

## CHAPTER 16

# STRUCTURAL DESIGN

### SECTION 1601 GENERAL

**1601.1 Scope.** The provisions of this chapter shall govern the structural design of buildings, structures and portions thereof regulated by this code.

### SECTION 1602 DEFINITIONS

**1602.1 Definitions.** The following words and terms shall, for the purposes of this chapter, have the meanings shown herein.

**ALLOWABLE STRESS DESIGN.** A method of proportioning structural members, such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses (also called “working stress design”).

**BALCONY, EXTERIOR.** An exterior floor projecting from and supported by a structure without additional independent supports.

**BASE SHEAR.** Total design lateral force or shear at the base.

#### BASIC SEISMIC-FORCE-RESISTING SYSTEMS.

**Bearing wall system.** A structural system without a complete vertical load-carrying space frame. Bearing walls or bracing elements provide support for substantial vertical loads. Seismic lateral force resistance is provided by shear walls or braced frames.

**Building frame system.** A structural system with an essentially complete space frame providing support for vertical loads. Seismic lateral force resistance is provided by shear walls or braced frames.

**Dual system.** A structural system with an essentially complete space frame providing support for vertical loads. Seismic lateral force resistance is provided by a moment frame and shear walls or braced frames.

**Inverted pendulum system.** A structure with a large portion of its mass concentrated at the top; therefore, having essentially one degree of freedom in horizontal translation. Seismic lateral force resistance is provided by the columns acting as cantilevers.

**Moment-resisting frame system.** A structural system with an essentially complete space frame providing support for vertical loads. Seismic lateral force resistance is provided by moment frames.

**Shear wall-frame interactive system.** A structural system which uses combinations of shear walls and frames designed to resist seismic lateral forces in proportion to their rigidities, considering interaction between shear walls and frames on all levels. Support of vertical loads is provided by the same shear walls and frames.

**BOUNDARY MEMBERS.** Strengthened portions along shear wall and diaphragm edges (also called “boundary elements”).

**Boundary element.** In light-frame construction, diaphragms and shear wall boundary members to which sheathing transfers forces. Boundary elements include chords and drag struts at diaphragm and shear wall perimeters, interior openings, discontinuities and reentrant corners.

**CANTILEVERED COLUMN SYSTEM.** A structural system relying on column elements that cantilever from a fixed base and have minimal rotational resistance capacity at the top with lateral forces applied essentially at the top and are used for lateral resistance.

**COLLECTOR ELEMENTS.** Members that serve to transfer forces between floor diaphragms and members of the lateral-force-resisting system.

**CONFINED REGION.** The portion of a reinforced concrete component in which the concrete is confined by closely spaced special transverse reinforcement restraining the concrete in directions perpendicular to the applied stress.

**DEAD LOADS.** The weight of materials of construction incorporated into the building, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment, including the weight of cranes. All dead loads are considered permanent loads.

**DECK.** An exterior floor supported on at least two opposing sides by an adjacent structure, and/or posts, piers or other independent supports.

**DEFORMABILITY.** The ratio of the ultimate deformation to the limit deformation.

**High deformability element.** An element whose deformability is not less than 3.5 when subjected to four fully reversed cycles at the limit deformation.

**Limited deformability element.** An element that is neither a low deformability or a high deformability element.

**Low deformability element.** An element whose deformability is 1.5 or less.

#### DEFORMATION.

**Limit deformation.** Two times the initial deformation that occurs at a load equal to 40 percent of the maximum strength.

**Ultimate deformation.** The deformation at which failure occurs and which shall be deemed to occur if the sustainable load reduces to 80 percent or less of the maximum strength.

**DESIGN STRENGTH.** The product of the nominal strength and a resistance factor (or strength reduction factor).

**DIAPHRAGM.** A horizontal or sloped system acting to transmit lateral forces to the vertical-resisting elements. When the term “diaphragm” is used, it shall include horizontal bracing systems.

**Diaphragm, blocked.** In light-frame construction, a diaphragm in which all sheathing edges not occurring on a framing member are supported on and fastened to blocking.

**Diaphragm boundary.** In light-frame construction, a location where shear is transferred into or out of the diaphragm sheathing. Transfer is either to a boundary element or to another force-resisting element.

**Diaphragm chord.** A diaphragm boundary element perpendicular to the applied load that is assumed to take axial stresses due to the diaphragm moment.

**Diaphragm, flexible.** A diaphragm is flexible for the purpose of distribution of story shear and torsional moment when the computed maximum in-plane deflection of the diaphragm itself under lateral load is more than two times the average drift of adjoining vertical elements of the lateral-force-resisting system of the associated story under equivalent tributary lateral load (see Section 1617.5.3).

**Diaphragm, rigid.** A diaphragm is rigid for the purpose of distribution of story shear and torsional moment when the lateral deformation of the diaphragm is less than or equal to two times the average story drift.

