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	Overstrength Factor, Ω_0^b	Deflection Amplification Factor, C_d^c	Structural System Limitations Including Structural Height, h_n (ft) Limits[d] — Seismic Design Category: B	C	D[e]	E[e]	F[f]
A. BEARING WALL SYSTEMS									
1. Special reinforced concrete shear walls[g,h]	14.2	5	2½	5	NL	NL	160	160	100
2. Ordinary reinforced concrete shear walls[g]	14.2	4	2½	4	NL	NL	NP	NP	NP
3. Detailed plain concrete shear walls[g]	14.2	2	2½	2	NL	NP	NP	NP	NP
4. Ordinary plain concrete shear walls[g]	14.2	1½	2½	1½	NL	NP	NP	NP	NP
5. Intermediate precast shear walls[g]	14.2	4	2½	4	NL	NL	40[i]	40[i]	40[i]
6. Ordinary precast shear walls[g]	14.2	3	2½	3	NL	NP	NP	NP	NP
7. Special reinforced masonry shear walls	14.4	5	2½	3½	NL	NL	160	160	100
8. Intermediate reinforced masonry shear walls	14.4	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. Ordinary reinforced AAC masonry shear walls	14.4	2	2½	2	NL	35	NP	NP	NP
14. Ordinary plain AAC masonry shear walls	14.4	1½	2½	1½	NL	NP	NP	NP	NP
15. Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	14.5	6½	3	4	NL	NL	65	65	65
16. Light-frame (cold-formed steel) walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1	6½	3	4	NL	NL	65	65	65
17. Light-frame walls with shear panels of all other materials	14.1 and 14.5	2	2½	2	NL	NL	35	NP	NP
18. Light-frame (cold-formed steel) wall systems using flat strap bracing	14.1	4	2	3½	NL	NL	65	65	65
B. BUILDING FRAME SYSTEMS									
1. Steel eccentrically braced frames	14.1	8	2	4	NL	NL	160	160	100
2. Steel special concentrically braced frames	14.1	6	2	5	NL	NL	160	160	100
3. Steel ordinary concentrically braced frames	14.1	3¼	2	3¼	NL	NL	35[j]	35[j]	NP[j]
4. Special reinforced concrete shear walls[g,h]	14.2	6	2½	5	NL	NL	160	160	100
5. Ordinary reinforced concrete shear walls[g]	14.2	5	2½	4½	NL	NL	NP	NP	NP
6. Detailed plain concrete shear walls[g]	14.2 and 14.2.2.7	2	2½	2	NL	NP	NP	NP	NP
7. Ordinary plain concrete shear walls[g]	14.2	1½	2½	1½	NL	NP	NP	NP	NP
8. Intermediate precast shear walls[g]	14.2	5	2½	4½	NL	NL	40[i]	40[i]	40[i]
9. Ordinary precast shear walls[g]	14.2	4	2½	4	NL	NP	NP	NP	NP
10. Steel and concrete composite eccentrically braced frames	14.3	8	2½	4	NL	NL	160	160	100
11. Steel and concrete composite special concentrically braced frames	14.3	5	2	4½	NL	NL	160	160	100
12. Steel and concrete composite ordinary braced frames	14.3	3	2	3	NL	NL	NP	NP	NP
13. Steel and concrete composite plate shear walls	14.3	6½	2½	5½	NL	NL	160	160	100
14. Steel and concrete composite special shear walls	14.3	6	2½	5	NL	NL	160	160	100
15. Steel and concrete composite ordinary shear walls	14.3	5	2½	4½	NL	NL	NP	NP	NP
16. Special reinforced masonry shear walls	14.4	5½	2½	4	NL	NL	160	160	100
17. Intermediate reinforced masonry shear walls	14.4	4	2½	4	NL	NL	NP	NP	NP

