CHAPTER 3

LOADS

3.1 GENERAL

All structures must be designed to support their own weight along with any superimposed forces, such as the dead loads from other materials, live loads, wind pressures, seismic forces, snow and ice loads, and earth pressures. These vertical and lateral loads may be of short duration such as those from earthquakes, or they may be of longer duration, such as the dead loads of machinery and equipment. Proper design must consider all possible applied forces along with the interaction of these forces on the structure.

3.2 LOAD COMBINATIONS

Because various loads may act on a structure simultaneously, load combinations should be evaluated to determine the most severe conditions for design. These load combinations vary from one document to another, depending upon the jurisdiction. There are a set of combinations for the allowable stress design and another set that incorporates load factors for strength design. Paragraphs below provide these load combinations.

The 2012 IBC has three sets of load combinations. Section 1605.2 provides the load combinations for strength design and Section 1605.3 provides two sets of load combinations for allowable stress design. The strength design load combinations and the first set of allowable stress design load combinations, found in Section 1605.3.1, are labeled as the “basic load combinations”. These basic load combinations align closely with the load combinations found in ASCE 7. The second set of allowable stress design load combinations, found in Section 1605.3.2, is labeled as the “alternative basic load combinations”. The alternative load combinations used to be important to masonry designers as using these load combinations allowed increases in allowable stresses for load combinations including wind or seismic loads. Since the 2011 MSJC Code no longer permits allowable stresses to be increased, the alternative combinations are less important.

The selection of the load combinations to be used for design is largely a matter of personal preference. With the recalibration of the allowable stress design provisions in the 2011 MSJC Code, the results obtained using those provisions are more comparable to those obtained using strength design. In addition, the design provisions themselves are becoming more similar over time. For example, the anchor bolt and shear design provisions are now the same between the two design methodologies, just with different factors for allowable stress design and strength design.

Lastly, it should be noted that the earthquake load, E, in the load cases discussed below includes both a vertical and horizontal component. The vertical seismic component is typically accounted for by adjusting the factor on the dead loads. The vertical seismic load is discussed in Section 3.9.4.1 of this chapter.

3.2.1 ALLOWABLE STRESS DESIGN LOAD COMBINATIONS

The goal of allowable stress design is to proportion the structure so that it can resist the loads that are expected to occur during the life of the structure while maintaining a factor of safety against inelastic behavior. For reinforced masonry, cracking of the masonry under tension is allowed because the masonry is not relied upon to resist tension. While each one of the loads may be expected to occur during the life of the structure, it is less likely that these loads will occur simultaneously. The load combinations below have been determined to account for the likelihood of the various loads occurring simultaneously.

The "Basic load combinations" for allowable stress design (working stress design) are given in 2012 IBC Section 1605.3.1 as follows:

1. Dead load plus lateral fluid pressures, [$D + F$],
2. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus live load, [$D + H + F + L$],
3. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus either roof live load, or snow load, or rain load, [$D + H + F + (L_r$ or S or $R)$],
4. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus 0.75 times live load plus 0.75 times either roof live load, or snow load, or rain load [$D + H + F + 0.75(L) + 0.75(L_r$ or S or $R)$],
5. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus (0.6 times wind load or 0.7 times earthquake load) [$D + H + F + (0.6W$ or $0.7E)$],
6. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus 0.75 times (0.6 times wind load or 0.7 times earthquake load) plus 0.75 times live load plus 0.75 times (either roof live load or snow load, or rain load) [$D + H + F + 0.75(0.6W$ or $0.7E) + 0.75L + 0.75(L_r$ or S or $R)$],
7. 0.6 times dead load plus 0.6 times wind load plus hydrostatic lateral soil [$0.6D + 0.6W + H$],
8. 0.6 times (dead load plus lateral fluid pressures) plus 0.7 times earthquake load plus hydrostatic lateral soil [$0.6(D + F) + 0.7E + H$],

Footnotes to the Basic load combinations:

