CHAPTER 7 — LOADS

7.1 — Scope

7.1.1 — The provisions of this chapter shall govern load factors and combinations used to design structural concrete systems.

7.1.2 — Loads shall include self weight, applied loads, and effects of prestressing, earthquakes, restraint of volume change, and differential settlement.

7.2 — General

7.2.1 — Loads and Seismic Design Categories shall be in accordance with the General Building Code of which this code forms a part, or determined by other authority having jurisdiction in areas without a legally adopted building code.

7.2.2 — Live load reductions are permitted in accordance with the General Building Code.

7.3 — Load Factors and Combinations

7.3.1 — Required strength $U$ shall be at least equal to the effects of factored loads in Table 7.3.1, with exceptions and additions in 7.3.3 through 7.3.13.

Table 7.3.1–Load Combinations

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>Equation</th>
<th>Primary Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U = 1.4D$</td>
<td>(7.3.1a)</td>
<td>$D$</td>
</tr>
<tr>
<td>$U = 1.2D + 1.6L + 0.5(L_r or S or R)$</td>
<td>(7.3.1b)</td>
<td>$L$</td>
</tr>
<tr>
<td>$U = 1.2D + 1.6(L_r or S or R) + 1.0L + 0.5W$</td>
<td>(7.3.1c)</td>
<td>$L_r or S or R$</td>
</tr>
<tr>
<td>$U = 1.2D + 1.0W + 1.0L + 0.5(L_r or S or R)$</td>
<td>(7.3.1d)</td>
<td>$W$</td>
</tr>
<tr>
<td>$U = 1.2D + 1.0E + 1.0L + 0.2S$</td>
<td>(7.3.1e)</td>
<td>$E$</td>
</tr>
<tr>
<td>$U = 0.9D + 1.0W$</td>
<td>(7.3.1f)</td>
<td>$W$</td>
</tr>
<tr>
<td>$U = 0.9D + 1.0E$</td>
<td>(7.3.1g)</td>
<td>$E$</td>
</tr>
</tbody>
</table>

7.3.2— The effect of one or more loads not acting simultaneously shall be investigated.
7.3.3 — The load factor on live load $L$ in Eq. (7.3.1c), (7.3.1d) and (7.3.1e) 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$^2$. <9.2.1>

7.3.4 — If applicable, $L$ shall include:

(a) Concentrated live loads;

(b) Vehicular loads;

(c) Crane loads;

(d) Loads on hand rails, guardrails, and vehicular barrier systems;

(e) Impact effects; and

(f) Vibration effects. <8.2.4><9.2.2><~>

7.3.5 — If wind load $W$ is based on service-level loads, 1.6$W$ shall be used in place of 1.0$W$ in Eq. (7.3.1d) and (7.3.1f), and 0.8$W$ shall be used in place of 0.5$W$ in Eq. (7.3.1c).<9.2.1>

7.3.6 — If load effects of earthquake, $E$, are based on service-level forces, 1.4$E$ shall be used in place of 1.0$E$ in Eq. (7.3.1e) and (7.3.1g). <9.2.1>

7.3.7 — 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. <318-11: 9.2.3>

7.3.8 — If fluid load $F$ is present, it shall be included in the load combination equations of 7.3.1 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. 7.3.1a;

(b) If $F$ adds to the primary load, it shall be included with a load factor of 1.2 in Eq. 7.3.1b through 7.3.1e;

(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. 7.3.1g.
(d) If the effect of $F$ is not permanent but, when present, counteracts the primary load, $F$ shall not be included in Eq. 7.3.1(a) through 7.3.1(g). <318-11: 9.2.4>

7.3.9—If lateral earth pressure $H$ is present, it shall be included in the load combination equations of 7.3.1 in accordance with (a), (b), or (c):

(a) If $H$ acts alone or adds to the primary load, it shall be included with a load factor of 1.6 in Eq. 7.3.1a through 7.3.1e;

(b) If the effect of $H$ is permanent and counteracts the primary load, it shall be included with a load factor of 0.9 in Eq. 7.3.1f and 7.3.1g;

(c) If the effect of $H$ is not permanent but, when present, counteracts the primary load, $H$ shall not be included in Eq. 7.3.1(a) through 7.3.1(g). <318-11: 9.2.5>

7.3.10—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. <9.2.4>

7.3.11—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. <9.2.4>

7.3.12—Required strength $U$ shall include internal load effects due to reactions induced by prestressing with a load factor of 1.0. <18.10.3>

7.3.13—For post-tensioned anchorage zone design, a load factor of 1.2 shall be applied to the maximum prestressing reinforcement jacking force. <9.2.5>
Chapter 7—Loads

COMMENTARY

R7.1.1—If the service loads specified by the general building code (of which this Code forms a part) 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 this Code may need modification to reflect the difference.

R7.1.2—The provisions in the Code are for live, wind, and earthquake loads such as those recommended in “Minimum Design Loads for Buildings and Other Structures” (ASCE/SEI 7), formally known as ANSI A58.1.

If the service loads specified by the General Building Code (of which this Code forms a part) 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 this Code may need modification to reflect the difference.

Design requirements for an earthquake-resistant structure in this Code are determined by the Seismic Design Category (SDC) to which the structure is assigned. In general, the SDC relates to seismic hazard level, soil type, occupancy, and use of the building. Assignment of a building to a SDC is under the jurisdiction of a general building code rather than ACI 318.

