CHAPTER 5—LOADS

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5.1—Scope

5.1.1 This chapter shall apply to selection of load factors and combinations used in design, except as permitted in Chapter 27.

5.2—General

5.2.1 Loads shall include self-weight; applied loads; and effects of prestressing, earthquakes, restraint of volume change, and differential settlement.

5.2.2 Loads and Seismic Design Categories (SDCs) shall be in accordance with the general building code, or determined by the building official.

5.2.3 Live load reductions shall be permitted in accordance with the general building code or, in the absence of a general building code, in accordance with ASCE/SEI 7.

5.3—Load factors and combinations

5.3.1 Required strength U shall be at least equal to the effects of factored loads in Table 5.3.1, with exceptions and additions in 5.3.3 through 5.3.16.

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R5.1—Scope

R5.1.1 The loading provisions of this chapter are intended for the design of new structures and analytical strength evaluation of existing structures. Loads, load factors, and load combinations for evaluation of structures during construction are presented in ASCE/SEI 37.

R5.2—General

R5.2.1 The loading provisions in this chapter are associated with dead, live, wind, rain, snow, earthquake, lateral earth pressure, fluid, flood, ice, tornado, tsunami, water in soil, restraint of volume change and differential settlement loads such as those recommended in ASCE/SEI 7. The commentary to Appendix C of ASCE/SEI 7 provides service-level wind and snow loads for serviceability checks; however, these loads are not appropriate for strength design.

If the service loads specified by the general building code differ from those of ASCE/SEI 7, the general building code governs. However, if the nature of the loads contained in a general building code differs considerably from ASCE/SEI 7 loads, some provisions of the Code may need modification to reflect the difference.

ASCE/SEI 7 provides maps used to determine wind, snow, ice, seismic, and tornado loads for the United States and its territories. The loads for wind, snow, ice, seismic, and tornadoes are provided at the strength-level. If the Code is used in other locations, the design professional should confirm the loads used in design are strength-level loads.

R5.2.2 Seismic Design Categories (SDCs) in the Code are adopted directly from ASCE/SEI 7.

Design requirements for earthquake-resistant structures in the Code are determined by the SDC to which the structure is assigned. In general, the SDC relates to seismic hazard level, soil type, occupancy, and building use. Assignment of a building to an SDC is under the jurisdiction of the general building code rather than the Code.

In the absence of a general building code that prescribes SDC, it is the intent of Committee 318 that application of provisions for earthquake-resistant design be consistent with national standards or model building codes such as ASCE/SEI 7, IBC, and NFPA 5000.

R5.3—Load factors and combinations

R5.3.1 The required strength U is expressed in terms of factored loads. Factored loads are the loads specified in the general building code multiplied by appropriate load factors. If the load effects such as internal forces and moments are linearly related to the loads, the required strength U may be expressed in terms of load effects multiplied by the appropriate load factors with the identical result. If the load effects

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Table 5.3.1—Load combinations

Load combination	Equation	Primary load
$U = 1.4D$	(5.3.1a)	D
$U = 1.2D + 1.6L + (0.5L_r$ or $0.3S$ or $0.5R)$	(5.3.1b)	L
$U = 1.2D + (1.6L_r$ or $1.0S$ or $1.6R) + (1.0L$ or $0.5W)$	(5.3.1c)	L_r or S or R
$U = 1.2D + 1.0W + 1.0L + (0.5L_r$ or $0.3S$ or $0.5R)$	(5.3.1d)	W
$U = 1.2D + 1.0E + 1.0L + 0.15S$	(5.3.1e)	E
$U = 0.9D + 1.0W$	(5.3.1f)	W
$U = 0.9D + 1.0E$	(5.3.1g)	E

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are nonlinearly related to the loads, such as frame P-delta effects, the loads are factored before determining the load effects (Rogowsky and Wight 2010). Typical practice for foundation design is discussed in R13.2.6.1. Nonlinear finite element analysis using factored load cases is discussed in R6.9.3.

The factor assigned to each load is influenced by the degree of accuracy to which the load effect usually can be calculated and the variation that might be expected in the load during the lifetime of the structure. Dead loads, because they are more accurately determined and less variable, are assigned a lower load factor than live loads. Load factors also account for variability in the structural analysis used to calculate moments and shears.

The Code gives load factors for specific combinations of loads. In assigning factors to combinations of loading, some consideration is given to the probability of simultaneous occurrence. While most of the usual combinations of loadings are included, it should not be assumed that all cases are covered.

Due regard is to be given to the sign (positive or negative) in determining U for combinations of loadings, as one type of loading may produce effects of opposite sense to that produced by another type. The load combinations with $0.9D$ are included for the case where a higher dead load reduces the effects of other loads. The loading case may also be critical for tension-controlled column sections. In such a case, a reduction in compressive axial load or development of tension with or without an increase in moment may result in a critical load combination.