18. Ordinary reinforced masonry shear walls	14.4	2	2½	2	NL	160	NP	NP	NP
19. Detailed plain masonry shear walls	14.4	2	2½	2	NL	NP	NP	NP	NP
20. Ordinary plain masonry shear walls	14.4	1½	2½	1¼	NL	NP	NP	NP	NP
21. Prestressed masonry shear walls	14.4	1½	2½	1¾	NL	NP	NP	NP	NP
22. Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	14.5	7	2½	4½	NL	NL	65	65	65
23. Light-frame (cold-formed steel) walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1	7	2½	4½	NL	NL	65	65	65
24. Light-frame walls with shear panels of all other materials	14.1 and 14.5	2½	2½	2½	NL	NL	35	NP	NP
25. Steel buckling-restrained braced frames	14.1	8	2½	5	NL	NL	160	160	100
26. Steel special plate shear walls	14.1	7	2	6	NL	NL	160	160	100
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Steel special moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Steel special truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Steel intermediate moment frames	12.2.5.7 and 14.1	4½	3	4	NL	NL	35[k]	NP[k]	NP[k]
4. Steel ordinary moment frames	12.2.5.6 and 14.1	3½	3	3	NL	NL	NP[l]	NP[l]	NP[l]
5. Special reinforced concrete moment frames[m]	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. Steel and concrete composite special moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Steel and concrete composite intermediate moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Steel and concrete composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Steel and concrete composite ordinary moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP
12. Cold-formed steel—special bolted moment frame[n]	14.1	3½	3[o]	3½	35	35	35	35	35
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. Steel special concentrically braced frames	14.1	7	2½	5½	NL	NL	NL	NL	NL
3. Special reinforced concrete shear walls[g,h]	14.2	7	2½	5½	NL	NL	NL	NL	NL
4. Ordinary reinforced concrete shear walls[g]	14.2	6	2½	5	NL	NL	NP	NP	NP
5. Steel and concrete composite eccentrically braced frames	14.3	8	2½	4	NL	NL	NL	NL	NL
6. Steel and concrete composite special concentrically braced frames	14.3	6	2½	5	NL	NL	NL	NL	NL
7. Steel and concrete composite plate shear walls	14.3	7½	2½	6	NL	NL	NL	NL	NL
8. Steel and concrete composite special shear walls	14.3	7	2½	6	NL	NL	NL	NL	NL
9. Steel and concrete composite ordinary shear walls	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. Steel buckling-restrained braced frames	14.1	8	2½	5	NL	NL	NL	NL	NL
13. Steel special plate shear walls	14.1	8	2½	6½	NL	NL	NL	NL	NL
E. DUAL SYSTEMS WITH INTERMEDIATE MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES	12.2.5.1								
1. Steel special concentrically braced frames[p]	14.1	6	2½	5	NL	NL	35	NP	NP
2. Special reinforced concrete shear walls[g,h]	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

continues

R/ρ of the upper portion over R/ρ of the lower portion. This ratio shall not be less than 1.0.

e. The upper portion is analyzed with the equivalent lateral force or modal response spectrum procedure, and the lower portion is analyzed with the equivalent lateral force procedure.

12.2.3.3 R, C_d, and Ω_0 Values for Horizontal Combinations. The value of the response modification coefficient, R, used for design in the direction under consideration shall not be greater than the least value of R for any of the systems used in that direction. The deflection amplification factor, C_d, and the overstrength factor, Ω_0, shall be consistent with R required in that direction.

EXCEPTION: 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) Risk Category I or II building, (2) two stories or fewer above grade plane, 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 of R for any of the systems used in that same direction.

12.2.4 Combination Framing Detailing Requirements. Structural members common to different framing systems used to resist seismic forces 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% 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 required axial strength of individual cantilever column elements, considering only the load combinations that include seismic load effects, shall not exceed 15% of the available axial strength, including slenderness effects.

Foundation and other elements used to provide overturning resistance at the base of cantilever column elements shall be designed to resist the seismic load effects, including overstrength of Section 12.4.3.

