

by nonbuilding structures shall be designed in accordance with Chapter 13 of this standard.

15.4 STRUCTURAL DESIGN REQUIREMENTS

15.4.1 Design Basis. Nonbuilding structures having specific seismic design criteria established in reference documents shall be designed using the standards as amended herein. Where reference documents are not cited herein, nonbuilding structures shall be designed in compliance with Sections 15.5 and 15.6 to resist minimum seismic lateral forces that are not less than the requirements of Section 12.8 with the following additions and exceptions:

1. The seismic force-resisting system shall be selected as follows:
 - a. For nonbuilding structures similar to buildings, a system shall be selected from among the types indicated in Table 12.2-1 or Table 15.4-1 subject to the system limitations and height limits, based on the seismic design category indicated in the table. The appropriate values of R , Ω_0 , and C_d indicated in Table 15.4-1 shall be used in determining the base shear, element design forces, and design story drift as indicated in this standard. Design and detailing requirements shall comply with the sections referenced in Table 15.4-1.
 - b. For nonbuilding structures not similar to buildings, a system shall be selected from among the types indicated in Table 15.4-2 subject to the system limitations and height limits, based on seismic design category indicated in the table. The appropriate values of R , Ω_0 , and C_d indicated in Table 15.4-2 shall be used in determining the base shear, element design forces, and design story drift as indicated in this standard. Design and detailing

requirements shall comply with the sections referenced in Table 15.4-2.

- c. Where neither Table 15.4-1 nor Table 15.4-2 contains an appropriate entry, applicable strength and other design criteria shall be obtained from a reference document that is applicable to the specific type of nonbuilding structure. Design and detailing requirements shall comply with the reference document.

2. For nonbuilding systems that have an R value provided in Table 15.4-2, the seismic response coefficient (C_s) shall not be taken less than

$$C_s = 0.03 \quad (15.4-1)$$

and for nonbuilding structures located where $S_1 \geq 0.6g$, C_s shall not be taken less than

$$C_s = \frac{0.8S_1}{\left(\frac{R}{T}\right)} \quad (15.4-2)$$

EXCEPTION: Tanks and vessels that are designed to AWWA D100, AWWA D103, API 650 Appendix E, and API 620 Appendix L as modified by this standard, shall be subject to the larger of the minimum base shear values defined by the reference document or the following equations:

$$C_s = 0.01 \quad (15.4-3)$$

and for nonbuilding structures located where $S_1 \geq 0.6g$, C_s shall not be taken less than

$$C_s = \frac{0.5S_1}{\left(\frac{R}{T}\right)} \quad (15.4-4)$$

Minimum base shear requirements need not apply to the convective (sloshing) component of liquid in tanks.

3. The importance factor, I , shall be as set forth in Section 15.4.1.1.

TABLE 15.4-1 SEISMIC COEFFICIENTS FOR NONBUILDING STRUCTURES SIMILAR TO BUILDINGS

Nonbuilding Structure Type	Detailing Requirements	R	Ω_0	C_d	STRUCTURAL SYSTEM AND HEIGHT LIMITS (ft) ^{a,e}				
					A & B	C	D	E	F
Steel storage racks	15.5.3	4	2	3.5	NL	NL	NL	NL	NL
Building frame systems:									
Special steel concentrically braced frames	AISC 341	6	2	5	NL	NL	160	160	100
Ordinary steel concentrically braced frame	AISC 341	3 ^{1/4}	2	3 ^{1/4}	NL	NL	35 ^b	35 ^b	NP ^b
With permitted height increase	AISC 341	2 ^{1/2}	2	2 ^{1/2}	NL	NL	160	160	100
With unlimited height	AISC 360	1.5	1	1.5	NL	NL	NL	NL	NL
Moment-resisting frame systems:									
Special steel moment frames	AISC 341	8	3	5.5	NL	NL	NL	NL	NL
Special reinforced concrete moment frames	14.2.2.6 & ACI 318, including Chapter 21	8	3	5.5	NL	NL	NL	NL	NL
Intermediate steel moment frames	AISC 341	4.5	3	4	NL	NL	35 ^{c,d}	NP ^{c,d}	NP ^{c,d}
With permitted height increase	AISC 341	2.5	2	2.5	NL	NL	160	160	100
With unlimited height	AISC 341	1.5	1	1.5	NL	NL	NL	NL	NL
Intermediate reinforced concrete moment frames	ACI 318, including Chapter 21	5	3	4.5	NL	NL	NP	NP	NP
With permitted height increase	ACI 318, including Chapter 21	3	2	2.5	NL	NL	50	50	50
With unlimited height	ACI 318, including Chapter 21	0.8	1	1	NL	NL	NL	NL	NL
Ordinary moment frames of steel	AISC 341	3.5	3	3	NL	NL	NP ^{c,d}	NP ^{c,d}	NP ^{c,d}
With permitted height increase	AISC 341	2.5	2	2.5	NL	NL	100	100	NP ^{c,d}
With unlimited height	AISC 360	1	1	1	NL	NL	NL	NL	NL
Ordinary reinforced concrete moment frames	ACI 318, excluding Chapter 21	3	3	2.5	NL	NP	NP	NP	NP
With permitted height increase	ACI 318, excluding Chapter 21	0.8	1	1	NL	NL	50	50	50

^aNL = no limit and NP = not permitted. Height shall be measured from the base.

^bSteel ordinary braced frames are permitted in pipe racks up to 65 ft (20 m).

^cSteel ordinary moment frames and intermediate moment frames are permitted in pipe racks up to a height of 65 ft (20 m) where the moment joints of field connections are constructed of bolted end plates.

