

5.2 Load Combinations

IBC §1605

General

IBC §1605.1

Buildings (and other structures) and portions thereof shall be designed to resist the:

- *Strength Design* (SD/LRFD) load combinations specified in *ASCE 7-22 – §2.3*, or
- *Allowable Stress Design* (ASD) load combinations specified in *ASCE 7-22 – §2.4*, or
- *Alternative Allowable Stress Design* (ASD) load combinations of *IBC – §1605.2*

NOTE: See *IBC – §1605.1 - Exceptions 1, 2, 3 & 4*.

Load combinations are a way of considering the maximum (or minimum) forces on a structural element considering the combined effects of gravity loads (e.g., dead load, floor live load, roof live load, rain load, snow load) and other load effects as a result of earthquake, wind, flood, earth pressure, fluid pressure, etc.

Notations –

D = Dead load

E = Combined effect of *horizontal* and *vertical* earthquake induced forces as defined in *ASCE 7-22 – §12.4.2*

F = Load due to fluids with well-defined pressures and maximum heights

F_a = Flood load, determined in accordance with *ASCE 7-22 – Chapter 5*

H = Load due to lateral earth pressures, ground water pressure, or pressure of bulk materials

L = Live load (other than roof)

L_r = Roof live load

R = Rain load

S = Snow load

T = Cumulative effect of self-straining load forces and effects (e.g., contraction or expansion resulting from temperature change, shrinkage, moisture change, creep in component materials, movement due to differential settlement or combinations thereof)

W = Wind load

W_T = Tornado load, determined in accordance with *ASCE 7-22 – Chapter 32*

Load Combinations for Strength Design

ASCE 7 – §2.3

All applicable basic *Strength Design* (SD/LRFD) load combinations must be considered since the most critical load effect may occur when one or more of the contributing loads (e.g., D , E , L , L_r , S) are not acting.

- | | |
|--|------------------------|
| ➤ $1.4D$ | <i>ASCE 7 (2.3-1a)</i> |
| ➤ $1.2D + 1.6L + (0.5L_r \text{ or } 0.3S \text{ or } 0.5R)$ | <i>ASCE 7 (2.3-2a)</i> |
| ➤ $1.2D + (1.6L_r \text{ or } 1.0S \text{ or } 1.6R) + (L \text{ or } 0.5W)$ | <i>ASCE 7 (2.3-3a)</i> |
| ➤ $1.2D + 1.0(W \text{ or } W_T) + L + (0.5L_r \text{ or } 0.3S \text{ or } 0.5R)$ | <i>ASCE 7 (2.3-4a)</i> |
| ➤ $0.9D + 1.0(W \text{ or } W_T)$ | <i>ASCE 7 (2.3-5a)</i> |

SD/LRFD Load Combinations with Seismic Load Effects**ASCE 7 – §2.3.6**

When a structure is subject to seismic load effects, the following load combinations shall be considered in addition to the basic SD/LRFD load combinations of ASCE 7 – §2.3.1:

$$\triangleright 1.2 D + E_v + E_h + L + 0.15 S \quad \text{ASCE 7 (2.3-6)}$$

$$\text{or ... } (1.2 + 0.2 S_{DS}) D + \rho Q_E + L + 0.15 S$$

$$\triangleright 0.9 D - E_v + E_h \quad \text{ASCE 7 (2.3-7)}$$

$$\text{or ... } (0.9 - 0.2 S_{DS}) D - \rho Q_E$$

NOTE: See ASCE 7-22 – §2.3.6 - *Exception 1 & 2* for additional requirements on the equations above (e.g., use of $0.5 L$ in ASCE 7 (2.3-6) where $L_0 \leq 100$ psf with the exception of garages or areas occupied as places of public assembly, etc.).

Load Combinations for Allowable Stress Design**ASCE 7 – §2.4**

All applicable *Allowable Stress Design* (ASD) load combinations must be considered since the most critical load effect may occur when one or more of the contributing loads (e.g., D , E , L , L_r , S) are not acting.

