls	14.4	4	2½	4	NL	NL	NP	NP	NP
19. Ordinary reinforced masonry shear walls	14.4	2	2½	2	NL	160	NP	NP	NP
20. Detailed plain masonry shear walls	14.4	2	2½	2	NL	NP	NP	NP	NP
21. Ordinary plain masonry shear walls	14.4	1½	2½	1¼	NL	NP	NP	NP	NP

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS (continued)

Seismic Force–Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	System Overstrength Factor, $\Omega_0{}^g$	Deflection Amplification Factor, $C_d{}^b$	Structural System Limitations and Building Height (ft) Limit^c				
					Seismic Design Category				
					B	C	D^d	E^d	F^e
22. Prestressed masonry shear walls	14.4	1½	2½	1¾	NL	NP	NP	NP	NP
23. Light-framed walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1, 14.1.4.2, and 14.5	7	2½	4½	NL	NL	65	65	65
24. Light-framed walls with shear panels of all other materials	14.1, 14.1.4.2, and 14.5	2½	2½	2½	NL	NL	35	NP	NP
25. Buckling-restrained braced frames, non-moment-resisting beam-column connections	14.1	7	2	5½	NL	NL	160	160	100
26. Buckling-restrained braced frames, moment-resisting beam-column connections	14.1	8	2½	5	NL	NL	160	160	100
27. Special steel plate shear wall	14.1	7	2	6	NL	NL	160	160	100
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Special steel moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Special steel truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Intermediate steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, 12.2.5.9, and 14.1	4.5	3	4	NL	NL	$35^{h,i}$	NP^h	NP^i
4. Ordinary steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, and 14.1	3.5	3	3	NL	NL	NP^h	NP^h	NP^i
5. Special reinforced concrete moment frames	12.2.5.5 and 14.2	8	3	5½	NL	NL	NL	NL	NL
6. Intermediate reinforced concrete moment frames	14.2	5	3	4½	NL	NL	NP	NP	NP
7. Ordinary reinforced concrete moment frames	14.2	3	3	2½	NL	NP	NP	NP	NP
8. Special composite steel and concrete moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Intermediate composite moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Ordinary composite moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP
D. DUAL SYSTEMS WITH SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES	12.2.5.1								
1. Steel eccentrically braced frames	14.1	8	2½	4	NL	NL	NL	NL	NL
2. Special steel concentrically braced frames	14.1	7	2½	5½	NL	NL	NL	NL	NL
3. Special reinforced concrete shear walls	14.2	7	2½	5½	NL	NL	NL	NL	NL
4. Ordinary reinforced concrete shear walls	14.2	6	2½	5	NL	NL	NP	NP	NP
5. Composite steel and concrete eccentrically braced frames	14.3	8	2½	4	NL	NL	NL	NL	NL
6. Composite steel and concrete concentrically braced frames	14.3	6	2½	5	NL	NL	NL	NL	NL
7. Composite steel plate shear walls	14.3	7½	2½	6	NL	NL	NL	NL	NL
8. Special composite reinforced concrete shear walls with steel elements	14.3	7	2½	6	NL	NL	NL	NL	NL
9. Ordinary composite reinforced concrete shear walls with steel elements	14.3	6	2½	5	NL	NL	NP	NP	NP
10. Special reinforced masonry shear walls	14.4	5½	3	5	NL	NL	NL	NL	NL
11. Intermediate reinforced masonry shear walls	14.4	4	3	3½	NL	NL	NP	NP	NP
12. Buckling-restrained braced frame	14.1	8	2½	5	NL	NL	NL	NL	NL
13. Special steel plate shear walls	14.1	8	2½	6½	NL	NL	NL	NL	NL

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS (continued)

Seismic Force-Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	System Overstrength Factor, $\Omega_0{}^g$	Deflection Amplification Factor, $C_d{}^b$	Structural System Limitations and Building Height (ft) Limit[c] Seismic Design Category B	C	D^d	E^d	F^e
E. DUAL SYSTEMS WITH INTERMEDIATE MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES	12.2.5.1								
1. Special steel concentrically braced frames[f]	14.1	6	2½	5	NL	NL	35	NP	NP[h,k]
2. Special reinforced concrete shear walls	14.2	6½	2½	5	NL	NL	160	100	100
3. Ordinary reinforced masonry shear walls	14.4	3	3	2½	NL	160	NP	NP	NP
4. Intermediate reinforced masonry shear walls	14.4	3½	3	3	NL	NL	NP	NP	NP
5. Composite steel and concrete concentrically braced frames	14.3	5½	2½	4½	NL	NL	160	100	NP
6. Ordinary composite braced frames	14.3	3½	2½	3	NL	NL	NP	NP	NP
7. Ordinary composite reinforced concrete shear walls with steel elements	14.3	5	3	4½	NL	NL	NP	NP	NP
8. Ordinary reinforced concrete shear walls	14.2	5½	2½	4½	NL	NL	NP	NP	NP
F. SHEAR WALL-FRAME INTERACTIVE SYSTEM WITH ORDINARY REINFORCED CONCRETE MOMENT FRAMES AND ORDINARY REINFORCED CONCRETE SHEAR WALLS	12.2.5.10 and 14.2	4½	2½	4	NL	NP	NP	NP	NP
G. CANTILEVERED COLUMN SYSTEMS DETAILED TO CONFORM TO THE REQUIREMENTS FOR:	12.2.5.2								
1. Special steel moment frames	12.2.5.5 and 14.1	2½	1¼	2½	35	35	35	35	35
2. Intermediate steel moment frames	14.1	1½	1¼	1½	35	35	35[h]	NP[h,i]	NP[h,i]
3. Ordinary steel moment frames	14.1	1¼	1¼	1¼	35	35	NP	NP[h,i]	NP[h,i]
4. Special reinforced concrete moment frames	12.2.5.5 and 14.2	2½	1¼	2½	35	35	35	35	35
5. Intermediate concrete moment frames	14.2	1½	1¼	1½	35	35	NP	NP	NP
6. Ordinary concrete moment frames	14.2	1	1¼	1	35	NP	NP	NP	NP
7. Timber frames	14.5	1½	1½	1½	35	35	35	NP	NP
H. STEEL SYSTEMS NOT SPECIFICALLY DETAILED FOR SEISMIC RESISTANCE, EXCLUDING CANTILEVER COLUMN SYSTEMS	14.1	3	3	3	NL	NL	NP	NP	NP

[a] Response modification coefficient, R, for use throughout the standard. Note R reduces forces to a strength level, not an allowable stress level.
[b] Reflection amplification factor, C_d, for use in Sections 12.8.6, 12.8.7, and 12.9.2
[c] NL = Not Limited and NP = Not Permitted. For metric units use 30.5 m for 100 ft and use 48.8 m for 160 ft. Heights are measured from the base of the structure as defined in Section 11.2.
[d] See Section 12.2.5.4 for a description of building systems limited to buildings with a height of 240 ft (73.2 m) or less.
[e] See Section 12.2.5.4 for building systems limited to buildings with a height of 160 ft (48.8 m) or less.
[f] Ordinary moment frame is permitted to be used in lieu of intermediate moment frame for Seismic Design Categories B or C.
[g] The tabulated value of the overstrength factor, Ω_0, is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure.
[h] See Sections 12.2.5.6 and 12.2.5.7 for limitations for steel OMFs and IMFs in structures assigned to Seismic Design Category D or E.
[i] See Sections 12.2.5.8 and 12.2.5.9 for limitations for steel OMFs and IMFs in structures assigned to Seismic Design Category F.
[j] Steel ordinary concentrically braced frames are permitted in single-story buildings up to a height of 60 ft (18.3 m) where the dead load of the roof does not exceed 20 psf (0.96 kN/m^2) and in penthouse structures.
[k] Increase in height to 45 ft (13.7 m) is permitted for single story storage warehouse facilities.

dual systems, the more stringent system limitation contained in Table 12.2-1 shall apply and the design shall comply with the requirements of this section.

12.2.3.1 R, C_d, and Ω_0 Values for Vertical Combinations. The value of the response modification coefficient, R, used for design at any story shall not exceed the lowest value of R that is used in the same direction at any story above that story. Likewise, the deflection amplification factor, C_d, and the system over strength factor, Ω_0, used for the design at any story shall not be less than the largest value of this factor that is used in the same direction at any story above that story.

EXCEPTIONS:

1. Rooftop structures not exceeding two stories in height and 10 percent of the total structure weight.

2. Other supported structural systems with a weight equal to or less than 10 percent of the weight of the structure.
3. Detached one- and two-family dwellings of light-frame construction.

A two-stage equivalent lateral force procedure is permitted to be used for structures having a flexible upper portion above a rigid lower portion, provided that the design of the structure complies with the following:

a. The stiffness of the lower portion must be at least 10 times the stiffness of the upper portion.
b. The period of the entire structure shall not be greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.
c. The flexible upper portion shall be designed as a separate structure using the appropriate values of R and ρ.
d. The rigid lower portion shall be designed as a separate structure using the appropriate values of R and ρ. The reactions from the upper portion shall be those determined from the analysis of the upper portion amplified by the ratio of the R/ρ of the upper portion over R/ρ of the lower portion. This ratio shall not be less than 1.0.

12.2.3.2 R, C_d, and Ω_0 Values for Horizontal Combinations. Where a combination of different structural systems is utilized to resist lateral forces in the same direction, the value of R used for design in that direction shall not be greater than the least value of R for any of the systems utilized in that direction. Resisting elements are permitted to be designed using the least value of R for the different structural systems found in each independent line of resistance if the following three conditions are met: (1) Occupancy Category I or II building, (2) two stories or less in height, and (3) use of light-frame construction or flexible diaphragms. The value of R used for design of diaphragms in such structures shall not be greater than the least value for any of the systems utilized in that same direction.

The deflection amplification factor, C_d, and the system over strength factor, Ω_0, in the direction under consideration at any story shall not be less than the largest value of this factor for the R factor used in the same direction being considered.

12.2.4 Combination Framing Detailing Requirements. Structural components common to different framing systems used to resist seismic motions in any direction shall be designed using the detailing requirements of Chapter 12 required by the highest response modification coefficient, R, of the connected framing systems.

12.2.5 System Specific Requirements. The structural framing system shall also comply with the following system specific requirements of this section.

12.2.5.1 Dual System. For a dual system, the moment frames shall be capable of resisting at least 25 percent of the design seismic forces. The total seismic force resistance is to be provided by the combination of the moment frames and the shear walls or braced frames in proportion to their rigidities.

12.2.5.2 Cantilever Column Systems. Cantilever column systems are permitted as indicated in Table 12.2-1 and as follows. The axial load on individual cantilever column elements calculated in accordance with the load combinations of Section 2.3 shall not exceed 15 percent of the design strength of the column to resist axial loads alone, or for allowable stress design, the axial load stress on individual cantilever column elements, calculated in accordance with the load combinations of Section 2.4 shall not exceed 15 percent of the permissible axial stress.

Foundation and other elements used to provide overturning resistance at the base of cantilever column elements shall have the strength to resist the load combinations with over strength factor of Section 12.4.3.2.

12.2.5.3 Inverted Pendulum-Type Structures. Regardless of the structural system selected, inverted pendulums as defined in Section 11.2, shall comply with this section. Supporting columns or piers of inverted pendulum-type structures shall be designed for the bending moment calculated at the base determined using the procedures given in Section 12.8 and varying uniformly to a moment at the top equal to one-half the calculated bending moment at the base.

12.2.5.4 Increased Building Height Limit for Steel Braced Frames and Special Reinforced Concrete Shear Walls. The height limits in Table 12.2-1 are permitted to be increased from 160 ft (50 m) to 240 ft (75 m) for structures assigned to Seismic Design Categories D or E and from 100 ft (30 m) to 160 ft (50 m) for structures assigned to Seismic Design Category F that have steel braced frames or special reinforced concrete cast-in-place shear walls and that meet both of the following requirements:

1. The structure shall not have an extreme torsional irregularity as defined in Table 12.2-1 (horizontal structural irregularity Type 1b).
2. The braced frames or shear walls in any one plane shall resist no more than 60 percent of the total seismic forces in each direction, neglecting accidental torsional effects.

12.2.5.5 Special Moment Frames in Structures Assigned to Seismic Design Categories D through F. For structures assigned to Seismic Design Categories D, E, or F, a special moment frame that is used but not required by Table 12.1-1 shall not be discontinued and supported by a more rigid system with a lower response modification coefficient, R, unless the requirements of Sections 12.3.3.2 and 12.3.3.4 are met. Where a special moment frame is required by Table 12.1-1, the frame shall be continuous to the foundation.

12.2.5.6 Single-Story Steel Ordinary and Intermediate Moment Frames in Structures Assigned to Seismic Design Category D or E. Single-story steel ordinary moment frames and intermediate moment frames in structures assigned to Seismic Design Category D or E are permitted up to a height of 65 ft (20 m) where the dead load supported by and tributary to the roof does not exceed 20 psf (0.96 kN/m^2). In addition, the dead loads tributary to the moment frame, of the exterior wall more than 35 ft above the base shall not exceed 20 psf (0.96 kN/m^2).