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 Structural Height Limit for Steel Eccentrically Braced Frames, Steel Special Concentrically Braced Frames, Steel Buckling-Restrained Braced Frames, Steel Special Plate Shear Walls, and Special Reinforced Concrete Shear Walls. The limits on structural height, h_n, 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, provided that the seismic force-resisting systems are limited to steel eccentrically braced frames, steel special concentrically braced frames, steel buckling-restrained braced frames, steel special plate shear walls, or special reinforced concrete cast-in-place shear walls and both of the following requirements are met:

1. The structure shall not have an extreme torsional irregularity as defined in Table 12.3-1 (horizontal structural irregularity Type 1b).
2. The steel eccentrically braced frames, steel special concentrically braced frames, steel buckling-restrained braced frames, steel special plate shear walls, or special reinforced cast-in-place concrete shear walls in any one plane shall resist no more than 60% 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, where a special moment frame is required by Table 12.2-1 because of the structural system limitations, the frame shall be continuous to the base.

A special moment frame that is used but not required by Table 12.2-1 is permitted to be discontinued above the base and supported by a more rigid system with a lower response modification coefficient, R, provided that the requirements of Sections 12.2.3.1 and 12.3.3.4 are met.

12.2.5.6 Steel Ordinary Moment Frames

12.2.5.6.1 Seismic Design Category D or E

a. Single-story steel ordinary moment frames in structures assigned to Seismic Design Category D or E are permitted up to a structural height, h_n, 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 load of the exterior walls more than 35 ft (10.6 m) above the base tributary to the moment frames shall not exceed 20 psf (0.96 kN/m^2).

   EXCEPTION: Single-story structures with steel ordinary moment frames whose purpose is to enclose equipment or machinery and whose occupants are engaged in maintenance or monitoring of that equipment, machinery, or their associated processes shall be permitted to be of unlimited height where the sum of the dead and equipment loads supported by and tributary to the roof does not exceed 20 psf (0.96 kN/m^2). In addition, the dead load of the exterior wall system, including exterior columns more than 35 ft (10.6 m) above the base, shall not exceed 20 psf (0.96 kN/m^2). For determining compliance with the exterior wall or roof load limits, the weight of equipment or machinery, including cranes, not self-supporting for all loads shall be assumed to be fully tributary to the area of the adjacent exterior wall or roof not to exceed 600 ft^2 (55.8 m^2), regardless of its height above the base of the structure.

b. Steel ordinary moment frames in structures assigned to Seismic Design Category D or E not meeting the limitations set forth in Section 12.2.5.6.1.a are permitted within light-frame construction up to a structural height, h_n, of 35 ft (10.6 m) where neither the roof dead load nor the dead load of any floor above the base 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 frames shall not exceed 20 psf (0.96 kN/m^2).

CHAPTER E

MOMENT-FRAME SYSTEMS

This chapter provides the basis of design, the requirements for analysis, and the requirements for the system, members and connections for steel moment-frame systems.

The chapter is organized as follows:

User Note: The requirements of this chapter are in addition to those required by the *Specification* and the applicable building code.

E1. ORDINARY MOMENT FRAMES (OMF)

1. Scope

Ordinary moment frames (OMF) of structural steel shall be designed in conformance with this section.

2. Basis of Design

OMF designed in accordance with these provisions are expected to provide minimal inelastic deformation capacity in their members and connections.

3. Analysis

There are no requirements specific to this system.

4. System Requirements

There are no requirements specific to this system.

5. Members

5a. Basic Requirements

There are no limitations on width-to-thickness ratios of members for OMF beyond those in the *Specification*. There are no requirements for stability bracing of beams or joints in OMF, beyond those in the *Specification*. Structural steel beams in OMF are permitted to be composite with a reinforced concrete slab to resist gravity loads.

5b. Protected Zones

There are no designated protected zones for OMF members.

6. Connections

Beam-to-column connections are permitted to be fully restrained (FR) or partially restrained (PR) moment connections in accordance with this section.

6a. Demand Critical Welds

Complete-joint-penetration (CJP) groove welds of beam flanges to columns are demand critical welds, and shall satisfy the requirements of Sections A3.4b and I2.3.