Consideration should be given to various combinations of loading to determine the most critical design condition. This is particularly true when strength is dependent on more than one load effect, such as strength for combined flexure and axial load or shear strength in members with axial load.

If unusual circumstances require greater reliance on the strength of particular members than circumstances encountered in usual practice, some reduction in the stipulated strength reduction factors ϕ or increase in the stipulated load factors may be appropriate for such members.

Rain load R in Eq. (5.3.1b), (5.3.1c), and (5.3.1d) should account for all likely accumulations of water. Roofs should be designed with sufficient slope or camber to ensure adequate drainage accounting for any long-term deflection of the roof due to the dead loads. If deflection of roof members may result in ponding of water accompanied by increased deflection and additional ponding, the design should ensure that this process is self-limiting.

Model building codes and standards refer to earthquake forces at the strength level, and the corresponding load factor is 1.0 (ASCE/SEI 7; 2021 IBC). In the absence of a general building code that prescribes strength level earthquake effects, a higher load factor on E would be required. The load effect E in model building codes and design load reference standards includes the effect of both horizontal and

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vertical ground motions (as E_h and E_v, respectively). The effect for vertical ground motions is applied as an addition to or subtraction from the dead load effect (D), and it applies to all structural elements, whether part of the seismic force-resisting system or not, unless specifically excluded by the general building code.

In ASCE/SEI 7-22, snow loads were changed to strength-level loads from the service-level loads that had been specified in prior versions of ASCE/SEI 7. The change from service to strength-level is reflected in the modifications in the load factor for snow loads in Table 5.3.1.

5.3.2 The effect of one or more loads not acting simultaneously shall be investigated.

5.3.3 The load factor on live load L in Eq. (5.3.1c), (5.3.1d), and (5.3.1e) shall be permitted to be reduced to 0.5 except for (a), (b), or (c):

(a) Garages
(b) Areas occupied as places of public assembly
(c) Areas where L is greater than 100 lb/ft^2

R5.3.3 The load modification factor in this provision is different than the live load reductions based on the loaded area that may be allowed in the general building code. The live load reduction, based on loaded area, adjusts the nominal live load (L_0 in ASCE/SEI 7) to L. The live load reduction, as specified in the general building code, can be used in combination with the 0.5 load factor specified in this provision.

5.3.4 If applicable, L shall include (a) through (f):

(a) Concentrated live loads
(b) Vehicular loads
(c) Crane loads
(d) Loads on hand rails, guardrails, and vehicular barrier systems
(e) Impact effects
(f) Vibration effects

5.3.5 If wind load W is provided at service-level loads, 1.6W shall be used in place of 1.0W in Eq. (5.3.1d) and (5.3.1f), and 0.8W shall be used in place of 0.5W in Eq. (5.3.1c).

R5.3.5 In ASCE/SEI 7-05, wind loads are consistent with service-level design; a wind load factor of 1.6 is appropriate for use in Eq. (5.3.1d) and (5.3.1f) and a wind load factor of 0.8 is appropriate for use in Eq. (5.3.1c). ASCE/SEI 7-22 prescribes wind loads for strength-level design and the wind load factor is 1.0. Design wind speeds for strength-level design are based on storms with mean recurrence intervals of 300, 700, 1700, and 3000 years depending on the risk category of the structure. The higher load factors in 5.3.5 apply where service-level wind loads corresponding to a 50-year mean recurrence interval are used for design.

5.3.6 The structural effects of forces due to restraint of volume change and differential settlement T shall be considered in combination with other loads if the effects of T can adversely affect structural safety or performance. The load factor for T shall be established considering the uncertainty associated with the likely magnitude of T, the probability that the maximum effect of T will occur simultaneously with other applied loads, and the potential adverse consequences if the effect of T is greater than assumed. The load factor on T shall not have a value less than 1.0.

R5.3.6 Several strategies can be used to accommodate movements due to volume change and differential settlement. Restraint of such movements can cause significant member forces and moments, such as tension in slabs and shear forces and moments in vertical members. Forces due to T effects are not commonly calculated and combined with other load effects. Rather, designs rely on successful past practices using compliant structural members and ductile connections to accommodate differential settlement

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and volume change movement while providing the needed resistance to gravity and lateral loads. Expansion joints and construction closure strips are used to limit volume change movements based on the performance of similar structures. Shrinkage and temperature reinforcement, which may exceed the required flexural reinforcement, is commonly proportioned based on gross concrete area rather than calculated force.

Where structural movements can lead to damage of nonductile elements, calculation of the predicted force should consider the inherent variability of the expected movement and structural response.