12.2.5.7 Other Steel Ordinary and Intermediate Moment Frames in Structures Assigned to Seismic Design Category D or E. Steel ordinary moment frames in structures assigned to Seismic Design Category D or E not meeting the limitations set forth in Section 12.2.5.6 are permitted within light-frame construction up to a height of 35 ft (10.6 m) where neither the roof nor the floor dead load supported by and tributary to the moment frames exceeds 35 psf (1.68 kN/m^2). In addition, the dead load of the exterior walls tributary to the moment frame shall not exceed 20 psf (0.96 kN/m^2). Steel intermediate moment frames in structures assigned to Seismic Design Category D or E not meeting the limitations set forth in Section 12.2.5.6 are permitted as follows:

1. In Seismic Design Category D, intermediate moment frames are permitted to a height of 35 ft (10.6 m).
2. In Seismic Design Category E, intermediate moment frames are permitted to a height of 35 ft (10.6 m) provided neither the roof nor the floor dead load supported by and tributary

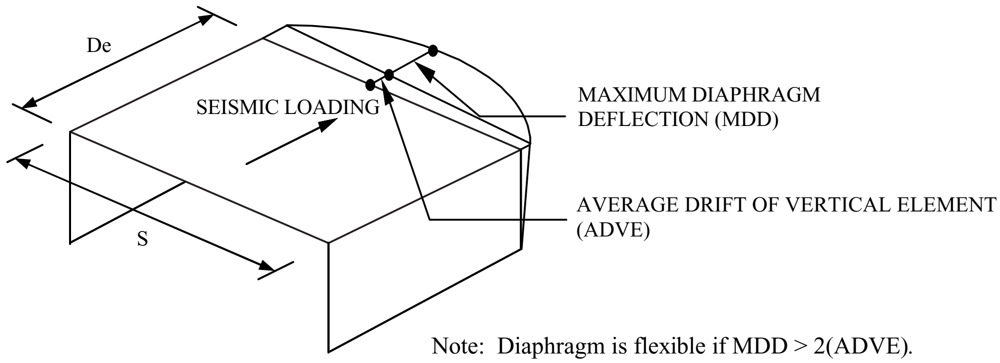

FIGURE 12.3-1 FLEXIBLE DIAPHRAGM

to the moment frames exceeds 35 psf (1.68 kN/m^2). In addition, the dead load of the exterior walls tributary to the moment frame shall not exceed 20 psf (0.96 kN/m^2).

12.2.5.8 Single-Story Steel Ordinary and Intermediate Moment Frames in Structures Assigned to Seismic Design Category F. Single-story steel ordinary moment frames and intermediate moment frames in structures assigned to Seismic Design Category F are permitted up to a height of 65 ft (20 m) where the dead load supported by and tributary to the roof does not exceed 20 psf (0.96 kN/m^2). In addition, the dead loads of the exterior walls tributary to the moment frame shall not exceed 20 psf (0.96 kN/m^2).

12.2.5.9 Other Steel Intermediate Moment Frame Limitations in Structures Assigned to Seismic Design Category F. In addition to the limitations for steel intermediate moment frames in structures assigned to Seismic Design Category E as set forth in Section 12.2.5.7, steel intermediate moment frames in structures assigned to Seismic Design Category F are permitted in light-frame construction.

12.2.5.10 Shear Wall-Frame Interactive Systems. The shear strength of the shear walls of the shear wall-frame interactive system shall be at least 75 percent of the design story shear at each story. The frames of the shear wall-frame interactive system shall be capable of resisting at least 25 percent of the design story shear in every story.

12.3 DIAPHRAGM FLEXIBILITY, CONFIGURATION IRREGULARITIES, AND REDUNDANCY

12.3.1 Diaphragm Flexibility. The structural analysis shall consider the relative stiffnesses of diaphragms and the vertical elements of the seismic force–resisting system. Unless a diaphragm can be idealized as either flexible or rigid in accordance with Sections 12.3.1.1, 12.3.1.2, or 12.3.1.3, the structural analysis shall explicitly include consideration of the stiffness of the diaphragm (i.e., semirigid modeling assumption).

12.3.1.1 Flexible Diaphragm Condition. Diaphragms constructed of untopped steel decking or wood structural panels are permitted to be idealized as flexible in structures in which the vertical elements are steel or composite steel and concrete braced frames, or concrete, masonry, steel, or composite shear walls. Diaphragms of wood structural panels or untopped steel decks in one- and two-family residential buildings of light-frame construction shall also be permitted to be idealized as flexible.

12.3.1.2 Rigid Diaphragm Condition. Diaphragms of concrete slabs or concrete filled metal deck with span-to-depth ratios of 3 or less in structures that have no horizontal irregularities are permitted to be idealized as rigid.

12.3.1.3 Calculated Flexible Diaphragm Condition. Diaphragms not satisfying the conditions of Sections 12.3.1.1 or 12.3.1.2 are permitted to be idealized as flexible where the computed maximum in-plane deflection of the diaphragm under lateral load is more than two times the average story drift of adjoining vertical elements of the seismic force–resisting system of the associated story under equivalent tributary lateral load as shown in Fig. 12.3-1. The loadings used for this calculation shall be those prescribed by Section 12.8.

12.3.2 Irregular and Regular Classification. Structures shall be classified as regular or irregular based upon the criteria in this section. Such classification shall be based on horizontal and vertical configurations.

12.3.2.1 Horizontal Irregularity. Structures having one or more of the irregularity types listed in Table 12.3-1 shall be designated as having horizontal structural irregularity. Such structures assigned to the seismic design categories listed in Table 12.3-1 shall comply with the requirements in the sections referenced in that table.

12.3.2.2 Vertical Irregularity. Structures having one or more of the irregularity types listed in Table 12.3-2 shall be designated as having vertical irregularity. Such structures assigned to the seismic design categories listed in Table 12.3-2 shall comply with the requirements in the sections referenced in that table.

EXCEPTIONS:

1. Vertical structural irregularities of Types 1a, 1b, or 2 in Table 12.3-2 do not apply where no story drift ratio under design lateral seismic force is greater than 130 percent of the story drift ratio of the next story above. Torsional effects need not be considered in the calculation of story drifts. The story drift ratio relationship for the top two stories of the structure are not required to be evaluated.
2. Irregularities Types 1a, 1b, and 2 of Table 12.3-2 are not required to be considered for one-story buildings in any seismic design category or for two-story buildings assigned to Seismic Design Categories B, C, or D.

12.3.3 Limitations and Additional Requirements for Systems with Structural Irregularities.

12.3.3.1 Prohibited Horizontal and Vertical Irregularities for Seismic Design Categories D through F. Structures assigned to Seismic Design Category E or F having horizontal irregularity Type 1b of Table 12.3-1 or vertical irregularities Type 1b, 5a, or 5b of Table 12.3-2 shall not be permitted. Structures assigned to Seismic Design Category D having vertical irregularity Type 5b of Table 12.3-2 shall not be permitted.

TABLE 12.3-1 HORIZONTAL STRUCTURAL IRREGULARITIES

	Irregularity Type and Description	Reference Section	Seismic Design Category Application
1a.	**Torsional Irregularity** is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.4 12.8.4.3 12.7.3 12.12.1 Table 12.6-1 Section 16.2.2	D, E, and F C, D, E, and F B, C, D, E, and F C, D, E, and F D, E, and F B, C, D, E, and F
1b.	**Extreme Torsional Irregularity** is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.1 12.3.3.4 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 Section 16.2.2	E and F D B, C, and D C and D C and D D B, C, and D
2.	**Reentrant Corner Irregularity** is defined to exist where both plan projections of the structure beyond a reentrant corner are greater than 15% of the plan dimension of the structure in the given direction.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
3.	**Diaphragm Discontinuity Irregularity** is defined to exist where there are diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50% of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50% from one story to the next.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
4.	**Out-of-Plane Offsets Irregularity** is defined to exist where there are discontinuities in a lateral force-resistance path, such as out-of-plane offsets of the vertical elements.	12.3.3.4 12.3.3.3 12.7.3 Table 12.6-1 16.2.2	D, E, and F B, C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F
5.	**Nonparallel Systems-Irregularity** is defined to exist where the vertical lateral force-resisting elements are not parallel to or symmetric about the major orthogonal axes of the seismic force–resisting system.	12.5.3 12.7.3 Table 12.6-1 Section 16.2.2	C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F

12.3.3.2 Extreme Weak Stories. Structures with a vertical irregularity Type 5b as defined in Table 12.3-2, shall not be over two stories or 30 ft (9 m) in height.

EXCEPTION: The limit does not apply where the "weak" story is capable of resisting a total seismic force equal to Ω_0 times the design force prescribed in Section 12.8.

12.3.3.3 Elements Supporting Discontinuous Walls or Frames. Columns, beams, trusses, or slabs supporting discontinuous walls or frames of structures having horizontal irregularity Type 4 of Table 12.3-1 or vertical irregularity Type 4 of Table 12.3-2 shall have the design strength to resist the maximum axial force that can develop in accordance with the load combinations with overstrength factor of Section 12.4.3.2. The connections of such discontinuous elements to the supporting members shall be adequate to transmit the forces for which the discontinuous elements were required to be designed.

12.3.3.4 Increase in Forces Due to Irregularities for Seismic Design Categories D through F. For structures assigned to Seismic Design Category D, E, or F and having a horizontal structural irregularity of Type 1a, 1b, 2, 3, or 4 in Table 12.3-1 or a vertical structural irregularity of Type 4 in Table 12.3-2, the design forces determined from Section 12.8.1 shall be increased 25 percent for connections of diaphragms to vertical elements and to collectors and for connections of collectors to the vertical elements. Collectors and their connections also shall be designed for these increased forces unless they are designed for the load combinations with overstrength factor of Section 12.4.3.2, in accordance with Section 12.10.2.1.

12.3.4 Redundancy. A redundancy factor, ρ, shall be assigned to the seismic force–resisting system in each of two orthogonal directions for all structures in accordance with this section.

TABLE 12.3-2 VERTICAL STRUCTURAL IRREGULARITIES

	Irregularity Type and Description	Reference Section	Seismic Design Category Application
1a.	**Stiffness-Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.	Table 12.6-1	D, E, and F
1b.	**Stiffness-Extreme Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.	12.3.3.1 Table 12.6-1	E and F D, E, and F
2.	**Weight (Mass) Irregularity** is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	Table 12.6-1	D, E, and F
3.	**Vertical Geometric Irregularity** is defined to exist where the horizontal dimension of the seismic force–resisting system in any story is more than 130% of that in an adjacent story.	Table 12.6-1	D, E, and F
4.	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity** is defined to exist where an in-plane offset of the lateral force-resisting elements is greater than the length of those elements or there exists a reduction in stiffness of the resisting element in the story below.	12.3.3.3 12.3.3.4 Table 12.6-1	B, C, D, E, and F D, E, and F D, E, and F
5a.	**Discontinuity in Lateral Strength–Weak Story Irregularity** is defined to exist where the story lateral strength is less than 80% of that in the story above. The story lateral strength is the total lateral strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 Table 12.6-1	E and F D, E, and F
5b.	**Discontinuity in Lateral Strength–Extreme Weak Story Irregularity** is defined to exist where the story lateral strength is less than 65% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 12.3.3.2 Table 12.6-1	D, E, and F B and C D, E, and F

12.3.4.1 Conditions Where Value of ρ is 1.0. The value of ρ is permitted to equal 1.0 for the following:

1. Structures assigned to Seismic Design Category B or C.
2. Drift calculation and P-delta effects.
3. Design of nonstructural components.
4. Design of nonbuilding structures that are not similar to buildings.
5. Design of collector elements, splices, and their connections for which the load combinations with overstrength factor of Section 12.4.3.2 are used.
6. Design of members or connections where the load combinations with overstrength of Section 12.4.3.2 are required for design.
7. Diaphragm loads determined using Eq. 12.10-1.
8. Structures with damping systems designed in accordance with Section 18.

12.3.4.2 Redundancy Factor, ρ, for Seismic Design Categories D through F. For structures assigned to Seismic Design Category D, E, or F, ρ shall equal 1.3 unless one of the following two conditions is met, whereby ρ is permitted to be taken as 1.0:

a. Each story resisting more than 35 percent of the base shear in the direction of interest shall comply with Table 12.3-3.

b. Structures that are regular in plan at all levels provided that the seismic force–resisting systems consist of at least two bays of seismic force–resisting perimeter framing on each side of the structure in each orthogonal direction at each story resisting more than 35 percent of the base shear. The number of bays for a shear wall shall be calculated as the length of shear wall divided by the story height or two times the length of shear wall divided by the story height for light-framed construction.

TABLE 12.3-3 REQUIREMENTS FOR EACH STORY RESISTING MORE THAN 35% OF THE BASE SHEAR

Lateral Force-Resisting Element	Requirement
Braced Frames	Removal of an individual brace, or connection thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Moment Frames	Loss of moment resistance at the beam-to-column connections at both ends of a single beam would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Shear Walls or Wall Pier with a height-to-length ratio of greater than 1.0	Removal of a shear wall or wall pier with a height-to-length ratio greater than 1.0 within any story, or collector connections thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Cantilever Columns	Loss of moment resistance at the base connections of any single cantilever column would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Other	No requirements

12.4 SEISMIC LOAD EFFECTS AND COMBINATIONS

12.4.1 Applicability. All members of the structure, including those not part of the seismic force–resisting system, shall be designed using the seismic load effects of Section 12.4 unless otherwise exempted by this standard. Seismic load effects are the axial, shear, and flexural member forces resulting from application of horizontal and vertical seismic forces as set forth in Section 12.4.2. Where specifically required, seismic load effects shall be modified to account for system overstrength, as set forth in Section 12.4.3.