- Include lateral earth pressures in the design where they result in a more critical combination.
- The IBC does not require crane hook loads to be combined with roof live loads nor with more than three fourths of the snow load or one-half of the wind load.
- For flat roof snow loads exceeding 30 psf, 20 percent of the snow load shall be combined with the seismic loads. Flat roof snow loads of 30 psf or less need not be combined with seismic loads.
- The floor live load should not be included if its inclusion would result in lower stresses for the structure or member being designed.
- Increases in allowable stresses shall not be used with the load combinations given in this section of the IBC.
- Multiply hydrostatic lateral soil pressures by 0.6 when they are permanent and they resist the primary variable load effects. If the hydrostatic lateral soil pressures are not permanent, do not consider that they provide any resistance to other load effects.
- In Load Combination 8 (IBC load combination 16-16), the dead load factor may be increased to 0.9 for special reinforced masonry shear walls.

The following "alternative basic load combinations", as given in IBC Section 1605.3.2, may be used in lieu of the basic load combinations given above for Section 1605.3.1.

1. Dead load plus live load plus either roof live load, snow load, or rain load, [$D + L + (L_r$ or S or $R)$],
2. Dead load plus live load plus 0.6 times the coefficient ω times the wind load, [$D + L + 0.6 \omega W$],
3. Dead load plus live load plus 0.6 times the coefficient ω times the wind load plus one-half times the snow load, [$D + L + 0.6 \omega W + S/2$],
4. Dead load plus live load plus snow load plus 0.6 times one-half coefficient ω times the wind load, [$D + L + S + 0.6 \omega W/2$],
5. Dead load plus live load plus snow load plus (1/1.4) times the earthquake load, [$D + L + S + E/1.4$],
6. 0.9 times the dead load plus (1/1.4) times the earthquake load, [$0.9D + E/1.4$],

Footnotes to the above combinations:

- Include lateral earth pressures in the design where they result in a more critical combination.

- The IBC does not require crane hook loads to be combined with roof live loads nor with more than three fourths of the snow load or one-half of the wind load.
- For flat roof snow loads exceeding 30 psf, 20 percent of the snow load shall be combined with the seismic loads. Flat roof snow loads of 30 psf or less need not be combined with seismic loads.
- When using these alternate basic load combinations that include wind or seismic loads, allowable stresses are permitted to be increased or load combinations reduced, where permitted by the IBC or by the referenced standard of IBC, provided that when wind loads are calculated by Chapters 26 through 31 of ASCE 7, the coefficient ω in the above equations shall be taken as 1.3. For other wind loads ω shall be taken as 1.0.
- If allowable stresses are not increased, the coefficient ω may be taken as 1.
- When these combinations are used for foundations for loads including seismic, the vertical seismic effect, E_V, in Equation 12.4-4 of ASCE 7 is permitted to be taken as zero.
- When these combinations are used to evaluate sliding, overturning, and soil bearing at the soil-structure interface, the reduction of foundation overturning from Section 12.13.4 of ASCE 7 shall not be used.
- For load combinations that include counteracting effects of dead and wind loads, only two-thirds of the minimum dead load that is likely to be in place during the designed wind event shall be used.

3.2.2 STRENGTH DESIGN LOAD COMBINATIONS

The goal of strength design is to proportion the structure so that it can resist rarely occurring loads without reaching a limit or failure state. “Rarely occurring” is understood to be a load that has about a 10% chance of occurring within the 50 year life of a typical structure. Since most of the loads prescribed by the building code are expected to occur during the life of the structure, these actual or specified code loads are increased by prescribed load factors to determine the rarely occurring, ultimate load for which failure is to be avoided. The load factors used in the strength design load combinations have been determined to account for the following:

- Deviations of the actual loads from the prescribed loads.
- Uncertainties in the analysis and distribution of forces that create the load effects.
- The probability that more than one extreme load effect will occur simultaneously.