R7.2.1 — Seismic Design Categories in this Code are adopted directly from the 2010 ASCE/SEI 7 standard. Similar designations are used by the 2009 edition of the “International Building Code” (IBC), and the 2009 NFPA 5000 “Building Construction and Safety Code.” The “BOCA National Building Code” (NBC) and “Standard Building Code” (SBC) used Seismic Performance Categories. The 1997 “Uniform Building Code” (UBC) relates seismic design requirements to seismic zones, whereas previous editions of ACI 318 related seismic design requirements to seismic risk levels. Table R7.2.1 correlates Seismic Design Categories to the low, moderate/intermediate, and high seismic risk terminology used in ACI 318 for several editions before the 2008 edition, and to the various methods of assigning design requirements in use in the U.S. under the various model building codes, the ASCE/SEI 7 standard, and the NEHRP Recommended Provisions.

Design requirements for an earthquake-resistant structures in this Code are determined by the Seismic Design Category (SDC) to which the structure is assigned. In general, the SDC relates to seismic hazard level, soil type, occupancy, and use of the building. Assignment of a building to a SDC is under the jurisdiction of the General Building Code rather than ACI 318.
### TABLE R7.2.1—CORRELATION BETWEEN SEISMIC-RELATED TERMINOLOGY IN MODEL CODES

<table>
<thead>
<tr>
<th>Code, standard, or resource document and edition</th>
<th>Level of seismic risk or assigned seismic performance or design categories as defined in the Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACI 318-05 and previous editions</td>
<td>Low seismic risk</td>
</tr>
<tr>
<td>Uniform Building Code 1991, 1994, 1997</td>
<td>Seismic Zone 0, 1</td>
</tr>
</tbody>
</table>

<sup>*</sup>SDC = Seismic design category as defined in code, standard, or resource document.
<sup>†</sup>SPC = Seismic performance category as defined in code, standard, or resource document.

In the absence of a general building code that prescribes earthquake loads and seismic zoning, it is the intent of Committee 318 that application of provisions for seismic design be consistent with national standards or model building codes such as References 7.1, 7.2, and 7.3. The model building codes also specify overstrength factors, $\Omega_o$, that are related to the seismic-force-resisting system used for the structure and used for the design of certain elements.

**R7.3.1**—The required strength $U$ is expressed in terms of factored loads, or related internal moments and forces. Factored loads are the loads specified in the General Building Code multiplied by appropriate load factors.

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 compute 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 specifically 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 axial load and 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 encountered in usual practice, some reduction in the stipulated strength reduction factors, \( \phi \), or increase in the stipulated load factors may be appropriate for such members.

Rain load \( R \) in Eq. (7.3.1b), (7.3.1c) and (7.3.1d) 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.

**R7.3.3** — The load modification factor of 7.3.3 is different than the live load reductions based on the loaded area that may be allowed in the legally adopted 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 legally adopted General Building Code can be used in combination with the 0.5 load factor specified in 7.3.3.

**R7.3.4** — If the live load is applied rapidly, as may be the case for parking structures, loading docks, warehouse floors, elevator shafts, etc., impact effects should be considered. In all equations, substitute \( \text{Generally, } (L + \text{impact}) \) may be substituted for \( L \) when impact should be considered.

**R7.3.5** — ASCE/SEI 7-10 has converted wind loads to strength level, and reduced the wind load factor to 1.0. ACI 318-14 requires use of the previous load factor for wind loads, 1.6, when service-level wind loads are used. For serviceability checks, the commentary to Appendix C of ASCE/SEI 7-10 provides service-level wind loads, \( W_a \).

**R7.3.6** — Model building codes and design load references have converted earthquake forces to strength level, and reduced the earthquake load factor to 1.0 (ASCE \( 7.93^{10}_{17} \times^{7.2} \), BOCA/NBC \( 93^{7.8}_{7} \times^{5} \), SBC \( 94^{7.8}_{7} \times^{5} \), UBC \( 97^{7.8}_{7} \times^{6} \), and IBC \( 2000^{7.5}_{7.2} \)). The Code requires use of the
previous load factor for earthquake loads, approximately 1.4, when service-level earthquake
forces from earlier editions of these references are used.

R7.3.7 — Several strategies can be used to accommodate movements due to volume change and
differential settlement and volume change. 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 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 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.

However, where structural movements can lead to damage of non-ductile elements,
calculation of the predicted force should consider the inherent variability of the expected
movement and structure response.

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

Reference 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.

R7.3.9 — 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 7-10 includes additional useful discussion pertaining to load factors
for $H$.

R7.3.10 — Areas subject to flooding are defined by flood hazard maps, usually maintained by
local governmental jurisdictions.

R7.3.11 — Ice buildup on a structural member increases the applied load and the projected area
exposed to wind. ASCE/SEI 7-10 provides maps of probable ice thicknesses due to freezing
rain, with concurrent 3-second gust speeds, for a 50-year return period.

R7.3.12 — For statically indeterminate structures, the moments due to reactions induced by
prestressing forces, referred to as secondary moments, are significant in both the elastic
and inelastic states (see References 7.10 through 7.12).

R7.3.13 — The load factor of 1.2 applied to the maximum tendon jacking force results in a
design load of about 113 percent of the specified prestressing steel yield strength but not more
than 96 percent of the nominal ultimate tensile strength of the prestressing steel. This compares well with the maximum attainable jacking force, which is limited by the anchor efficiency factor.

References, Chapter 7

7.8 Klein, G. J., and Lindenberg, R. J., “Volume Change Response of Precast Concrete Buildings,” PCI Journal, Precast/Prestressed Concrete Institute, Chicago, IL, V. 54, No. 4, Fall 2009, pp. 112-131.

ACI Staff: Please verify that all citations are correct. Note that references to model codes are made for purposes of the commentary in R7.2.1