12.4.2 Seismic Load Effect. The seismic load effect, E, shall be determined in accordance with the following:

1. For use in load combination 5 in Section 2.3.2 or load combination 5 and 6 in Section 2.4.1, E shall be determined in accordance with Eq. 12.4-1 as follows:

$$E = E_h + E_v \qquad (12.4\text{-}1)$$

2. For use in load combination 7 in Section 2.3.2 or load combination 8 in Section 2.4.1, E shall be determined in accordance with Eq. 12.4-2 as follows:

$$E = E_h - E_v \qquad (12.4\text{-}2)$$

where

E = seismic load effect
E_h = effect of horizontal seismic forces as defined in Section 12.4.2.1
E_v = effect of vertical seismic forces as defined in Section 12.4.2.2

12.4.2.1 Horizontal Seismic Load Effect. The horizontal seismic load effect, E_h, shall be determined in accordance with Eq. 12.4-3 as follows:

$$E_h = \rho Q_E \qquad (12.4\text{-}3)$$

where

Q_E = effects of horizontal seismic forces from V or F_p. Where required in Sections 12.5.3 and 12.5.4, such effects shall result from application of horizontal forces simultaneously in two directions at right angles to each other.
ρ = redundancy factor, as defined in Section 12.3.4

12.4.2.2 Vertical Seismic Load Effect. The vertical seismic load effect, E_v, shall be determined in accordance with Eq. 12.4-4 as follows:

$$E_v = 0.2 S_{DS} D \qquad (12.4\text{-}4)$$

where

S_{DS} = design spectral response acceleration parameter at short periods obtained from Section 11.4.4
D = effect of dead load

EXCEPTIONS: The vertical seismic load effect, E_v, is permitted to be taken as zero for either of the following conditions:

1. In Eqs. 12.4-1, 12.4-2, 12.4-5, and 12.4-6 where S_{DS} is equal to or less than 0.125.
2. In Eq. 12.4-2 where determining demands on the soil-structure interface of foundations.

12.4.2.3 Seismic Load Combinations. Where the prescribed seismic load effect, E, defined in Section 12.4.2 is combined with the effects of other loads as set forth in Chapter 2, the following seismic load combinations for structures not subject to flood or atmospheric ice loads shall be used in lieu of the seismic load combinations in either Section 2.3.2 or 2.4.1:

Basic Combinations for Strength Design (see Sections 2.3.2 and 2.2 for notation).

5. $(1.2 + 0.2S_{DS})D + \rho Q_E + L + 0.2S$
7. $(0.9 - 0.2S_{DS})D + \rho Q_E + 1.6H$

NOTES:

1. The load factor on L in combination 5 is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf (4.79 kN/m^2), with the exception of garages or areas occupied as places of public assembly.
2. The load factor on H shall be set equal to zero in combination 7 if the structural action due to H counteracts that due to E. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H but shall be included in the design resistance.

Basic Combinations for Allowable Stress Design (see Sections 2.4.1 and 2.2 for notation).

5. $(1.0 + 0.14S_{DS})D + H + F + 0.7\rho Q_E$
6. $(1.0 + 0.105_{DS})D + H + F + 0.525\rho Q_E + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
8. $(0.6 - 0.14S_{DS})D + 0.7\rho Q_E + H$

12.4.3 Seismic Load Effect Including Overstrength Factor. Where specifically required, conditions requiring overstrength factor applications shall be determined in accordance with the following:

1. For use in load combination 5 in Section 2.3.2 or load combinations 5 and 6 in Section 2.4.1, E shall be taken equal to E_m as determined in accordance with Eq. 12.4-5 as follows:

$$E_m = E_{mh} + E_v \tag{12.4-5}$$

2. For use in load combination 7 in Section 2.3.2 or load combination 8 in Section 2.4.1, E shall be taken equal to E_m as determined in accordance with Eq. 12.4-6 as follows:

$$E_m = E_{mh} - E_v \tag{12.4-6}$$

where

E_m = seismic load effect including overstrength factor
E_{mh} = effect of horizontal seismic forces including structural overstrength as defined in Section 12.4.3.1
E_v = vertical seismic load effect as defined in Section 12.4.2.2

12.4.3.1 Horizontal Seismic Load Effect with Overstrength Factor. The horizontal seismic load effect with overstrength factor, E_{mh}, shall be determined in accordance with Eq. 12.4-7 as follows:

$$E_{mh} = \Omega_o Q_E \tag{12.4-7}$$

where

Q_E = effects of horizontal seismic forces from V or F_p as specified in Sections 12.8.1 and 13.3.1, respectively. Where required in Sections 12.5.3 and 12.5.4, such effects shall result from application of horizontal forces simultaneously in two directions at right angles to each other.
Ω_o = overstrength factor

EXCEPTION: The value of E_{mh} need not exceed the maximum force that can develop in the element as determined by a rational, plastic mechanism analysis or nonlinear response analysis utilizing realistic expected values of material strengths.

12.4.3.2 Load Combinations with Overstrength Factor. Where the seismic load effect with overstrength, E_m, defined in Section 12.4.3 is combined with the effects of other loads as set forth in Chapter 2, the following seismic load combination for structures not subject to flood or atmospheric ice loads shall be shall be used in lieu of the seismic load combinations in either Section 2.3.2 or 2.4.1:

Basic Combinations for Strength Design with Overstrength Factor (see Sections 2.3.2 and 2.2 for notation).

5. $(1.2 + 0.2S_{DS})D + \Omega_o Q_E + L + 0.2S$
7. $(0.9 - 0.2S_{DS})D + \Omega_o Q_E + 1.6H$

NOTES:

1. The load factor on L in combination 5 is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf (4.79 kN/m^2), with the exception of garages or areas occupied as places of public assembly.
2. The load factor on H shall be set equal to zero in combination 7 if the structural action due to H counteracts that due to E. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H but shall be included in the design resistance.

Basic Combinations for Allowable Stress Design with Overstrength Factor (see Sections 2.4.1 and 2.2 for notation).

5. $(1.0 + 0.14S_{DS})D + H + F + 0.7\Omega_o Q_E$
6. $(1.0 + 0.105S_{DS})D + H + F + 0.525\Omega_o Q_E + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
8. $(0.6 - 0.14S_{DS})D + 0.7\Omega_o Q_E + H$

12.4.3.3 Allowable Stress Increase for Load Combinations with Overstrength. Where allowable stress design methodologies are used with the seismic load effect defined in Section 12.4.3 applied in load combinations 5, 6, or 8 of Section 2.4.1, allowable stresses are permitted to be determined using an allowable stress increase of 1.2. This increase shall not be combined with increases in allowable stresses or load combination reductions otherwise permitted by this standard or the material reference document except that combination with the duration of load increases permitted in AF&PA NDS is permitted.

12.4.4 Minimum Upward Force for Horizontal Cantilevers for Seismic Design Categories D through F. In structures assigned to Seismic Design Category D, E, or F, horizontal cantilever structural components shall be designed for a minimum net upward force of 0.2 times the dead load in addition to the applicable load combinations of Section 12.4.

12.5 DIRECTION OF LOADING

12.5.1 Direction of Loading Criteria. The directions of application of seismic forces used in the design shall be those which will produce the most critical load effects. It is permitted to satisfy this requirement using the procedures of Section 12.5.2 for Seismic Design Category B, Section 12.5.3 for Seismic Design Category C, and Section 12.5.4 for Seismic Design Categories D, E, and F.

12.5.2 Seismic Design Category B. For structures assigned to Seismic Design Category B, the design seismic forces are permitted to be applied independently in each of two orthogonal directions and orthogonal interaction effects are permitted to be neglected.

12.5.3 Seismic Design Category C. Loading applied to structures assigned to Seismic Design Category C shall, as a minimum, conform to the requirements of Section 12.5.2 for Seismic Design Category B and the requirements of this section. Structures that have horizontal structural irregularity Type 5 in Table 12.3-1 shall use one of the following procedures:

a. **Orthogonal Combination Procedure.** The structure shall be analyzed using the equivalent lateral force analysis procedure of Section 12.8, the modal response spectrum analysis procedure of Section 12.9, or the linear response history procedure of Section 16.1, as permitted under Section 12.6, with the loading applied independently in any two orthogonal directions and the most critical load effect due to direction of application of seismic forces on the structure is permitted to be assumed to be satisfied if components and their foundations are designed for the following combination of prescribed loads: 100 percent of the forces for one direction plus 30 percent of the forces for the perpendicular direction; the combination requiring the maximum component strength shall be used.

b. **Simultaneous Application of Orthogonal Ground Motion.** The structure shall be analyzed using the linear response history procedure of Section 16.1 or the nonlinear response history procedure of Section 16.2, as permitted by Section 12.6, with orthogonal pairs of ground motion acceleration histories applied simultaneously.

12.5.4 Seismic Design Categories D through F. Structures assigned to Seismic Design Category D, E, or F shall, as a minimum, conform to the requirements of Section 12.5.3. In addition, any column or wall that forms part of two or more intersecting seismic force–resisting systems and is subjected to axial load due to seismic forces acting along either principal plan axis equaling or exceeding 20 percent of the axial design strength of the column or wall shall be designed for the most critical load effect due to application of seismic forces in any direction. Either of the procedures of Section 12.5.3 a or b are permitted to be used to satisfy this requirement. Except as required by Section 12.7.3, 2-D analyses are permitted for structures with flexible diaphragms.

12.6 ANALYSIS PROCEDURE SELECTION

The structural analysis required by Chapter 12 shall consist of one of the types permitted in Table 12.6-1, based on the structure's seismic design category, structural system, dynamic properties, and regularity, or with the approval of the authority having jurisdiction, an alternative generally accepted procedure is permitted to be used. The analysis procedure selected shall be completed in accordance with the requirements of the corresponding section referenced in Table 12.6-1.

TABLE 12.6-1 PERMITTED ANALYTICAL PROCEDURES

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Analysis Section 12.8	Modal Response Spectrum Analysis Section 12.9	Seismic Response History Procedures Chapter 16
B, C	Occupancy Category I or II buildings of light-framed construction not exceeding 3 stories in height	P	P	P
	Other Occupancy Category I or II buildings not exceeding 2 stories in height	P	P	P
	All other structures	P	P	P
D, E, F	Occupancy Category I or II buildings of light-framed construction not exceeding 3 stories in height	P	P	P
	Other Occupancy Category I or II buildings not exceeding 2 stories in height	P	P	P
	Regular structures with $T < 3.5T_s$ and all structures of light frame construction	P	P	P
	Irregular structures with $T < 3.5T_s$ and having only horizontal irregularities Type 2, 3, 4, or 5 of Table 12.2-1 or vertical irregularities Type 4, 5a, or 5b of Table 12.3-1	P	P	P
	All other structures	NP	P	P

NOTE: P: Permitted; NP: Not Permitted

12.7 MODELING CRITERIA

12.7.1 Foundation Modeling. For purposes of determining seismic loads, it is permitted to consider the structure to be fixed at the base. Alternatively, where foundation flexibility is considered, it shall be in accordance with Section 12.13.3 or Chapter 19.

12.7.2 Effective Seismic Weight. The effective seismic weight, W, of a structure shall include the total dead load and other loads listed below:

1. In areas used for storage, a minimum of 25 percent of the floor live load (floor live load in public garages and open parking structures need not be included).
2. Where provision for partitions is required by Section 4.2.2 in the floor load design, the actual partition weight or a minimum weight of 10 psf (0.48 kN/m^2) of floor area, whichever is greater.
3. Total operating weight of permanent equipment.
4. Where the flat roof snow load, P_f, exceeds 30 psf (1.44 kN/m^2), 20 percent of the uniform design snow load, regardless of actual roof slope.

12.7.3 Structural Modeling. A mathematical model of the structure shall be constructed for the purpose of determining member forces and structure displacements resulting from applied loads and any imposed displacements or P-Delta effects. The model shall include the stiffness and strength of elements that are significant to the distribution of forces and deformations in the structure and represent the spatial distribution of mass and stiffness throughout the structure.

Structures that have horizontal structural irregularity Type 1a, 1b, 4, or 5 of Table 12.3-1 shall be analyzed using a 3-D representation. Where a 3-D model is used, a minimum of three dynamic degrees of freedom consisting of translation in two orthogonal plan directions and torsional rotation about the vertical axis shall be included at each level of the structure. Where the diaphragms have not been classified as rigid or flexible in accordance with Section 12.3.1, the model shall include representation of the diaphragm's stiffness characteristics and such additional dynamic degrees of freedom as are required to account for the participation of the diaphragm in the structure's dynamic response. In addition, the model shall comply with the following:

a. Stiffness properties of concrete and masonry elements shall consider the effects of cracked sections.

b. For steel moment frame systems, the contribution of panel zone deformations to overall story drift shall be included.