A long-term study of the volume change behavior of precast concrete buildings (Klein and Lindenberg 2009) recommends procedures to account for connection stiffness, thermal exposure, member softening due to creep, and other factors that influence T forces.

Fintel et al. (1986) provides information on the magnitudes of volume change effects in tall structures and recommends procedures for including the forces resulting from these effects in design.

5.3.7 If fluid load F is present, it shall be included in the load combination equations of 5.3.1 in accordance with (a), (b), (c), or (d):

(a) If F acts alone or adds to the effects of D, it shall be included with a load factor of 1.4 in Eq. (5.3.1a).
(b) If F adds to the primary load, it shall be included with a load factor of 1.2 in Eq. (5.3.1b) through (5.3.1e).
(c) If the effect of F is permanent and counteracts the primary load, it shall be included with a load factor of 0.9 in Eq. (5.3.1g).
(d) If the effect of F is not permanent but, when present, counteracts the primary load, F shall not be included in Eq. (5.3.1a) through (5.3.1g).

5.3.8 If lateral earth pressure H is present, it shall be included in the load combination equations of 5.3.1 in accordance with (a), (b), or (c):

(a) If H acts alone or adds to the primary load effect, it shall be included with a load factor of 1.6.
(b) If the effect of H is permanent and counteracts the primary load effect, it shall be included with a load factor of 0.9.
(c) If the effect of H is not permanent but, when present, counteracts the primary load effect, H shall not be included.

R5.3.8 The required load factors for lateral pressures from soil, water in soil, and other materials, reflect their variability and the possibility that the materials may be removed. The commentary of ASCE/SEI 7 includes additional useful discussion pertaining to load factors for H.

5.3.9 If a structure is in a flood zone, the flood loads and the appropriate load factors and combinations of ASCE/SEI 7 shall be used.

R5.3.9 Areas subject to flooding are defined by flood hazard maps, usually maintained by local governmental jurisdictions.

5.3.10 If a structure is subjected to forces from atmospheric ice loads, the ice loads and the appropriate load factors and combinations of ASCE/SEI 7 shall be used.

R5.3.10 Ice buildup on a structural member increases the applied load and the projected area exposed to wind. ASCE/SEI 7 provides maps of probable ice thicknesses due to

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5.3.11 For structures required to resist loads from tornadoes, the tornado loads and appropriate load factors and combinations of ASCE/SEI 7 shall be used.

5.3.12 For structures required to resist loads from tsunamis, the loads and appropriate load factors and combinations of ASCE/SEI 7 shall be used.

5.3.13 For structures subjected to loads from water in soil, the alternate method for loads from water in soil of ASCE/SEI 7 shall be permitted.

5.3.14 Required strength U shall include internal load effects due to reactions induced by prestressing with a load factor of 1.0.

5.3.15 For post-tensioned anchorage zone design, a load factor of 1.2 shall be applied to the maximum prestressing reinforcement jacking force.

5.3.16 Load factors for the effects of prestressing used with the strut-and-tie method shall be included in the load combination equations of 5.3.1 in accordance with (a) or (b):

(a) A load factor of 1.2 shall be applied to the prestressing effects where the prestressing effects increase the net force in struts or ties.

(b) A load factor of 0.9 shall be applied to the prestressing effects where the prestressing effects reduce the net force in struts or ties.

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freezing rain, with concurrent 3-second gust speeds, for a 50-year return period.

R5.3.11 For some critical structures, wind loads resulting from tornadoes are included in the basic load combinations of ASCE/SEI 7. ASCE/SEI 7 provides a map and a procedure to estimate loads associated with tornadoes acting on the main wind-force-resisting system, components, and cladding.

R5.3.12 For some structures, loads resulting from tsunamis are considered in design. ASCE/SEI 7 provides a map and procedures to determine loads associated with tsunamis.

R5.3.13 The alternate method in ASCE/SEI 7 allows the effect of ground water pressure to be decoupled from soil pressure. The basic method in ASCE/SEI 7 includes water pressure as a part of the earth pressure and does not account for uncertainty in the groundwater elevation. The load factor on earth pressure effectively increases the density of water, which is technically inconsistent. Additional information on this method is presented in the commentary of ASCE/SEI 7.

R5.3.14 For statically indeterminate structures, the internal load effects due to reactions induced by prestressing forces, sometimes referred to as secondary moments, can be significant (Bondy 2003; Lin and Thornton 1972; Collins and Mitchell 1997).

R5.3.15 The load factor of 1.2 applied to the maximum tendon jacking force results in a design load of about 113% of the specified prestressing reinforcement yield strength, but not more than 96% of the nominal tensile strength of the prestressing reinforcement. This compares well with the maximum anchorage capacity, which is at least 95% of the nominal tensile strength of the prestressing reinforcement.

Notes