$$\triangleright D \quad \text{ASCE 7 (2.4-1a)}$$

$$\triangleright D + L \quad \text{ASCE 7 (2.4-2a)}$$

$$\triangleright D + (L_r \text{ or } 0.7 S \text{ or } R) \quad \text{ASCE 7 (2.4-3a)}$$

$$\triangleright D + 0.75 L + 0.75 (L_r \text{ or } 0.7 S \text{ or } R) \quad \text{ASCE 7 (2.4-4a)}$$

$$\triangleright D + 0.6 (W \text{ or } W_T) \quad \text{ASCE 7 (2.4-5a)}$$

$$\triangleright D + 0.75 L + 0.75 (0.6 (W \text{ or } W_T)) + 0.75 (L_r \text{ or } 0.7 S \text{ or } R) \quad \text{ASCE 7 (2.4-6a)}$$

$$\triangleright 0.6 D + 0.6 (W \text{ or } W_T) \quad \text{ASCE 7 (2.4-7a)}$$

ASD Load Combinations with Seismic Load Effects**ASCE 7 – §2.4.5**

When a structure is subject to seismic load effects, the following load combinations shall be considered in addition to the basic ASD load combinations of ASCE 7 – §2.4.1:

$$\triangleright 1.0 D + 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-8)}$$

$$\text{or ... } (1.0 + 0.14 S_{DS}) D + 0.7 \rho Q_E$$

$$\triangleright 1.0 D + 0.525 E_v + 0.525 E_h + 0.75 L + 0.1 S \quad \text{ASCE 7 (2.4-9)}$$

$$\text{or ... } (1.0 + 0.105 S_{DS}) D + 0.525 \rho Q_E + 0.75 L + 0.1 S$$

$$\triangleright 0.6 D - 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-10)}$$

$$\text{or ... } (0.6 - 0.14 S_{DS}) D - 0.7 \rho Q_E$$

NOTE: See ASCE 7-22 – §2.4.5 – *Exceptions 1 & 2* for additional requirements on the equations above (e.g., S in ASCE 7 (2.4-9), $0.9D$ in lieu of $0.6D$ in ASCE 7 (2.4-10) for special masonry shear walls, etc.).

➤ **Diagonal Brace A**

$$D = 0$$

$$L_r = 0$$

$$Q_E = \pm 33 \text{ kips}$$

$$E_h = 1.3 Q_E = 1.3 (\pm 33 \text{ kips}) = \pm 42.9 \text{ kips}$$

$$E_v = 0.13 D = 0.13 (0) = 0$$

Column B

$$D = 50 \text{ kips}$$

$$L_r = 12 \text{ kips}$$

$$Q_E = \pm 17 \text{ kips}$$

$$E_h = 1.3 Q_E = 1.3 (\pm 17 \text{ kips}) = \pm 22.1 \text{ kips}$$

$$E_v = 0.13 D = 0.13 (50 \text{ kips}) = 6.5 \text{ kips}$$

A.) STRENGTH DESIGN (SD/LRFD) BASIC LOAD COMBINATIONS:**1. Maximum Axial Force in Brace A**

By inspection - since there are no gravity load effects in the brace, *ASCE 7 (2.3-1a)* through *(2.3-5a)* will not govern and only the basic load combinations with seismic load effects need to be calculated.

$$1.2D + E_v + E_h + L + 0.15S \quad \text{ASCE 7 (2.3-6)}$$

$$1.2(0) + 0 + 42.9 \text{ kips} + 0 + 0.15(0) = +42.9 \text{ kips} \text{ (compression)}$$

$$0.9D - E_v + E_h \quad \text{ASCE 7 (2.3-7)}$$

$$1.2(0) - 0 + (-42.9 \text{ kips}) = -42.9 \text{ kips} \text{ (tension)}$$

$$\therefore \text{Maximum SD/LRFD axial force, } P = \boxed{\pm 42.9 \text{ kips}} \text{ compression or tension}$$

2. Maximum Axial Force in Column B

By inspection - since there are only dead load (D) and roof live load (L_r) gravity load effects in the column, *ASCE 7 (2.3-1a)* & *(2.3-3a)* will be calculated in addition to basic load combination with seismic load effects *ASCE 7 (2.3-6)* to determine the maximum axial force in the column.

$$1.4D \quad \text{ASCE 7 (2.3-1a)}$$

$$1.4(50 \text{ kips}) = +70.0 \text{ kips} \text{ (compression)}$$

$$1.2D + (1.6L_r \text{ or } 1.0S \text{ or } 1.6R) + (L \text{ or } 0.5W) \quad \text{ASCE 7 (2.3-3a)}$$

$$1.2(50 \text{ kips}) + 1.6(12 \text{ kips}) + (0) = +79.2 \text{ kips} \text{ (compression)}$$

$$1.2D + E_v + E_h + L + 0.15S \quad \text{ASCE 7 (2.3-6)}$$

$$1.2(50) + 6.5 \text{ kips} + 22.1 \text{ kips} + 0 + 0.15(0) = +88.6 \text{ kips} \text{ (compression)}$$

$$\therefore \text{Maximum SD/LRFD axial force, } P = \boxed{+88.6 \text{ kips}} \text{ compression}$$