12.7.4 Interaction Effects. Moment-resisting frames that are enclosed or adjoined by elements that are more rigid and not considered to be part of the seismic force–resisting system shall be designed so that the action or failure of those elements will not impair the vertical load and seismic force–resisting capability of the frame. The design shall provide for the effect of these rigid elements on the structural system at structural deformations corresponding to the design story drift (Δ) as determined in Section 12.8.6. In addition, the effects of these elements shall be considered where determining whether a structure has one or more of the irregularities defined in Section 12.3.2.

12.8 EQUIVALENT LATERAL FORCE PROCEDURE

12.8.1 Seismic Base Shear. The seismic base shear, V, in a given direction shall be determined in accordance with the following equation:

$$V = C_s W \tag{12.8-1}$$

where

C_s = the seismic response coefficient determined in accordance with Section 12.8.1.1
W = the effective seismic weight per Section 12.7.2.

12.8.1.1 Calculation of Seismic Response Coefficient. The seismic response coefficient, C_s, shall be determined in accordance with Eq. 12.8-2.

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I}\right)} \tag{12.8-2}$$

where

S_{DS} = the design spectral response acceleration parameter in the short period range as determined from Section 11.4.4
R = the response modification factor in Table 12.2-1
I = the occupancy importance factor determined in accordance with Section 11.5.1

The value of C_s computed in accordance with Eq. 12.8-2 need not exceed the following:

$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I}\right)} \quad \text{for } T \leq T_L \tag{12.8-3}$$

$$C_s = \frac{S_{D1} T_L}{T^2\left(\frac{R}{I}\right)} \quad \text{for } T > T_L \tag{12.8-4}$$

C_s shall not be less than

$$C_s = 0.01 \tag{12.8-5}$$

In addition, for structures located where S_1 is equal to or greater than $0.6g$, C_s shall not be less than

$$C_s = \frac{0.5 S_1}{\left(\frac{R}{I}\right)} \tag{12.8-6}$$

TABLE 12.8-1 COEFFICIENT FOR UPPER LIMIT ON CALCULATED PERIOD

Design Spectral Response Acceleration Parameter at 1 s, S_{D1}	Coefficient C_u
≥ 0.4	1.4
0.3	1.4
0.2	1.5
0.15	1.6
≤ 0.1	1.7

where I and R are as defined in Section 12.8.1.1 and

S_{D1} = the design spectral response acceleration parameter at a period of 1.0 s, as determined from Section 11.4.4
T = the fundamental period of the structure (s) determined in Section 12.8.2
T_L = long-period transition period (s) determined in Section 11.4.5
S_1 = the mapped maximum considered earthquake spectral response acceleration parameter determined in accordance with Section 11.4.1

12.8.1.2 Soil Structure Interaction Reduction. A soil structure interaction reduction is permitted where determined using Chapter 19 or other generally accepted procedures approved by the authority having jurisdiction.

12.8.1.3 Maximum S_s Value in Determination of C_s. For regular structures five stories or less in height and having a period, T, of 0.5 s or less, C_s is permitted to be calculated using a value of 1.5 for S_S.

12.8.2 Period Determination. The fundamental period of the structure, T, in the direction under consideration shall be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The fundamental period, T, shall not exceed the product of the coefficient for upper limit on calculated period (C_u) from Table 12.8-1 and the approximate fundamental period, T_a, determined from Eq. 12.8-7. As an alternative to performing an analysis to determine the fundamental period, T, it is permitted to use the approximate building period, T_a, calculated in accordance with Section 12.8.2.1, directly.

12.8.2.1 Approximate Fundamental Period. The approximate fundamental period (T_a), in s, shall be determined from the following equation:

$$T_a = C_t h_n^x \tag{12.8-7}$$

where h_n is the height in ft above the base to the highest level of the structure and the coefficients C_t and x are determined from Table 12.8-2.

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)[a]	0.8
Concrete moment-resisting frames	0.016 (0.0466)[a]	0.9
Eccentrically braced steel frames	0.03 (0.0731)[a]	0.75
All other structural systems	0.02 (0.0488)[a]	0.75

[a]Metric equivalents are shown in parentheses.

Alternatively, it is permitted to determine the approximate fundamental period (T_a), in s, from the following equation for structures not exceeding 12 stories in height in which the seismic force–resisting system consists entirely of concrete or steel moment resisting frames and the story height is at least 10 ft (3 m):

$$T_a = 0.1\,N \tag{12.8-8}$$

where N = number of stories.

The approximate fundamental period, T_a, in s for masonry or concrete shear wall structures is permitted to be determined from Eq. 12.8-9 as follows:

$$T_a = \frac{0.0019}{\sqrt{C_w}} h_n \tag{12.8-9}$$

where h_n is as defined in the preceding text and C_w is calculated from Eq. 12.8-10 as follows:

$$C_W = \frac{100}{A_B}\sum_{i=1}^{x}\left(\frac{h_n}{h_i}\right)^2 \frac{A_i}{\left[1+0.83\left(\frac{h_i}{D_i}\right)^2\right]} \tag{12.8-10}$$

where

A_B = area of base of structure, ft^2
A_i = web area of shear wall "i" in ft^2
D_i = length of shear wall "i" in ft
h_i = height of shear wall "i" in ft
x = number of shear walls in the building effective in resisting lateral forces in the direction under consideration.

12.8.3 Vertical Distribution of Seismic Forces. The lateral seismic force (F_x) (kip or kN) induced at any level shall be determined from the following equations:

$$F_x = C_{vx} V \tag{12.8-11}$$

and

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} \tag{12.8-12}$$

where

C_{vx} = vertical distribution factor,
V = total design lateral force or shear at the base of the structure (kip or kN)
w_i and w_x = the portion of the total effective seismic weight of the structure (W) located or assigned to Level i or x
h_i and h_x = the height (ft or m) from the base to Level i or x
k = an exponent related to the structure period as follows:
for structures having a period of 0.5 s or less, $k = 1$
for structures having a period of 2.5 s or more, $k = 2$
for structures having a period between 0.5 and 2.5 s, k shall be 2 or shall be determined by linear interpolation between 1 and 2

12.8.4 Horizontal Distribution of Forces. The seismic design story shear in any story (V_x) (kip or kN) shall be determined from the following equation:

$$V_x = \sum_{i=x}^{n} F_i \tag{12.8-13}$$

where F_i = the portion of the seismic base shear (V) (kip or kN) induced at Level i.

The seismic design story shear (V_x) (kip or kN) shall be distributed to the various vertical elements of the seismic force–resisting system in the story under consideration based on the relative lateral stiffness of the vertical resisting elements and the diaphragm.

12.8.4.1 Inherent Torsion. For diaphragms that are not flexible, the distribution of lateral forces at each level shall consider the effect of the inherent torsional moment, M_t, resulting from eccentricity between the locations of the center of mass and the center of rigidity. For flexible diaphragms, the distribution of forces to the vertical elements shall account for the position and distribution of the masses supported.

12.8.4.2 Accidental Torsion. Where diaphragms are not flexible, the design shall include the inherent torsional moment (M_t) (kip or kN) resulting from the location of the structure masses plus the accidental torsional moments (M_{ta}) (kip or kN) caused by assumed displacement of the center of mass each way from its actual location by a distance equal to 5 percent of the dimension of the structure perpendicular to the direction of the applied forces.

Where earthquake forces are applied concurrently in two orthogonal directions, the required 5 percent displacement of the center of mass need not be applied in both of the orthogonal directions at the same time, but shall be applied in the direction that produces the greater effect.

12.8.4.3 Amplification of Accidental Torsional Moment. Structures assigned to Seismic Design Category C, D, E, or F, where Type 1a or 1b torsional irregularity exists as defined in Table 12.3-1 shall have the effects accounted for by multiplying M_{ta} at each level by a torsional amplification factor (A_x) as illustrated in Fig. 12.8-1 and determined from the following equation:

$$A_x = \left(\frac{\delta_{max}}{1.2\delta_{avg}}\right)^2 \tag{12.8-14}$$

where

δ_{max} = the maximum displacement at Level x (in. or mm) computed assuming $A_x = 1$
δ_{avg} = the average of the displacements at the extreme points of the structure at Level x computed assuming $A_x = 1$ (in. or mm)

EXCEPTION: The accidental torsional moment need not be amplified for structures of light-frame construction.

The torsional amplification factor (A_x) is not required to exceed 3.0. The more severe loading for each element shall be considered for design.

12.8.5 Overturning. The structure shall be designed to resist overturning effects caused by the seismic forces determined in Section 12.8.3.

12.8.6 Story Drift Determination. The design story drift (Δ) shall be computed as the difference of the deflections at the centers of mass at the top and bottom of the story under consideration. See Fig. 12.8-2. Where allowable stress design is used, Δ shall be computed using the strength level seismic forces specified in Section 12.8 without reduction for allowable stress design.

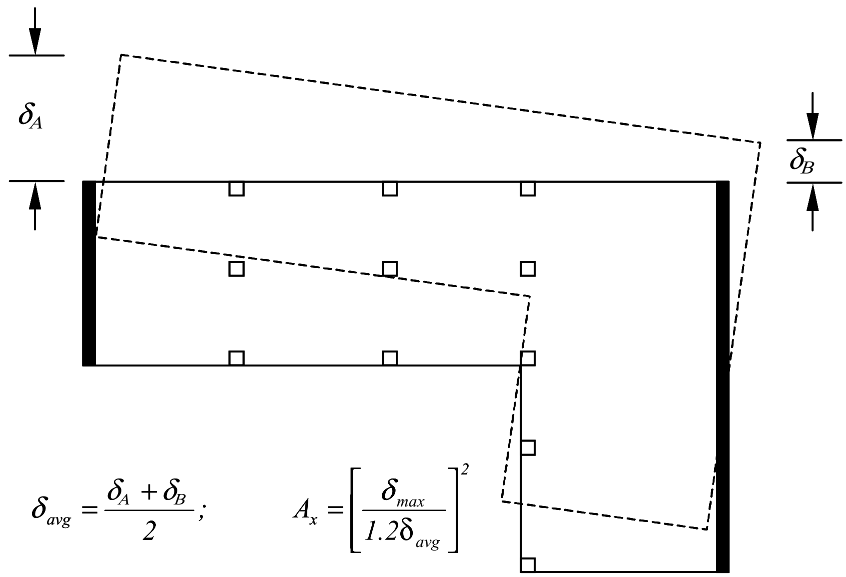

FIGURE 12.8-1 TORSIONAL AMPLIFICATION FACTOR, A_x

The deflections of Level x at the center of the mass (δ_x) (in. or mm) shall be determined in accordance with the following equation:

$$\delta_x = \frac{C_d\, \delta_{xe}}{I} \tag{12.8-15}$$

where

C_d = the deflection amplification factor in Table 12.2-1
δ_{xe} = the deflections determined by an elastic analysis
I = the importance factor determined in accordance with Section 11.5.1

12.8.6.1 Minimum Base Shear for Computing Drift. The elastic analysis of the seismic force–resisting system shall be made using the prescribed seismic design forces of Section 12.8.

12.8.6.2 Period for Computing Drift. For determining compliance with the story drift limits of Section 12.12.1, it is permitted to determine the elastic drifts, (δ_{xe}), using seismic design forces based on the computed fundamental period of the structure without the upper limit ($C_u T_a$) specified in Section 12.8.2.

12.8.7 P-Delta Effects. P-delta effects on story shears and moments, the resulting member forces and moments, and the story drifts induced by these effects are not required to be considered

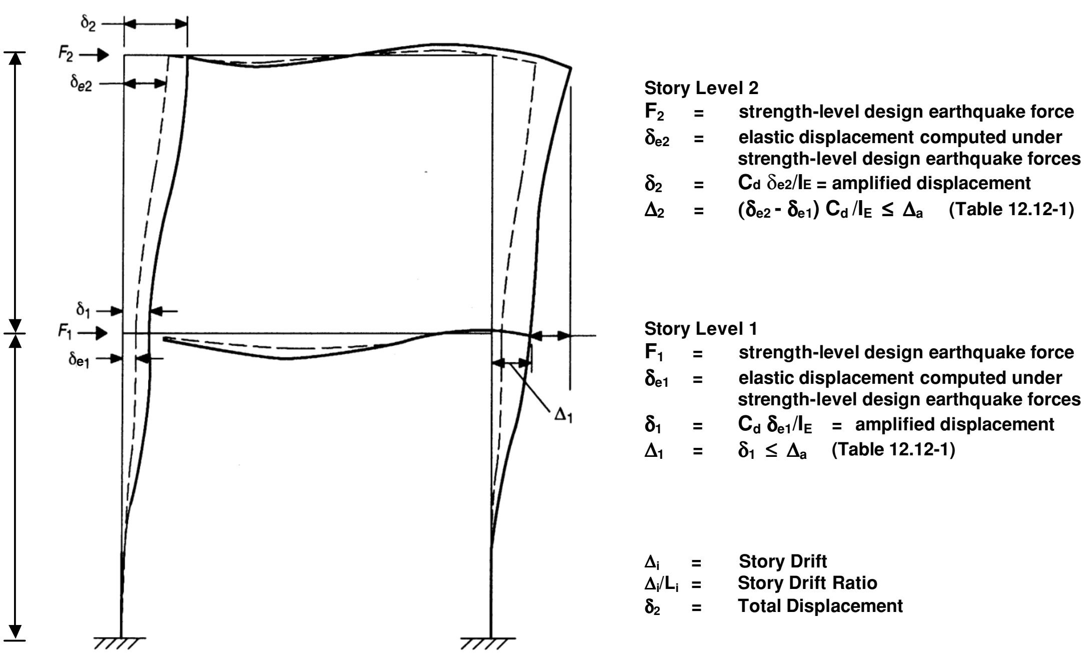

FIGURE 12.8-2 STORY DRIFT DETERMINATION

where the stability coefficient (θ) as determined by the following equation is equal to or less than 0.10:

$$\theta = \frac{P_x \Delta}{V_x h_{sx} C_d} \tag{12.8-16}$$

where

P_x = the total vertical design load at and above Level x (kip or kN); where computing P_x, no individual load factor need exceed 1.0
Δ = the design story drift as defined in Section 12.8.6 occurring simultaneously with V_x (in. or mm)
V_x = the seismic shear force acting between Levels x and $x - 1$ (kip or kN)
h_{sx} = the story height below Level x (in. or mm)
C_d = the deflection amplification factor in Table 12.2-1

The stability coefficient (θ) shall not exceed θ_{max} determined as follows:

$$\theta_{max} = \frac{0.5}{\beta C_d} \leq 0.25 \tag{12.8-17}$$

where β is the ratio of shear demand to shear capacity for the story between Levels x and $x - 1$. This ratio is permitted to be conservatively taken as 1.0.