**DURATION OF LOAD.** The period of continuous application of a given load, or the aggregate of periods of intermittent applications of the same load.

#### ELEMENT.

**Ductile element.** An element capable of sustaining large cyclic deformations beyond the attainment of its nominal strength without any significant loss of strength.

**Limited ductile element.** An element that is capable of sustaining moderate cyclic deformations beyond the attainment of nominal strength without significant loss of strength.

**Nonductile element.** An element having a mode of failure that results in an abrupt loss of resistance when the element is deformed beyond the deformation corresponding to the development of its nominal strength. Nonductile elements cannot reliably sustain significant deformation beyond that attained at their nominal strength.

**EQUIPMENT SUPPORT.** Those structural members or assemblies of members or manufactured elements, including braces, frames, lugs, snuggers, hangers or saddles, that transmit gravity load and operating load between the equipment and the structure.

**ESSENTIAL FACILITIES.** Buildings and other structures that are intended to remain operational in the event of extreme environmental loading from flood, wind, snow or earthquakes.

**FACTORED LOAD.** The product of a nominal load and a load factor.

**FLEXIBLE EQUIPMENT CONNECTIONS.** Those connections between equipment components that permit rotational

and/or translational movement without degradation of performance.

#### FRAME.

**Braced frame.** An essentially vertical truss, or its equivalent, of the concentric or eccentric type that is provided in a building frame system or dual system to resist lateral forces.

**Concentrically braced frame (CBF).** A braced frame in which the members are subjected primarily to axial forces.

**Eccentrically braced frame (EBF).** A diagonally braced frame in which at least one end of each brace frames into a beam a short distance from a beam-column or from another diagonal brace.

**Ordinary concentrically braced frame (OCBF).** A steel concentrically braced frame in which members and connections are designed in accordance with the provisions of AISC Seismic without modification.

**Special concentrically braced frame (SCBF).** A steel or composite steel and concrete concentrically braced frame in which members and connections are designed for ductile behavior.

**Moment frame.** A frame in which members and joints resist lateral forces by flexure as well as along the axis of the members. Moment frames are categorized as “intermediate moment frames” (IMF), “ordinary moment frames” (OMF), and “special moment frames” (SMF).

**GUARD.** See Section 1002.1.

**IMPACT LOAD.** The load resulting from moving machinery, elevators, craneways, vehicles and other similar forces and kinetic loads, pressure and possible surcharge from fixed or moving loads.

**JOINT.** A portion of a column bounded by the highest and lowest surfaces of the other members framing into it.

**LIMIT STATE.** A condition beyond which a structure or member becomes unfit for service and is judged to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state).

**LIVE LOADS.** Those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load or dead load.

**LIVE LOADS (ROOF).** Those loads produced (1) during maintenance by workers, equipment and materials; and (2) during the life of the structure by movable objects such as planters and by people.

**LOAD AND RESISTANCE FACTOR DESIGN (LRFD).** A method of proportioning structural members and their connections using load and resistance factors such that no applicable limit state is reached when the structure is subjected to appropriate load combinations. The term “LRFD” is used in the design of steel and wood structures.

**LOAD FACTOR.** A factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously.

**LOADS.** Forces or other actions that result from the weight of building materials, occupants and their possessions, environmental effects, differential movement and restrained dimensional changes. Permanent loads are those loads in which variations over time are rare or of small magnitude, such as dead loads. All other loads are variable loads (see also “Nominal loads”).

**LOADS EFFECTS.** Forces and deformations produced in structural members by the applied loads.

**NOMINAL LOADS.** The magnitudes of the loads specified in this chapter (dead, live, soil, wind, snow, rain, flood and earthquake).

#### NOTATIONS.

$D$  = Dead load.

$E$  = Combined effect of horizontal and vertical earthquake-induced forces as defined in Sections 1616.4.1 and 1617.1.

$E_m$  = Maximum seismic load effect of horizontal and vertical seismic forces as set forth in Sections 1616.4.1 and 1617.1.

$F$  = Load due to fluids.

$F_a$  = Flood load.

$H$  = Load due to lateral pressure of soil and water in soil.

$L$  = Live load, except roof live load, including any permitted live load reduction.

$L_r$  = Roof live load including any permitted live load reduction.

$P$  = Ponding load.

$R$  = Rain load.

$S$  = Snow load.

$T$  = Self-straining force arising from contraction or expansion resulting from temperature change, shrinkage, moisture change, creep in component materials, movement due to differential settlement or combinations thereof.

$W$  = Load due to wind pressure.

**OTHER STRUCTURES.** Structures, other than buildings, for which loads are specified in this chapter.

**P-DELTA EFFECT.** The second order effect on shears, axial forces and moments of frame members induced by axial loads on a laterally displaced building frame.