The "Basic load combinations" for strength design are given in 2012 IBC Section 1605.2 as follows:

1. 1.4 times (dead load plus lateral fluid pressures), [$1.4(D + F)$],
2. 1.2 times (dead load plus lateral fluid pressures) plus 1.6 times (live load plus hydrostatic lateral soil) plus 0.5 times either roof live load, or snow load, or rain load, [$1.2(D + F) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R)$],
3. 1.2 times (dead load plus lateral fluid pressures) plus 1.6 times either roof live load, or snow load, or rain load plus 1.6 times the hydrostatic soil load plus either factor f_1 times the live load or 0.5 times the wind load, [$1.2(D + F) + 1.6(L_r \text{ or } S \text{ or } R) + 1.6H + (f_1L \text{ or } 0.5W$],
4. 1.2 times (dead load plus lateral fluid pressures) plus wind load plus factor f_1 times the live load plus 1.6 times the hydrostatic soil load plus 0.5 times either roof live load, or snow load, or rain load, [$1.2(D + F) + 1.0W + f_1L + 1.6H + 0.5(L_r \text{ or } S \text{ or } R)$],
5. 1.2 times (dead load plus lateral fluid pressures) plus earthquake load plus factor f_1 times the live load plus 1.6 times the hydrostatic soil load plus f_2 times the snow load, [$1.2(D + F) + 1.0E + f_1L + 1.6H + f_2S$],
6. 0.9 times (dead load plus lateral fluid pressure) plus wind load plus 1.6 times hydrostatic lateral soil [$0.9(D + F) + 1.0W + 1.6H$],
7. 0.9 times (dead load plus lateral fluid pressures) plus earthquake load plus 1.6 times hydrostatic lateral soil [$0.9(D + F) + 1.0E + 1.6H$],

Footnotes to the Basic load combinations:

- Include lateral earth pressures in the design where they result in a more critical combination.
- The floor live load should not be included if its inclusion would result in lower stresses for the structure or member being designed.
- For places of public assembly, areas with live loads in excess of 100 psf and in parking garages, the factor f_1 in the above equations shall be taken as 1. For other conditions, f_1 shall be taken as 0.5.
- For roof configurations that do not shed snow (such as saw tooth), the factor f_2 in the above equations shall be taken as 0.7. For other conditions, f_2 shall be taken as 0.2.

3.2.3 LOAD COMBINATIONS WITH SEISMIC OVERSTRENGTH FACTOR

The basic philosophy of seismic design in the IBC, ASCE 7 and the MSJC Code is to detail the structure so that it can deform and dissipate energy in a strong seismic event. This detailing is focused on creating structural “fuses” that can respond with ductility. These ductile fuses protect the rest of the structure from damage that could lead to the collapse of the structure. If, however, these fuses are stronger than expected, other structural elements could fail before the fuses. The requirements in the building code to consider overstrength in designing critical elements is intended to ensure that the critical elements are strong enough so that the fuses will fail first.

IBC Section 1605.1 references ASCE 7 Section 12.4.3 for the consideration of overstrength effects. This IBC section also identifies the situations where design for overstrength is required. For masonry structures, the following situations require design for overstrength:

- Elements supporting discontinuous walls (ASCE 7 Section 12.3.3.3). For example, if a masonry shear wall steps or shifts such that overturning is resisted by a column, the column must be designed considering overstrength.

- Diaphragm collector elements in Seismic Design Category C or higher (ASCE 7 Section 12.10.2.1). Collector elements are discussed in more detail in Chapter 4.

The overstrength provisions apply to both allowable stress design and strength design methods. Where allowable stress design is used, ASCE 7 Section 12.4.3.3 permits the allowable stresses to be increased by a factor of 1.2 when considering overstrength.