3. Minimum Axial Force in Column B

By inspection - *ASCE 7 (2.3-1a)* through *(2.3-5a)* will not govern and the minimum axial force in the column will be governed by basic load combination with seismic load effects *ASCE 7 (2.3-7)*.

$$0.9D - E_v + E_h \quad \text{ASCE 7 (2.3-7)}$$

$$0.9(50) - 6.5 \text{ kips} + (-22.1 \text{ kips}) = +16.4 \text{ kips} \text{ (compression)}$$

$$\therefore \text{Minimum SD/LRFD axial force, } P = \boxed{+16.4 \text{ kips}} \text{ compression}$$

NOTE: Typically all SD basic load combination equations need to be checked (i.e., *ASCE 7 (2.3-1a)* to (2.3-7)) for structural members resisting gravity loads and seismic forces because sometimes a gravity load combination equation may govern over those with seismic load effects.

B.) ALLOWABLE STRESS DESIGN (ASD) BASIC LOAD COMBINATIONS:

1. Maximum Axial Force in Brace A

By inspection - since there are no gravity load effects in the brace, *ASCE 7 (2.4-1a)* through (2.4-7a) will not govern and only the basic load combinations with seismic load effects need to be calculated.

$$1.0 D + 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-8)}$$

$$1.0 (0) + 0.7 (0) + 0.7 (42.9 \text{ kips}) = + 30.0 \text{ kips (compression)}$$

$$1.0 D + 0.525 E_v + 0.525 E_h + 0.75 L + 0.1 S \quad \text{ASCE 7 (2.4-9)}$$

$$1.0 (0) + 0.525 (0) + 0.525 (42.9 \text{ kips}) + 0.75 (0) + 0.1 (0) = + 22.5 \text{ kips (compression)}$$

$$0.6 D - 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-10)}$$

$$0.6 (0) - 0.7 (0) + 0.7 (-42.9 \text{ kips}) = - 30.0 \text{ kips (tension)}$$

∴ Maximum ASD axial force, $P = \boxed{\pm 30.0 \text{ kips}}$ compression or tension

2. Maximum Axial Force in Column B

By inspection - since there are only dead load (D) and roof live load (L_r) gravity load effects in the column, *ASCE 7 (2.4-3a)* will be calculated in addition to basic load combination with seismic load effects *ASCE 7 (2.4-8)* & *ASCE 7 (2.4-9)* to determine the maximum axial force in the column.

$$D + (L_r \text{ or } 0.7 S \text{ or } R) \quad \text{ASCE 7 (2.4-3a)}$$

$$50 \text{ kips} + 12 \text{ kips} = + 62.0 \text{ kips (compression)}$$

$$1.0 D + 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-8)}$$

$$1.0 (50 \text{ kips}) + 0.7 (6.5 \text{ kips}) + 0.7 (22.1 \text{ kips}) = + 70.0 \text{ kips (compression)}$$

$$1.0 D + 0.525 E_v + 0.525 E_h + 0.75 L + 0.1 S \quad \text{ASCE 7 (2.4-9)}$$

$$1.0 (50 \text{ kips}) + 0.525 (6.5 \text{ kips}) + 0.525 (22.1 \text{ kips}) + 0.75 (0) + 0.1 (0) = + 65.0 \text{ kips (compression)}$$

∴ Maximum ASD axial force, $P = \boxed{+ 70.0 \text{ kips}}$ compression

3. Minimum Axial Force in Column B

By inspection - *ASCE 7 (2.4-1a)* through (2.4-7a) will not govern and the minimum axial force in the column will be governed by basic load combination with seismic load effects *ASCE 7 (2.4-10)*.

$$0.6 D - 0.7 E_v + 0.7 E_h \quad \text{ASCE 7 (2.4-10)}$$

$$0.6 (50 \text{ kips}) - 0.7 (6.5 \text{ kips}) + 0.7 (-22.1 \text{ kips}) = + 10.0 \text{ kips (compression)}$$

∴ Minimum ASD axial force, $P = \boxed{+ 10.0 \text{ kips}}$ compression

NOTE: Typically all ASD basic load combination equations need to be checked (i.e., *ASCE 7 (2.4-1a)* to (2.4-10)) for structural members resisting gravity loads and seismic forces because sometimes a gravity load combination equation may govern over those with seismic load effects.