Where the stability coefficient (θ) is greater than 0.10 but less than or equal to θ_{max}, the incremental factor related to P-delta effects on displacements and member forces shall be determined by rational analysis. Alternatively, it is permitted to multiply displacements and member forces by $1.0/(1 - \theta)$.

Where θ is greater than θ_{max}, the structure is potentially unstable and shall be redesigned.

Where the P-delta effect is included in an automated analysis, Eq. 12.8-17 shall still be satisfied, however, the value of θ computed from Eq. 12.8-16 using the results of the P-delta analysis is permitted to be divided by $(1 + \theta)$ before checking Eq. 12.8-17.

12.9 MODAL RESPONSE SPECTRUM ANALYSIS

12.9.1 Number of Modes. An analysis shall be conducted to determine the natural modes of vibration for the structure. The analysis shall include a sufficient number of modes to obtain a combined modal mass participation of at least 90 percent of the actual mass in each of the orthogonal horizontal directions of response considered by the model.

12.9.2 Modal Response Parameters. The value for each force-related design parameter of interest, including story drifts, support forces, and individual member forces for each mode of response shall be computed using the properties of each mode and the response spectra defined in either Section 11.4.5 or 21.2 divided by the quantity $\frac{R}{I}$. The value for displacement and drift quantities shall be multiplied by the quantity $\frac{Cd}{I}$.

12.9.3 Combined Response Parameters. The value for each parameter of interest calculated for the various modes shall be combined using either the square root of the sum of the squares method (SRSS) or the complete quadratic combination method (CQC), in accordance with ASCE 4. The CQC method shall be used for each of the modal values or where closely spaced modes that have significant cross-correlation of translational and torsional response.

12.9.4 Scaling Design Values of Combined Response. A base shear (V) shall be calculated in each of the two orthogonal horizontal directions using the calculated fundamental period of the structure T in each direction and the procedures of Section 12.8, except where the calculated fundamental period exceeds $(C_u)(T_a)$, then $(C_u)(T_a)$ shall be used in lieu of T in that direction. Where the combined response for the modal base shear (V_t) is less than 85 percent of the calculated base shear (V) using the equivalent lateral force procedure, the forces, but not the drifts, shall be multiplied by $0.85\frac{V}{Vt}$:

where

V = the equivalent lateral force procedure base shear, calculated in accordance with this section and Section 12.8
V_t = the base shear from the required modal combination

12.9.5 Horizontal Shear Distribution. The distribution of horizontal shear shall be in accordance with the requirements of Section 12.8.4 except that amplification of torsion per Section 12.8.4.3 is not required where accidental torsional effects are included in the dynamic analysis model.

12.9.6 P-Delta Effects. The P-delta effects shall be determined in accordance with Section 12.8.7. The base shear used to determine the story shears and the story drifts shall be determined in accordance with Section 12.8.6.

12.9.7 Soil Structure Interaction Reduction. A soil structure interaction reduction is permitted where determined using Chapter 19 or other generally accepted procedures approved by the authority having jurisdiction.

12.10 DIAPHRAGMS, CHORDS, AND COLLECTORS

12.10.1 Diaphragm Design. Diaphragms shall be designed for both the shear and bending stresses resulting from design forces. At diaphragm discontinuities, such as openings and reentrant corners, the design shall assure that the dissipation or transfer of edge (chord) forces combined with other forces in the diaphragm is within shear and tension capacity of the diaphragm.

12.10.1.1 Diaphragm Design Forces. Floor and roof diaphragms shall be designed to resist design seismic forces from the structural analysis, but shall not be less than that determined in accordance with Eq. 12.10-1 as follows:

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \tag{12.10-1}$$

where

F_{px} = the diaphragm design force
F_i = the design force applied to Level i
w_i = the weight tributary to Level i
w_{px} = the weight tributary to the diaphragm at Level x

The force determined from Eq. 12.10-1 need not exceed $0.4S_{DS} Iw_{px}$, but shall not be less than $0.2S_{DS} Iw_{px}$. Where the diaphragm is required to transfer design seismic force from the vertical resisting elements above the diaphragm to other vertical resisting elements below the diaphragm due to offsets in the placement of the elements or to changes in relative lateral stiffness in the vertical elements, these forces shall be added to those determined from Eq. 12.10-1. The redundancy factor, ρ, applies to the design of diaphragms in structures assigned to Seismic Design Category D, E, or F. For inertial forces calculated in accordance with Eq. 12.10-1, the redundancy factor shall equal 1.0. For transfer forces, the redundancy factor, ρ, shall be the same as that used for the structure. For structures having horizontal or vertical structural irregularities of the types indicated in Section 12.3.3.4, the requirements of that section shall also apply.

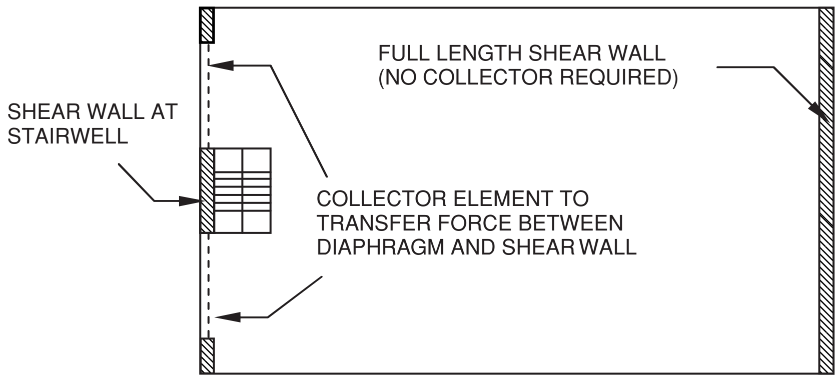

FIGURE 12.10-1 COLLECTORS

12.10.2 Collector Elements. Collector elements shall be provided that are capable of transferring the seismic forces originating in other portions of the structure to the element providing the resistance to those forces.

12.10.2.1 Collector Elements Requiring Load Combinations with Overstrength Factor for Seismic Design Categories C through F. In structures assigned to Seismic Design Category C, D, E, or F, collector elements (see Fig. 12.10-1), splices, and their connections to resisting elements shall resist the load combinations with overstrength of Section 12.4.3.2.

EXCEPTION: In structures or portions thereof braced entirely by light-frame shear walls, collector elements, splices, and connections to resisting elements need only be designed to resist forces in accordance with Section 12.10.1.1.

12.11 STRUCTURAL WALLS AND THEIR ANCHORAGE

12.11.1 Design for Out-of-Plane Forces. Structural walls and their anchorage shall be designed for a force normal to the surface equal to $0.4S_{DS}I$ times the weight of the structural wall with a minimum force of 10 percent of the weight of the structural wall. Interconnection of structural wall elements and connections to supporting framing systems shall have sufficient ductility, rotational capacity, or sufficient strength to resist shrinkage, thermal changes, and differential foundation settlement when combined with seismic forces.

12.11.2 Anchorage of Concrete or Masonry Structural Walls. The anchorage of concrete or masonry structural walls to supporting construction shall provide a direct connection capable of resisting the greater of the following:

a. The force set forth in Section 12.11.1.
b. A force of $400S_{DS}\ I$ lb/ linear ft ($5.84S_{DS}I$ kN/m) of wall
c. 280 lb/linear ft (4.09 kN/m) of wall

Structural walls shall be designed to resist bending between anchors where the anchor spacing exceeds 4 ft (1,219 mm).

12.11.2.1 Anchorage of Concrete or Masonry Structural Walls to Flexible Diaphragms. In addition to the requirements set forth in Section 12.11.2, anchorage of concrete or masonry structural walls to flexible diaphragms in structures assigned to Seismic Design Category C, D, E, or F shall have the strength to develop the out-of-plane force given by Eq. 12.11-1:

$$F_p = 0.8S_{DS}IW_p \qquad (12.11\text{-}1)$$

where

F_p = the design force in the individual anchors
S_{DS} = the design spectral response acceleration parameter at short periods per Section 11.4.4
I = the occupancy importance factor per Section 11.5.1
W_p = the weight of the wall tributary to the anchor

12.11.2.2 Additional Requirements for Diaphragms in Structures Assigned to Seismic Design Categories C through F.

12.11.2.2.1 Transfer of Anchorage Forces into Diaphragm. Diaphragms shall be provided with continuous ties or struts between diaphragm chords to distribute these anchorage forces into the diaphragms. Diaphragm connections shall be positive, mechanical, or welded. Added chords are permitted to be used to form subdiaphragms to transmit the anchorage forces to the main continuous cross-ties. The maximum length-to-width ratio of the structural subdiaphragm shall be 2.5 to 1. Connections and anchorages capable of resisting the prescribed forces shall be provided between the diaphragm and the attached components. Connections shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.

12.11.2.2.2 Steel Elements of Structural Wall Anchorage System. The strength design forces for steel elements of the structural wall anchorage system, with the exception of anchor bolts and reinforcing steel, shall be increased by 1.4 times the forces otherwise required by this section.

12.11.2.2.3 Wood Diaphragms. In wood diaphragms, the continuous ties shall be in addition to the diaphragm sheathing. Anchorage shall not be accomplished by use of toe nails or nails subject to withdrawal nor shall wood ledgers or framing be used in cross-grain bending or cross-grain tension. The diaphragm sheathing shall not be considered effective as providing the ties or struts required by this section.

12.11.2.2.4 Metal Deck Diaphragms. In metal deck diaphragms, the metal deck shall not be used as the continuous ties required by this section in the direction perpendicular to the deck span.

12.11.2.2.5 Embedded Straps. Diaphragm to structural wall anchorage using embedded straps shall be attached to, or hooked around, the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

12.11.2.2.6 Eccentrically Loaded Anchorage System. Where elements of the wall anchorage system are loaded eccentrically or are not perpendicular to the wall, the system shall be designed to resist all components of the forces induced by the eccentricity.

TABLE 12.12-1 ALLOWABLE STORY DRIFT, Δ_a[a,b]

Structure	Occupancy Category		
	I or II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$[c]	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures [d]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
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] h_{sx} is the story height below Level x.
[b] For seismic force–resisting systems comprised solely of moment frames in Seismic Design Categories D, E, and F, the allowable story drift shall comply with the requirements of Section 12.12.1.1.
[c] There shall be no drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts. The structure separation requirement of Section 12.12.3 is not waived.
[d] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support which are so constructed that moment transfer between shear walls (coupling) is negligible.

12.11.2.2.7 Walls with Pilasters. Where pilasters are present in the wall, the anchorage force at the pilasters shall be calculated considering the additional load transferred from the wall panels to the pilasters. However, the minimum anchorage force at a floor or roof shall not be reduced.

12.12 DRIFT AND DEFORMATION

12.12.1 Story Drift Limit. The design story drift (Δ) as determined in Sections 12.8.6, 12.9.2, or 16.1, shall not exceed the allowable story drift (Δ_a) as obtained from Table 12.12-1 for any story. For structures with significant torsional deflections, the maximum drift shall include torsional effects. For structures assigned to Seismic Design Category C, D, E, or F having horizontal irregularity Types 1a or 1b of Table 12.3-1, the design story drift, Δ, shall be computed as the largest difference of the deflections along any of the edges of the structure at the top and bottom of the story under consideration.

12.12.1.1 Moment Frames in Structures Assigned to Seismic Design Categories D through F. For seismic force–resisting systems comprised solely of moment frames in structures assigned to Seismic Design Categories D, E, or F, the design story drift (Δ) shall not exceed Δ_a/ρ for any story. ρ shall be determined in accordance with Section 12.3.4.2.

12.12.2 Diaphragm Deflection. The deflection in the plane of the diaphragm, as determined by engineering analysis, shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection that will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads.

12.12.3 Building Separation. All portions of the structure shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under total deflection (δ_x) as determined in Section 12.8.6

12.12.4 Deformation Compatibility for Seismic Design Categories D through F. For structures assigned to Seismic Design Category D, E, or F, every structural component not included in the seismic force–resisting system in the direction under consideration shall be designed to be adequate for the gravity load effects and the seismic forces resulting from displacement to the design story drift (Δ) as determined in accordance with Section 12.8.6 (see also Section 12.12.1).