The earthquake effects including overstrength are represented in ASCE 7 by the term E_m. The determination of E_m is discussed in detail in Section 3.9.4.2 of this Chapter. IBC Section 1605.1 requires that ASCE 7 overstrength load combinations replace the seismic load combinations in the IBC as follows:

Allowable Stress Design – Basic Load Combinations with Overstrength

5. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus 0.7 times the overstrength earthquake load, [$D + H + F + 0.7E_m$],
6. Dead load plus hydrostatic lateral soil plus lateral fluid pressures plus 0.75 times (0.7 times the overstrength earthquake load) + 0.75 times live load + 0.75 times (either roof live load or snow load, or rain load) [$D + H + F + 0.75(0.7E_m) + 0.75L + 0.75(L_r$ or S or $R)$],
8. 0.6 times dead load plus 0.7 times the overstrength earthquake load plus hydrostatic lateral soil [$0.6D + 0.7E_m + H$],

Allowable Stress Design – Alternative Basic Load Combinations with Overstrength

5. Dead load plus live load plus snow load plus 0.7 times the overstrength earthquake load, [$D + L + S + 0.7E_m$],
6. 0.9 times dead load plus 0.7 times the overstrength earthquake load [$0.9D + 0.7E_m$],

Strength Design – Basic Load Combinations with Overstrength

5. 1.2 times (dead load plus lateral fluid pressures) plus the overstrength earthquake load plus factor f_1 times the live load plus 1.6 times the hydrostatic lateral soil plus factor f_2 times the snow load, [$1.2(D + F) + 1.0E_m + f_1L + 1.6\text{H} + f_2S$],
7. 0.9 times (dead load plus lateral fluid pressures) plus the overstrength earthquake load plus 1.6 times hydrostatic lateral soil [$0.9D + 1.0E_m + 1.6H$],

Note that factors f_1 and f_2 are discussed above.

3.3 DEAD LOADS

Dead loads are long term stationary forces which include the self-weight of the structure and the weights of permanent equipment and machinery. The actual weights of materials and construction can be used. The weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, heating, ventilating and air-conditioning systems (HVAC) and fire sprinkler system are included.

Since the actual weight cannot be explicitly determined by weighing a structure or a component of the structure, the dead loads are usually obtained by calculating the weights of the structural and permanently fixed non-structural elements, including building equipment and machinery. Permanently fixed non-structural elements include, as examples, the cladding, floor slab wearing surfaces, ceiling tiles and mechanical, electrical and plumbing distribution systems. The IBC explicitly states in Section 1607.5 that partitions whose locations are subject to change – for example typical office partitions – are to be treated as live load.

Tables GN-3a and GN-3b provide weights of masonry walls, consistent with other published industry sources.

3.4 LIVE LOADS

Live loads are short duration forces which are variable in magnitude and location. Examples of live load items include people, furniture, planters, non-stationary equipment and pianos, and moveable storage materials. While also of short duration, wind, rain, earthquake and snow loads are considered independently of live loads and are discussed later in this chapter.

Building codes provide live loads based on the use of the structure. For instance, office areas must be designed for 50 psf live loads (*L*), residences for 40 psf *L* and corridors for 100 psf *L*. Table 3.1 (from Table 1607.1 of the IBC) provides a more complete list of design live loads based on use.

TABLE 3.1 Minimum Uniformly Distributed Live Loads, L_o, and Minimum Concentrated Live Loads[7] (IBC Table 1607.1)

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs)
1. Apartments (see residential)	—	—
2. Access floor systems		
Office use	50	2,000
Computer use	100	2,000
3. Armories and drill rooms	150[13]	—
4. Assembly areas		—
Fixed seats (fastened to floor)	60[13]	
Follow spot, projections and control rooms	50	
Lobbies	100[13]	
Movable seats	100[13]	
Stage floors	150[13]	
Platforms (assembly)	100[13]	
Other assembly areas	100[13]	
5. Balconies and decks[8]	Same as occupancy served	—
6. Catwalks	40	300
7. Cornices	60	—
8. Corridors		—
First floor	100	
Other floors	Same as occupancy served except as indicated	
9. Dining rooms and restaurants	100[13]	—
10. Dwellings (see residential)	—	—
11. Elevator machine room grating (on area of 2 inches by 2 inches)	—	300
12. Finish light floor plate construction (on area of 1 inch by 1 inch)	—	200
13. Fire escapes	100	—
On single-family dwellings only	40	
14. Garages (passenger vehicles only)	40[13]	Note 1
Trucks and buses	See IBC Section 1607.7	