^dSteel ordinary moment frames and intermediate moment frames are permitted in pipe racks up to a height of 35 ft (11 m).

^eFor the purpose of height limit determination, the height of the structure shall be taken as the height to the top of the structural frame making up the primary seismic-force resisting system.

TABLE 15.4-2 SEISMIC COEFFICIENTS FOR NONBUILDING STRUCTURES NOT SIMILAR TO BUILDINGS

Nonbuilding Structure Type	Detailing Requirements ^c	R	Ω_0	C_d	STRUCTURAL SYSTEM AND HEIGHT LIMITS (ft.) ^{a,d}				
					A & B	C	D	E	F
Elevated tanks, vessels, bins, or hoppers:									
On symmetrically braced legs (not similar to buildings)	15.7.10	3	2 ^b	2.5	NL	NL	160	100	100
On unbraced legs or asymmetrically braced legs (not similar to buildings)	15.7.10	2	2 ^b	2.5	NL	NL	100	60	60
Single pedestal or skirt supported									
- welded steel	15.7.10	2	2 ^b	2	NL	NL	NL	NL	NL
- welded steel with special detailing	15.7.10 and 15.7.10.5 a and b.	3	2 ^b	2	NL	NL	NL	NL	NL
- prestressed or reinforced concrete	15.7.10	2	2 ^b	2	NL	NL	NL	NL	NL
- prestressed or reinforced concrete with special detailing	15.7.10 and 14.2.3.6	3	2 ^b	2	NL	NL	NL	NL	NL
Horizontal, saddle supported welded steel vessels	15.7.14	3	2 ^b	2.5	NL	NL	NL	NL	NL
Tanks or vessels supported on structural towers similar to buildings	15.5.5	Use values for the appropriate structure type in the categories for building frame systems and moment resisting frame systems listed in Table 15.4-1.							
Flat-bottom ground-supported tanks:	15.7								
Steel or fiber-reinforced plastic:									
Mechanically anchored		3	2 ^b	2.5	NL	NL	NL	NL	NL
Self-anchored		2.5	2 ^b	2	NL	NL	NL	NL	NL
Reinforced or prestressed concrete:									
reinforced nonsliding base		2	2 ^b	2	NL	NL	NL	NL	NL
anchored flexible base		3.25	2 ^b	2	NL	NL	NL	NL	NL
unanchored and unconstrained flexible base		1.5	1.5 ^b	1.5	NL	NL	NL	NL	NL
All other		1.5	1.5 ^b	1.5	NL	NL	NL	NL	NL
Cast-in-place concrete silos, stacks, and chimneys having walls continuous to the foundation	15.6.2	3	1.75	3	NL	NL	NL	NL	NL
All other reinforced masonry structures not similar to buildings	14.4.1	3	2	2.5	NL	NL	NL	50	50
All other nonreinforced masonry structures not similar to buildings	14.4.1	1.25	2	1.5	NL	NL	50	50	50
All other steel and reinforced concrete distributed mass cantilever structures not covered herein including stacks, chimneys, silos, and skirt-supported vertical vessels that are not similar to buildings	15.6.2 15.7.10 and 15.7.10.5 a and b.	3	2	2.5	NL	NL	NL	NL	NL
Trussed towers (freestanding or guyed), guyed stacks and chimneys	15.6.2	3	2	2.5	NL	NL	NL	NL	NL
Cooling towers									
Concrete or steel		3.5	1.75	3	NL	NL	NL	NL	NL
Wood frames		3.5	3	3	NL	NL	NL	50	50
Telecommunication towers	15.6.6								
Truss: Steel		3	1.5	3	NL	NL	NL	NL	NL
Pole: Steel		1.5	1.5	1.5	NL	NL	NL	NL	NL
Wood		1.5	1.5	1.5	NL	NL	NL	NL	NL
Concrete		1.5	1.5	1.5	NL	NL	NL	NL	NL
Frame: Steel		3	1.5	1.5	NL	NL	NL	NL	NL
Wood		1.5	1.5	1.5	NL	NL	NL	NL	NL
Concrete		2	1.5	1.5	NL	NL	NL	NL	NL
Amusement structures and monuments	15.6.3	2	2	2	NL	NL	NL	NL	NL
Inverted pendulum type structures (except elevated tanks, vessels, bins, and hoppers)	12.2.5.3	2	2	2	NL	NL	NL	NL	NL
Signs and billboards		3.5	1.75	3	NL	NL	NL	NL	NL
All other self-supporting structures, tanks, or vessels not covered above or by reference standards that are similar to buildings		1.25	2	2.5	NL	NL	50	50	50

^aNL = no limit and NP = not permitted. Heights shall be measured from the base.

^bSee Section 15.7.3a for the application of the overstrength factors, Ω_0 , for tank and vessels.

^cIf a section is not indicated in the Detailing Requirements column, no specific detailing requirements apply.

^dFor the purpose of height limit determination, the height of the structure shall be taken as the height to the top of the structural frame making up the primary seismic force-resisting system.

4. The vertical distribution of the lateral seismic forces in nonbuilding structures covered by this section shall be determined:

- Using the requirements of Section 12.8.3, or
- Using the procedures of Section 12.9, or
- In accordance with reference document applicable to the specific nonbuilding structure.

5. For nonbuilding structural systems containing liquids, gases, and granular solids supported at the base as defined

in Section 15.7.1, the minimum seismic design force shall not be less than that required by the reference document for the specific system.

6. Where a reference document provides a basis for the earthquake resistant design of a particular type of nonbuilding structure covered by Chapter 15, such a standard shall not be used unless the following limitations are met:

- The seismic ground accelerations, and seismic coefficients, shall be in conformance with the requirements of Section 11.4.