EXCEPTION: Reinforced concrete frame members not designed as part of the seismic force–resisting system shall comply with Section 21.9 of ACI 318.

Where determining the moments and shears induced in components that are not included in the seismic force–resisting system in the direction under consideration, the stiffening effects of adjoining rigid structural and nonstructural elements shall be considered and a rational value of member and restraint stiffness shall be used.

12.13 FOUNDATION DESIGN

12.13.1 Design Basis. The design basis for foundations shall be as set forth in Section 12.1.5.

12.13.2 Materials of Construction. Materials used for the design and construction of foundations shall comply with the requirements of Chapter 14. Design and detailing of steel piles shall comply with Section 14.1.8. Design and detailing of concrete piles shall comply with Section 14.2.3.

12.13.3 Foundation Load-Deformation Characteristics.

Where foundation flexibility is included for the linear analysis procedures in Chapters 12 and 16, the load-deformation characteristics of the foundation-soil system (foundation stiffness) shall be modeled in accordance with the requirements of this section. The linear load-deformation behavior of foundations shall be represented by an equivalent linear stiffness using soil properties that are compatible with the soil strain levels associated with the design earthquake motion. The strain-compatible shear modulus, G, and the associated strain-compatible shear wave velocity, v_S, needed for the evaluation of equivalent linear stiffness shall be determined using the criteria in Section 19.2.1.1 or based on a site-specific study. A 50 percent increase and decrease in stiffness shall be incorporated in dynamic analyses unless smaller variations can be justified based on field measurements of dynamic soil properties or direct measurements of dynamic foundation stiffness. The largest values of response shall be used in design.

12.13.4 Reduction of Foundation Overturning. Overturning effects at the soil-foundation interface are permitted to be reduced by 25 percent for foundations of structures that satisfy both of the following conditions:

a. The structure is designed in accordance with the Equivalent Lateral Force Analysis as set forth in Section 12.8.
b. The structure is not an inverted pendulum or cantilevered column type structure.

Overturning effects at the soil-foundation interface are permitted to be reduced by 10 percent for foundations of structures designed in accordance with the modal analysis requirements of Section 12.9.

12.13.5 Requirements for Structures Assigned to Seismic Design Category C. In addition to the requirements of Section 11.8.2, the following foundation design requirements shall apply to structures assigned to Seismic Design Category C.

12.13.5.1 Pole-Type Structures. Where construction employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth is used to resist lateral loads, the depth of embedment required for posts or poles to resist seismic forces shall be determined by means of the design criteria established in the foundation investigation report.

12.13.5.2 Foundation Ties. Individual pile caps, drilled piers, or caissons shall be interconnected by ties. All ties shall have a design strength in tension or compression at least equal to a force equal to 10 percent of S_{DS} times the larger pile cap or column factored dead plus factored live load unless it is demonstrated that equivalent restraint will be provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade or confinement by competent rock, hard cohesive soils, very dense granular soils, or other approved means.

12.13.5.3 Pile Anchorage Requirements. In addition to the requirements of Section 14.2.3.1, anchorage of piles shall comply with this section. Where required for resistance to uplift forces, anchorage of steel pipe (round HSS sections), concrete-filled steel pipe or H piles to the pile cap shall be made by means other than concrete bond to the bare steel section.

EXCEPTION: Anchorage of concrete-filled steel pipe piles is permitted to be accomplished using deformed bars developed into the concrete portion of the pile.

12.13.6 Requirements for Structures Assigned to Seismic Design Categories D through F. In addition to the requirements of Sections 11.8.2, 11.8.3, 14.1.8, and 14.2.3.2, the following foundation design requirements shall apply to structures assigned to Seismic Design Category D, E, or F. Design and construction of concrete foundation components shall conform to the requirements of ACI 318, Section 21.8, except as modified by the requirements of this section.

EXCEPTION: Detached one- and two-family dwellings of light-frame construction not exceeding two stories in height above grade need only comply with the requirements for Sections 11.8.2, 11.8.3 (Items 2 through 4), 12.13.2, and 12.13.5.

12.13.6.1 Pole-Type Structures. Where construction employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth is used to resist lateral loads, the depth of embedment required for posts or poles to resist seismic forces shall be determined by means of the design criteria established in the foundation investigation report.

12.13.6.2 Foundation Ties. Individual pile caps, drilled piers, or caissons shall be interconnected by ties. In addition, individual spread footings founded on soil defined in Chapter 20 as Site Class E or F shall be interconnected by ties. All ties shall have a design strength in tension or compression at least equal to a force equal to 10 percent of S_{DS} times the larger pile cap or column factored dead plus factored live load unless it is demonstrated that equivalent restraint will be provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade or confinement by competent rock, hard cohesive soils, very dense granular soils, or other approved means.

12.13.6.3 General Pile Design Requirement. Piling shall be designed and constructed to withstand deformations from earthquake ground motions and structure response. Deformations shall include both free-field soil strains (without the structure) and deformations induced by lateral pile resistance to structure seismic forces, all as modified by soil-pile interaction.

12.13.6.4 Batter Piles. Batter piles and their connections shall be capable of resisting forces and moments from the load combinations with overstrength factor of Section 12.4.3.2 or 12.14.3.2.2. Where vertical and batter piles act jointly to resist foundation forces as a group, these forces shall be distributed to the individual piles in accordance with their relative horizontal and vertical rigidities and the geometric distribution of the piles within the group.

12.13.6.5 Pile Anchorage Requirements. In addition to the requirements of Section 12.3.5.3, anchorage of piles shall comply with this section. Design of anchorage of piles into the pile cap shall consider the combined effect of axial forces due to uplift and bending moments due to fixity to the pile cap. For piles required to resist uplift forces or provide rotational restraint, anchorage into the pile cap shall be capable of developing the following:

1. In the case of uplift, the lesser of the nominal tensile strength of the longitudinal reinforcement in a concrete pile, or the nominal tensile strength of a steel pile, or 1.3 times the pile pullout resistance, or the axial tension force resulting from the load combinations with overstrength factor of Section 12.4.3.2 or 12.14.3.2.2. The pile pullout resistance shall be taken as the ultimate frictional or adhesive force that can be developed between the soil and the pile plus the pile weight.
2. In the case of rotational restraint, the lesser of the axial and shear forces and moments resulting from the load combinations with overstrength factor of Section 12.4.3.2 or 12.14.3.2.2 or development of the full axial, bending, and shear nominal strength of the pile.

12.13.6.6 Splices of Pile Segments. Splices of pile segments shall develop the nominal strength of the pile section, but the splice need not develop the nominal strength of the pile in tension, shear, and bending where it has been designed to resist axial and shear forces and moments from the load combinations with overstrength factor of Section 12.4.3.2 or 12.14.3.2.2.

12.13.6.7 Pile Soil Interaction. Pile moments, shears, and lateral deflections used for design shall be established considering the interaction of the shaft and soil. Where the ratio of the depth of embedment of the pile to the pile diameter or width is less than or equal to 6, the pile is permitted to be assumed to be flexurally rigid with respect to the soil.

12.13.6.8 Pile Group Effects. Pile group effects from soil on lateral pile nominal strength shall be included where pile center-to-center spacing in the direction of lateral force is less than eight pile diameters or widths. Pile group effects on vertical nominal strength shall be included where pile center-to-center spacing is less than three pile diameters or widths.

12.14 SIMPLIFIED ALTERNATIVE STRUCTURAL DESIGN CRITERIA FOR SIMPLE BEARING WALL OR BUILDING FRAME SYSTEMS

12.14.1 General.

12.14.1.1 Simplified Design Procedure. The procedures of this section are permitted to be used in lieu of other analytical procedures in Chapter 12 for the analysis and design of simple buildings with bearing wall or building frame systems, subject to all of the limitations listed in this Section 12.14.1.1. Where these procedures are used, the seismic design category shall be determined from Table 11.6-1 using the value of S_{DS} from Section 12.14.8.1.

TABLE 12.14-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS FOR SIMPLIFIED DESIGN PROCEDURE

Seismic Force–Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	Limitations[b] Seismic Design Category B	C	D, E
A. BEARING WALL SYSTEMS					
1. Special reinforced concrete shear walls	14.2 and 14.2.3.6	5	P	P	P
2. Ordinary reinforced concrete shear walls	14.2 and 14.2.3.4	4	P	P	NP
3. Detailed plain concrete shear walls	14.2 and 14.2.3.2	2	P	NP	NP
4. Ordinary plain concrete shear walls	14.2 and 14.2.3.1	$1\frac{1}{2}$	P	NP	NP
5. Intermediate precast shear walls	14.2 and 14.2.3.5	4	P	P	40[c]
6. Ordinary precast shear walls	14.2 and 14.2.3.3	3	P	NP	NP
7. Special reinforced masonry shear walls	14.4 and 14.4.3	5	P	P	P
8. Intermediate reinforced masonry shear walls	14.4 and 14.4.3	$3\frac{1}{2}$	P	P	NP
9. Ordinary reinforced masonry shear walls	14.4	2	P	NP	NP
10. Detailed plain masonry shear walls	14.4	2	P	NP	NP
11. Ordinary plain masonry shear walls	14.4	$1\frac{1}{2}$	P	NP	NP
12. Prestressed masonry shear walls	14.4	$1\frac{1}{2}$	P	NP	NP
13. Light-frame walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1, 14.1.4.2, and 14.5	$6\frac{1}{2}$	P	P	P
14. Light-framed walls with shear panels of all other materials	14.1, 14.1.4.2, and 14.5	2	P	P	NP[d]
15. Light-framed wall systems using flat strap bracing	14.1, 14.1.4.2, and 14.5	4	P	P	P
B. BUILDING FRAME SYSTEMS					
1. Steel eccentrically braced frames, moment-resisting connections at columns away from links	14.1	8	P	P	P
2. Steel eccentrically braced frames, non-moment-resisting connections at columns away from links	14.1	7	P	P	P
3. Special steel concentrically braced frames	14.1	6	P	P	P
4. Ordinary steel concentrically braced frames	14.1	$3\frac{1}{4}$	P	P	P
5. Special reinforced concrete shear walls	14.2 and 14.2.3.6	6	P	P	P
6. Ordinary reinforced concrete shear walls	14.2 and 14.2.3.4	5	P	P	NP
7. Detailed plain concrete shear walls	14.2 and 14.2.3.2	2	P	NP	NP
8. Ordinary plain concrete shear walls	14.2 and 14.2.3.1	$1\frac{1}{2}$	P	NP	NP
9. Intermediate precast shear walls	14.2 and 14.2.3.5	5	P	P	40[c]
10. Ordinary precast shear walls	14.2 and 14.2.3.3	4	P	NP	NP
11. Composite steel and concrete eccentrically braced frames	14.3	8	P	P	P
12. Composite steel and concrete concentrically braced frames	14.3	5	P	P	P
13. Ordinary composite steel and concrete braced frames	14.3	3	P	P	NP
14. Composite steel plate shear walls	14.3	$6\frac{1}{2}$	P	P	P
15. Special composite reinforced concrete shear walls with steel elements	14.3	6	P	P	P
16. Ordinary composite reinforced concrete shear walls with steel elements	14.3	5	P	P	NP
17. Special reinforced masonry shear walls	14.4	$5\frac{1}{2}$	P	P	P
18. Intermediate reinforced masonry shear walls	14.4	4	P	P	NP
19. Ordinary reinforced masonry shear walls	14.4	2	P	NP	NP
20. Detailed plain masonry shear walls	14.4	2	P	NP	NP
21. Ordinary plain masonry shear walls	14.4	$1\frac{1}{2}$	P	NP	NP
22. Prestressed masonry shear walls	14.4	$1\frac{1}{2}$	P	NP	NP
23. Light-frame walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1, 14.1.4.2, and 14.5	7	P	P	P
24. Light-framed walls with shear panels of all other materials	14.1, 14.1.4.2, and 14.5	$2\frac{1}{2}$	P	P	NP[d]
25. Buckling-restrained braced frames, non-moment-resisting beam-column connections	14.1	7	P	P	P
26. Buckling-restrained braced frames, moment-resisting beam-column connections	14.1	8	P	P	P
27. Special steel plate shear wall	14.1	7	P	P	P

[a] Response modification coefficient, R, for use throughout the standard.
[b] P = permitted; NP = not permitted.
[c] Light-framed walls with shear panels of all other materials not permitted in Seismic Design Category E.
[d] Light-framed walls with shear panels of all other materials permitted up to 35 ft in height in Seismic Design Category D and not permitted in Seismic Design Category E.