6b. FR Moment Connections

FR moment connections that are part of the seismic force-resisting system (SFRS) shall satisfy at least one of the following requirements:

(a) FR moment connections shall be designed for a required flexural strength that is equal to the expected beam flexural strength, $R_y M_p$, multiplied by 1.1 and divided by α_s, where α_s = LRFD-ASD force level adjustment factor = 1.0 for LRFD and 1.5 for ASD.

The required shear strength of the connection, V_u or V_a, as applicable, shall be determined using the capacity-limited seismic load effect. The capacity-limited horizontal seismic load effect, E_{cl}, shall be determined as follows:

$$E_{cl} = 2(1.1 R_y M_p)/L_{cf} \tag{E1-1}$$

where

L_{cf} = clear length of beam, in. (mm)
M_p = plastic bending moment, kip-in. (N-mm)
R_y = ratio of expected yield stress to the specified minimum yield stress, F_y

(b) FR moment connections shall be designed for a required flexural strength and a required shear strength equal to the maximum moment and corresponding shear that can be transferred to the connection by the system, including the effects of material overstrength and strain hardening.

User Note: Factors that may limit the maximum moment and corresponding shear that can be transferred to the connection include column yielding, panel zone yielding, the development of the flexural strength of the beam at some distance away from the connection when web tapered members are used, and others. Further discussion is provided in the commentary.

(c) FR moment connections between wide-flange beams and the flange of wide-flange columns shall either satisfy the requirements of Section E2.6 or E3.6, or shall meet the following requirements:

of panel zone yielding, the forces at the connection can be computed assuming the shear force in the panel zone is $1.1R_y/\alpha_s$ times the nominal shear strength given by Equations J10-11 and J10-12 in the *Specification*. For frames with web-tapered members, as typically used in metal building systems, the flexural strength of the beam (rafter) or column will typically be first reached at some distance away from the connection. For such a case, the connection can be designed for the forces that will be generated when the flexural strength of a member is first reached anywhere along the length of the member. The flexural strength of the member may be controlled by local buckling or lateral-torsional buckling, and can be estimated using equations for the nominal flexural strength, M_n, in *Specification* Chapter F. However, lower-bound methods of determining M_n are not appropriate, and engineers should endeavor to establish a reasonable upper bound by considering items that contribute to the stability of the beam, even those that are typically ignored for design of the beam because they are difficult to quantify, not always present, etc. In particular, it is not appropriate to use $C_b = 1.0$. A realistic value of C_b should be used. Additionally, the stabilizing effects of the deck restraining the beam both laterally and torsionally should be included in determining this upper bound. M_p may always be used as the upper bound.

(c) The third option for beam-to-column connections is a prescriptive option for cases where a wide flange beam is connected to the flange of a wide flange column. The prescriptive connection specified in the section is similar to the welded unreinforced flange-bolted web (WUF-B) connection described in FEMA 350 (FEMA, 2000a). Some of the key features of this connection include the treatment of the complete-joint-penetration (CJP) beam flange-to-column welds as demand critical, treatment of backing bars and weld tabs using the same requirements as for SMF connections, and the use of special weld access hole geometry and quality requirements. Testing has shown that connections satisfying these requirements can develop moderate levels of ductility in the beam or panel zone prior to connection failure (Han et al., 2007).

Option (c) also permits the use of any connection in OMF that is permitted in IMF or SMF systems. Thus, any of the prequalified IMF or SMF connections in ANSI/AISC 358 can be used in OMF. However, when using ANSI/AISC 358 connections in an OMF, items specified in ANSI/AISC 358 that are not otherwise required in OMF systems are not required. For example, the WUF-W connection prequalified in ANSI/AISC 358 can be used for an OMF connection. However, items specified in ANSI/AISC 358 that would not be required when a WUF-W connection is used in an OMF include beam and column width-to-thickness limitations for IMF and SMF, beam stability bracing requirements for IMF or SMF, beam-column moment ratio requirements for SMF, column panel zone shear strength requirements for IMF or SMF, or requirements for a protected zone. None of these items are required for OMF, and therefore are not required when the WUF-W connection is used in an OMF. Similar comments apply to all connections prequalified in ANSI/AISC 358.