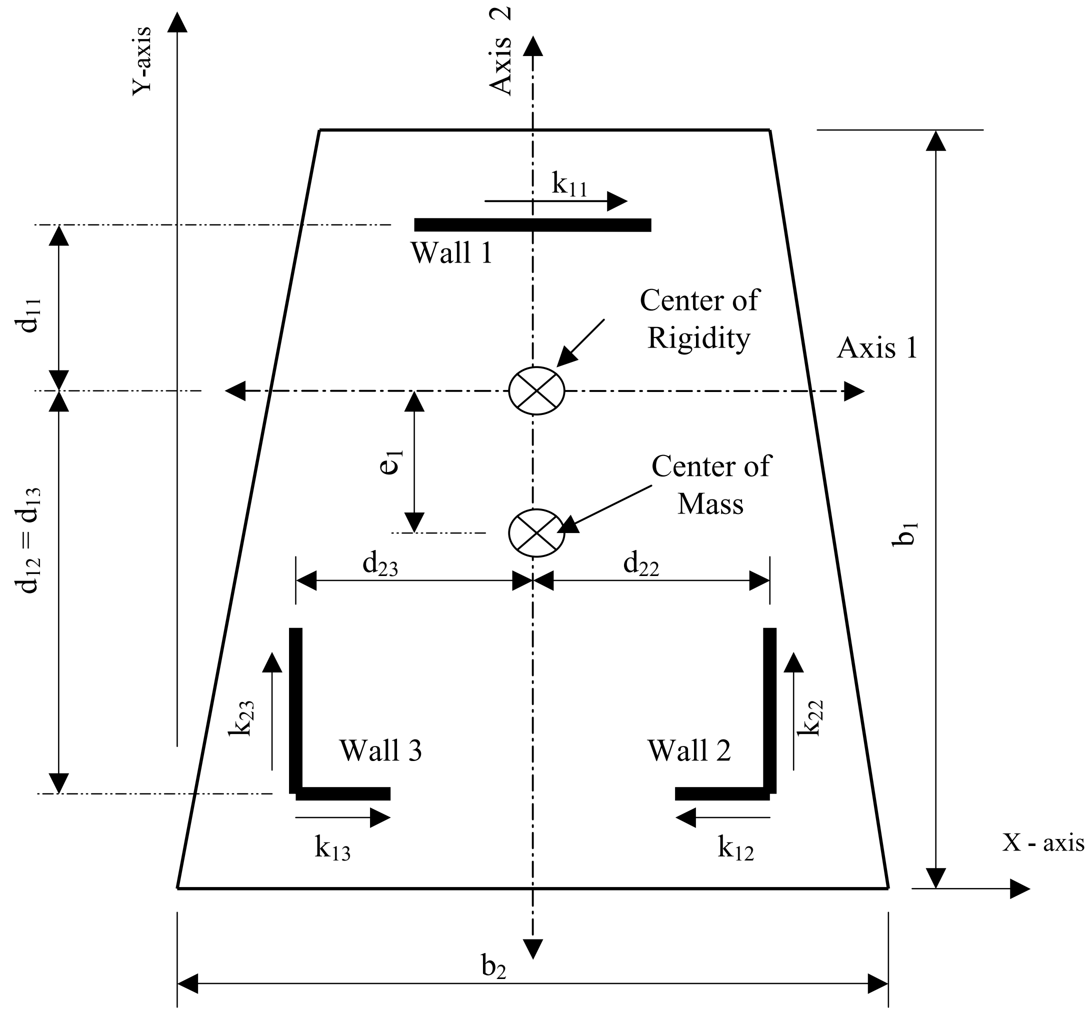

FIGURE 12.14-1 NOTATION USED IN TORSION CHECK FOR NONFLEXIBLE DIAPHRAGMS

The simplified design procedure is permitted to be used if the following limitations are met:

1. The structure shall qualify for Occupancy Category I or II in accordance with Table 1-1.
2. The site class, defined in Chapter 20, shall not be class E or F.
3. The structure shall not exceed three stories in height above grade.
4. The seismic-force resisting system shall be either a bearing wall system or building frame system, as indicated in Table 12.14-1.
5. The structure shall have at least two lines of lateral resistance in each of two major axis directions.
6. At least one line of resistance shall be provided on each side of the center of mass in each direction.
7. For structures with flexible diaphragms, overhangs beyond the outside line of shear walls or braced frames shall satisfy the following:

$$a \leq d/5 \tag{12.14-1}$$

where

a = the distance perpendicular to the forces being considered from the extreme edge of the diaphragm to the line of vertical resistance closest to that edge

d = the depth of the diaphragm parallel to the forces being considered at the line of vertical resistance closest to the edge

8. For buildings with a diaphragm that is not flexible, the distance between the center of rigidity and the center of mass parallel to each major axis shall not exceed 15 percent of the greatest width of the diaphragm parallel to that axis. In addition, the following shall be satisfied for each major axis direction:

$$\sum_{i=1}^{m} k_{1i} d_i^2 + \sum_{j=1}^{n} k_{2j} d_j^2 \geq 2.5 \left(0.05 + \frac{e_1}{b}\right) b^2 \sum_{i=1}^{m} k_{1i} \tag{12.14-2}$$

where (see Fig. 12.14-1):

k_{1i} = the lateral load stiffness of wall "i" or braced frame "i" parallel to major axis 1

k_{2j} = the lateral load stiffness of wall "j" or braced frame "j" parallel to major axis 2

d_{1i} = the distance from the wall "i" or braced frame "i" to the center of rigidity, perpendicular to major axis 1

d_{2j} = the distance from the wall "j" or braced frame "j" to the center of rigidity, perpendicular to major axis 2

e_1 = the distance perpendicular to major axis 1 between the center of rigidity and the center of mass

b_1 = the width of the diaphragm perpendicular to major axis 1

m = the number of walls and braced frames resisting lateral force in direction 1

n = the number of walls and braced frames resisting lateral force in direction 2

Eq. 12.14-2 need not be checked where a structure fulfills all the following limitations:

1. The arrangement of walls or braced frames is symmetric about each major axis direction.
2. The distance between the two most separated lines of walls or braced frames is at least 90 percent of the dimension of the structure perpendicular to that axis direction.
3. The stiffness along each of the lines considered for item 2 above is at least 33 percent of the total stiffness in that axis direction.

9. Lines of resistance of the lateral force-resisting system shall be oriented at angles of no more than 15° from alignment with the major orthogonal horizontal axes of the building.
10. The simplified design procedure shall be used for each major orthogonal horizontal axis direction of the building.
11. System irregularities caused by in-plane or out-of-plane offsets of lateral force-resisting elements shall not be permitted.

EXCEPTION: Out-of-plane and in-plane offsets of shear walls are permitted in two-story buildings of light-frame construction provided that the framing supporting the upper wall is designed for seismic force effects from overturning of the wall amplified by a factor of 2.5.

12. The lateral-load-resistance of any story shall not be less than 80 percent of the story above.

12.14.1.2 Reference Documents. The reference documents listed in Chapter 23 shall be used as indicated in Section 12.14.

12.14.1.3 Definitions. The definitions listed in Section 11.2 shall be used in addition to the following:

PRINCIPAL ORTHOGONAL HORIZONTAL DIRECTIONS: The orthogonal directions that overlay the majority of lateral force resisting elements.

12.14.1.4 Notation.

D = The effect of dead load

E = The effect of horizontal and vertical earthquake-induced forces

F_a = Acceleration-based site coefficient, see Section 12.14.8.1

F_i = The portion of the seismic base shear, V, induced at Level i

F_p = The seismic design force applicable to a particular structural component

F_x = See Section 12.14.8.2

h_i = The height above the base to Level i

h_x = The height above the base to Level x

Level I = The building level referred to by the subscript i; $i = 1$ designates the first level above the base

Level n = The level that is uppermost in the main portion of the building

Level x = See "Level i"

Q_E = The effect of horizontal seismic forces

R = The response modification coefficient as given in Table 12.14-1

S_{DS} = See Section 12.14.8.1

S_S = See Section 11.4.1

V = The total design shear at the base of the structure in the direction of interest, as determined using the procedure of 12.14.8.1

V_x = The seismic design shear in Story x. See Section 12.14.8.3

W = See Section 12.14.8.1

W_c = Weight of wall

W_p = Weight of structural component

w_i = The portion of the effective seismic weight, W, located at or assigned to Level i

w_x = See Section 12.14.8.2

12.14.2 Design Basis. The structure shall include complete lateral and vertical-force-resisting systems with adequate strength to resist the design seismic forces, specified in this section, in combination with other loads. Design seismic forces shall be distributed to the various elements of the structure and their connections using a linear elastic analysis in accordance with the procedures of Section 12.14.8. The members of the seismic force–resisting system and their connections shall be detailed to conform with the applicable requirements for the selected structural system as indicated in Section 12.14.4.1. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance. The foundation shall be designed to accommodate the forces developed.

12.14.3 Seismic Load Effects and Combinations. All members of the structure, including those not part of the seismic force–resisting system, shall be designed using the seismic load effects of Section 12.14.3 unless otherwise exempted by this standard. Seismic load effects are the axial, shear, and flexural member forces resulting from application of horizontal and vertical seismic forces as set forth in Section 12.14.3.1. Where specifically required, seismic load effects shall be modified to account for system overstrength, as set forth in Section 12.14.3.1.3.

12.14.3.1 Seismic Load Effect. The seismic load effect, E, shall be determined in accordance with the following:

1. For use in load combination 5 in Section 2.3.2 or load combination 5 and 6 in Section 2.4.1, E shall be determined in accordance with Eq. 12.14-3 as follows:

$$E = E_h + E_v \tag{12.14-3}$$

2. For use in load combination 7 in Section 2.3.2 or load combination 8 in Section 2.4.1, E shall be determined in accordance with Eq. 12.14-4 as follows:

$$E = E_h - E_v \tag{12.14-4}$$

where

E = seismic load effect
E_h = effect of horizontal seismic forces as defined in Section 12.14.3.1.1
E_v = effect of vertical seismic forces as defined in Section 12.14.3.1.2

12.14.3.1.1 Horizontal Seismic Load Effect. The horizontal seismic load effect, E_h, shall be determined in accordance with Eq. 12.14-5 as follows:

$$E_h = Q_E \quad (12.14\text{-}5)$$

where

Q_E = effects of horizontal seismic forces from V or F_p as specified in Sections 12.14.7.5, 12.14.8.1, and 13.3.1.

12.14.3.1.2 Vertical Seismic Load Effect. The vertical seismic load effect, E_v, shall be determined in accordance with Eq. 12.14-6 as follows:

$$E_v = 0.2S_{DS}D \quad (12.14\text{-}6)$$

where

S_{DS} = design spectral response acceleration parameter at short periods obtained from Section 11.4.4
D = effect of dead load

EXCEPTION: The vertical seismic load effect, E_v, is permitted to be taken as zero for either of the following conditions:

1. In Eqs. 12.4-3, 12.4-4, 12.4-7, and 12.14-8 where S_{DS} is equal to or less than 0.125.
2. In Eq. 12.14-4 where determining demands on the soil-structure interface of foundations.

12.14.3.1.3 Seismic Load Combinations. Where the prescribed seismic load effect, E, defined in Section 12.14.3.1 is combined with the effects of other loads as set forth in Chapter 2, the following seismic load combinations for structures not subject to flood or atmospheric ice loads shall be used in lieu of the seismic load combinations in Sections 2.3.2 or 2.4.1:

Basic Combinations for Strength Design (see Sections 2.3.2 and 2.2 for notation).

5. $(1.2 + 0.2S_{DS})D + Q_E + L + 0.2\,S$
7. $(0.9 - 0.2S_{DS})D + Q_E + 1.6H$

NOTES:

1. The load factor on L in combination (5) is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf (4.79 kN/m^2), with the exception of garages or areas occupied as places of public assembly.
2. The load factor on H shall be set equal to zero in combination 7 if the structural action due to H counteracts that due to E. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H but shall be included in the design resistance.

Basic Combinations for Allowable Stress Design (see Sections 2.4.1 and 2.2 for notation).

5. $(1.0 + 0.14S_{DS})D + H + F + 0.7Q_E$
6. $(1.0 + 0.105S_{DS})D + H + F + 0.525Q_E + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
8. $(0.6 - 0.14S_{DS})D + 0.7Q_E + H$

12.14.3.2 Seismic Load Effect Including a 2.5 Overstrength Factor. Where specifically required, conditions requiring overstrength factor applications shall be determined in accordance with the following:

1. For use in load combination 5 in Section 2.3.2 or load combinations 5 and 6 in Section 2.4.1, E shall be taken equal to E_m as determined in accordance with Eq. 12.14-7 as follows:

$$E_m = E_{mh} + E_v \quad (12.14\text{-}7)$$

2. For use in load combination 7 in Section 2.3.2 or load combination 8 in Section 2.4.1, E shall be taken equal to E_m as determined in accordance with Eq. 12.14-8 as follows:

$$E_m = E_{mh} - E_v \quad (12.14\text{-}8)$$

where

E_m = seismic load effect including overstrength factor
E_{mh} = effect of horizontal seismic forces including structural overstrength as defined in Section 12.14.3.2.1.
E_v = vertical seismic load effect as defined in Section 12.14.3.1.2

12.14.3.2.1 Horizontal Seismic Load Effect with a 2.5 Overstrength Factor. The horizontal seismic load effect with overstrength factor, E_{mh}, shall be determined in accordance with Eq. 12.14-9 as follows:

$$E_{mh} = 2.5Q_E \quad (12.14\text{-}9)$$

where

Q_E = effects of horizontal seismic forces from V or F_p as specified in Sections 12.14.8.1, 12.14.7.5, and 13.3.1

EXCEPTION: The value of E_{mh} need not exceed the maximum force that can develop in the element as determined by a rational, plastic mechanism analysis or nonlinear response analysis utilizing realistic expected values of material strengths.

12.14.3.2.2 Load Combinations with Overstrength Factor. Where the seismic load effect with overstrength, E_m, defined in Section 12.14.3.2 is combined with the effects of other loads as set forth in Section 2, the following seismic load combinations for structures not subject to flood or atmospheric ice loads shall be used in lieu of the seismic load combinations in Section 2.3.2 or 2.4.1:

Basic Combinations for Strength Design with Overstrength Factor (see Sections 2.3.2 and 2.2 for notation).

5. $(1.2 + 0.2S_{DS})D + 2.5Q_E + L + 0.2S$
7. $(0.9 - 0.2S_{DS})D + 2.5Q_E + 1.6H$

NOTES:

1. The load factor on L in combination 5 is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf (4.79 kN/m^2), with the exception of garages or areas occupied as places of public assembly.
2. The load factor on H shall be set equal to zero in combination 7 if the structural action due to H counteracts that due to E. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in H, but shall be included in the design resistance.

Basic Combinations for Allowable Stress Design with Overstrength Factor (see Sections 2.4.1 and 2.2 for notation).

5. $(1.0 + 0.14S_{DS})D + H + F + 1.75Q_E$
6. $(1.0 + 0.105S_{DS})D + H + F + 1.313Q_E + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
8. $(0.6 - 0.14S_{DS})D + 1.75Q_E + H$

12.14.3.2.3 Allowable Stress Increase for Load Combinations with Overstrength. Where allowable stress design methodologies are used with the seismic load effect defined in

Section 12.14.3.2 applied in load combinations 5, 6, or 8 of Section 2.4.1, allowable stresses are permitted to be determined using an allowable stress increase of 1.2. This increase shall not be combined with increases in allowable stresses or load combination reductions otherwise permitted by this standard or the material reference document except that combination with the duration of load increases permitted in AF&PA NDS is permitted.

12.14.4 Seismic Force–Resisting System.

12.14.4.1 Selection and Limitations. The basic lateral and vertical seismic force–resisting system shall conform to one of the types indicated in Table 12.14-1 and shall conform to all of the detailing requirements referenced in the table. The appropriate response modification coefficient, R, indicated in Table 12.14-1 shall be used in determining the base shear and element design forces as set forth in the seismic requirements of this standard.

Special framing and detailing requirements are indicated in Section 12.14.7 and in Sections 14.1, 14.2, 14.3, 14.4, and 14.5 for structures assigned to the various seismic design categories.

12.14.4.2 Combinations of Framing Systems.

12.14.4.2.1 Horizontal Combinations. Different seismic force-resisting systems are permitted to be used in each of the two principal orthogonal building directions. Where a combination of different structural systems is utilized to resist lateral forces in the same direction, the value of R used for design in that direction shall not be greater than the least value of R for any of the systems utilized in that direction.

EXCEPTION: For buildings of light-frame construction or have flexible diaphragms and that are two stories or less in height, resisting elements are permitted to be designed using the least value of R of the different seismic force–resisting systems found in each independent line of framing. The value of R used for design of diaphragms in such structures shall not be greater than the least value for any of the systems utilized in that same direction.

12.14.4.2.2 Vertical Combinations. Different seismic force–resisting systems are permitted to be used in different stories. The value of R used in a given direction shall not be greater than the least value of any of the systems used in that direction.

12.14.4.2.3 Combination Framing Detailing Requirements. The detailing requirements of Section 12.14.7 required by the higher response modification coefficient, R, shall be used for structural components common to systems having different response modification coefficients.

12.14.5 Diaphragm Flexibility. Diaphragms constructed of steel decking, (untopped), wood structural panels, or similar panelized construction are permitted to be considered flexible.

12.14.6 Application of Loading. The effects of the combination of loads shall be considered as prescribed in Section 12.14.3. The design seismic forces are permitted to be applied separately in each orthogonal direction and the combination of effects from the two directions need not be considered. Reversal of load shall be considered.

12.14.7 Design and Detailing Requirements. The design and detailing of the components of the seismic force–resisting system shall comply with the requirements of this section. The foundation shall be designed to resist the forces developed and accommodate the movements imparted to the structure by the design ground motions. The dynamic nature of the forces, the expected ground motion, the design basis for strength and energy dissipation capacity of the structure, and the dynamic properties of the soil shall be included in the determination of the foundation design criteria. The design and construction of foundations shall comply with Section 12.13. Structural elements including foundation elements shall conform to the material design and detailing requirements set forth in Chapter 14.

12.14.7.1 Connections. All parts of the structure between separation joints shall be interconnected, and the connection shall be capable of transmitting the seismic force, F_p, induced by the parts being connected. Any smaller portion of the structure shall be tied to the remainder of the structure with elements having a strength of 0.20 times the short period design spectral response acceleration coefficient, S_{DS}, times the weight of the smaller portion or 5 percent of the portion's weight, whichever is greater.

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder, or truss either directly to its supporting elements, or to slabs designed to act as diaphragms. Where the connection is through a diaphragm, then the member's supporting element must also be connected to the diaphragm. The connection shall have minimum design strength of 5 percent of the dead plus live load reaction.

12.14.7.2 Openings or Reentrant Building Corners. Except where as otherwise specifically provided for in this standard, openings in shear walls, diaphragms, or other plate-type elements, shall be provided with reinforcement at the edges of the openings or reentrant corners designed to transfer the stresses into the structure. The edge reinforcement shall extend into the body of the wall or diaphragm a distance sufficient to develop the force in the reinforcement.

EXCEPTION: Perforated shear walls of wood structural panels are permitted where designed in accordance with AF&PA SDPWS.

12.14.7.3 Collector Elements. Collector elements shall be provided with adequate strength to transfer the seismic forces originating in other portions of the structure to the element providing the resistance to those forces (see Fig. 12.10-1). Collector elements, splices, and their connections to resisting elements shall be designed to resist the forces defined in Section 12.14.3.2.

EXCEPTION: In structures, or portions thereof, braced entirely by light-frame shear walls, collector elements, splices, and connections to resisting elements are permitted to be designed to resist forces in accordance with Section 12.14.7.4.

12.14.7.4 Diaphragms. Floor and roof diaphragms shall be designed to resist the design seismic forces at each level, F_x, calculated in accordance with Section 12.14.8.2. Where the diaphragm is required to transfer design seismic forces from the vertical-resisting elements above the diaphragm to other vertical-resisting elements below the diaphragm due to changes in relative lateral stiffness in the vertical elements, the transferred portion of the seismic shear force at that level, V_x, shall be added to the diaphragm design force. Diaphragms shall provide for both the shear and bending stresses resulting from these forces. Diaphragms shall have ties or struts to distribute the wall anchorage forces into the diaphragm. Diaphragm connections shall be positive, mechanical, or welded type connections.

12.14.7.5 Anchorage of Concrete or Masonry Structural Walls. Concrete or masonry structural walls shall be anchored to all floors, roofs, and members that provide out-of-plane lateral support for the wall or that are supported by the wall. The anchorage shall provide a positive direct connection between the wall and floor, roof, or supporting member with the strength to resist horizontal forces specified in this section for structures with flexible diaphragms or of Section 13.3.1 (using a_p equal to 1.0 and R_p equal to 2.5) for structures with diaphragms that are not flexible.

Anchorage of structural walls to flexible diaphragms shall have the strength to develop the out-of-plane force given by Eq. 12.14-8:

$$F_p = 0.8 S_{DS} W_p \tag{12.14-10}$$

where

F_p = the design force in the individual anchors
S_{DS} = the design spectral response acceleration at short periods per Section 12.14.8.1
W_p = the weight of the wall tributary to the anchor

EXCEPTION: For Seismic Design Category B, the coefficient 0.8 shall be 0.4, with a minimum force of 10 percent of the tributary weight of the wall or $400S_{DS}$ in pounds per foot, whichever is greater.

12.14.7.5.1 Transfer of Anchorage Forces into Diaphragms. Diaphragms shall be provided with continuous ties or struts between diaphragm chords to distribute these anchorage forces into the diaphragms. Added chords are permitted to be used to form subdiaphragms to transmit the anchorage forces to the main continuous cross ties. The maximum length-to-width ratio of the structural subdiaphragm shall be 2.5 to 1. Connections and anchorages capable of resisting the prescribed forces shall be provided between the diaphragm and the attached components. Connections shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.

12.14.7.5.2 Wood Diaphragms. In wood diaphragms, the continuous ties shall be in addition to the diaphragm sheathing. Anchorage shall not be accomplished by use of toenails or nails subject to withdrawal nor shall wood ledgers or framing be used in cross-grain bending or cross-grain tension. The diaphragm sheathing shall not be considered effective as providing the ties or struts required by this section.

12.14.7.5.3 Metal Deck Diaphragms. In metal deck diaphragms, the metal deck shall not be used as the continuous ties required by this section in the direction perpendicular to the deck span.

12.14.7.5.4 Embedded Straps. Diaphragm to wall anchorage using embedded straps shall be attached to or hooked around the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

12.14.7.6 Bearing Walls and Shear Walls. Exterior and interior bearing walls and shear walls and their anchorage shall be designed for a force equal to 40 percent of the short period design spectral response acceleration S_{DS} times the weight of wall, W_c, normal to the surface, with a minimum force of 10 percent of the weight of the wall. Interconnection of wall elements and connections to supporting framing systems shall have sufficient ductility, rotational capacity, or sufficient strength to resist shrinkage, thermal changes, and differential foundation settlement where combined with seismic forces.

12.14.7.7 Anchorage of Nonstructural Systems. Where required by Chapter 13, all portions or components of the structure shall be anchored for the seismic force, F_p, prescribed therein.

12.14.8 Simplified Lateral Force Analysis Procedure. An equivalent lateral force analysis shall consist of the application of equivalent static lateral forces to a linear mathematical model of the structure. The lateral forces applied in each direction shall sum to a total seismic base shear given by Section 12.14.8.1 and shall be distributed vertically in accordance with Section 12.14.8.2. For purposes of analysis, the structure shall be considered fixed at the base.

12.14.8.1 Seismic Base Shear. The seismic base shear, V, in a given direction shall be determined in accordance with Eq. 12.14-9:

$$V = \frac{F S_{DS}}{R} W \tag{12.14-11}$$

where

$$S_{DS} = \frac{2}{3} F_a S_s$$

where F_a is permitted to be taken as 1.0 for rock sites, 1.4 for soil sites, or determined in accordance with Section 11.4.3. For the purpose of this section, sites are permitted to be considered to be rock if there is no more than 10 ft (3 m) of soil between the rock surface and the bottom of spread footing or mat foundation. In calculating S_{DS}, S_s shall be in accordance with Section 11.4.1, but need not be taken larger than 1.5.

F = 1.0 for one-story buildings
F = 1.1 for two-story buildings
F = 1.2 for three-story buildings
R = the response modification factor from Table 12.14-1
W = effective seismic weight of structure that shall include the total dead load and other loads listed in the following text

1. In areas used for storage, a minimum of 25 percent of the floor live load (floor live load in public garages and open parking structures need not be included).
2. Where provision for partitions is required by Section 4.2.2 in the floor load design, the actual partition weight, or a minimum weight of 10 psf (0.48 kN/m^2) of floor area, whichever is greater.
3. Total operating weight of permanent equipment.
4. Where the flat roof snow load, P_f, exceeds 30 psf (1.44 kN/m^2), 20 percent of the uniform design snow load, regardless of actual roof slope.

12.14.8.2 Vertical Distribution. The forces at each level shall be calculated using the following equation:

$$F_x = \frac{w_x}{W} V \tag{12.14-12}$$

where w_x = the portion of the effective seismic weight of the structure, W, at level x.

12.14.8.3 Horizontal Shear Distribution. The seismic design story shear in any story, V_x (kip or kN), shall be determined from the following equation:

$$V_x = \sum_{i=x}^{n} F_i \tag{12.14-13}$$

where F_i = the portion of the seismic base shear, V (kip or kN) induced at Level, i.

12.14.8.3.1 Flexible Diaphragm Structures. The seismic design story shear in stories of structures with flexible diaphragms, as defined in Section 12.14.5, shall be distributed to the vertical elements of the lateral force resisting system using tributary area rules. Two-dimensional analysis is permitted where diaphragms are flexible.

12.14.8.3.2 Structures with Diaphragms That Are Not Flexible. For structures with diaphragms that are not flexible, as defined in Section 12.14.5, the seismic design story shear, V_x, (kip or kN) shall be distributed to the various vertical elements of the seismic force–resisting system in the story under consideration based on the relative lateral stiffnesses of the vertical elements and the diaphragm.

12.14.8.3.2.1 Torsion. The design of structures with diaphragms that are not flexible shall include the torsional moment, M_t (kip-ft. or KN-m) resulting from eccentricity between the locations of center of mass and the center of rigidity.

12.14.8.4 Overturning. The structure shall be designed to resist overturning effects caused by the seismic forces determined in Section 12.14.8.2. The foundations of structures shall be designed for not less than 75 percent of the foundation overturning design moment, M_f (kip-ft or kN-m) at the foundation-soil interface.

12.14.8.5 Drift Limits and Building Separation. Structural drift need not be calculated. Where a drift value is needed for use in material standards, to determine structural separations between buildings, for design of cladding, or for other design requirements, it shall be taken as 1 percent of building height unless computed to be less. All portions of the structure shall be designed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under the total deflection.