**PANEL (PART OF A STRUCTURE).** The section of a floor, wall or roof comprised between the supporting frame of two adjacent rows of columns and girders or column bands of floor or roof construction.

**RESISTANCE FACTOR.** A factor that accounts for deviations of the actual strength from the nominal strength and the manner and consequences of failure (also called “strength reduction factor”).

**SHALLOW ANCHORS.** Shallow anchors are those with embedment length-to-diameter ratios of less than eight.

**SHEAR PANEL.** A floor, roof or wall component sheathed to act as a shear wall or diaphragm.

**SHEAR WALL.** A wall designed to resist lateral forces parallel to the plane of the wall.

**SPACE FRAME.** A structure composed of interconnected members, other than bearing walls, that is capable of supporting vertical loads and that also may provide resistance to seismic lateral forces.

**SPECIAL TRANSVERSE REINFORCEMENT.** Reinforcement composed of spirals, closed stirrups or hoops and supplementary cross ties provided to restrain the concrete and qualify the portion of the component, where used, as a confined region.

**STRENGTH, NOMINAL.** The capacity of a structure or member to resist the effects of loads, as determined by computations using specified material strengths and dimensions and equations derived from accepted principles of structural mechanics or by field tests or laboratory tests of scaled models, allowing for modeling effects and differences between laboratory and field conditions.

**STRENGTH, REQUIRED.** Strength of a member, cross section or connection required to resist factored loads or related internal moments and forces in such combinations as stipulated by these provisions.

**STRENGTH DESIGN.** A method of proportioning structural members such that the computed forces produced in the members by factored loads do not exceed the member design strength [also called “load and resistance factor design” (LRFD)]. The term “strength design” is used in the design of concrete and masonry structural elements.

**WALL, LOAD BEARING.** Any wall meeting either of the following classifications:

1. Any metal or wood stud wall that supports more than 100 pounds per linear foot (plf) (1459 N/m) of vertical load in addition to its own weight.
2. Any masonry or concrete wall that supports more than 200 plf (2919 N/m) of vertical load in addition to its own weight.

**WALL, NONLOAD BEARING.** Any wall that is not a load-bearing wall.

## SECTION 1603 CONSTRUCTION DOCUMENTS

**1603.1 General.** Construction documents shall show the size, section and relative locations of structural members with floor levels, column centers and offsets fully dimensioned. The design loads and other information pertinent to the structural design required by Sections 1603.1.1 through 1603.1.8 shall be clearly indicated on the construction documents for parts of the building or structure.

**Exception:** Construction documents for buildings constructed in accordance with the conventional light-frame construction provisions of Section 2308 shall indicate the following structural design information:

1. Floor and roof live loads.

2. Ground snow load,  $P_g$ .
3. Basic wind speed (3-second gust), miles per hour (mph) (km/hr) and wind exposure.
4. Seismic design category and site class.

**1603.1.1 Floor live load.** The uniformly distributed, concentrated and impact floor live load used in the design shall be indicated for floor areas. Live load reduction of the uniformly distributed floor live loads, if used in the design, shall be indicated.

**1603.1.2 Roof live load.** The roof live load used in the design shall be indicated for roof areas (Section 1607.11).

**1603.1.3 Roof snow load.** The ground snow load,  $P_g$ , shall be indicated. In areas where the ground snow load,  $P_g$ , exceeds 10 pounds per square foot (psf) (0.479 kN/m<sup>2</sup>), the following additional information shall also be provided, regardless of whether snow loads govern the design of the roof:

1. Flat-roof snow load,  $P_f$ .
2. Snow exposure factor,  $C_e$ .
3. Snow load importance factor,  $I_s$ .
4. Thermal factor,  $C_t$ .

**1603.1.4 Wind design data.** The following information related to wind loads shall be shown, regardless of whether wind loads govern the design of the lateral-force-resisting system of the building:

1. Basic wind speed (3-second gust), miles per hour (km/hr).
2. Wind importance factor,  $I_w$ , and building category.
3. Wind exposure, if more than one wind exposure is utilized, the wind exposure and applicable wind direction shall be indicated.
4. The applicable internal pressure coefficient.
5. Components and cladding. The design wind pressures in terms of psf (kN/m<sup>2</sup>) to be used for the design of exterior component and cladding materials not specifically designed by the registered design professional.

**1603.1.5 Earthquake design data.** The following information related to seismic loads shall be shown, regardless of whether seismic loads govern the design of the lateral-force-resisting system of the building:

1. Seismic importance factor,  $I_E$ , and seismic use group.
2. Mapped spectral response accelerations  $S_S$  and  $S_I$ .
3. Site class.
4. Spectral response coefficients  $S_{DS}$  and  $S_{DI}$ .
5. Seismic design category.
6. Basic seismic-force-resisting system(s).
7. Design base shear.
8. Seismic response coefficient(s),  $C_S$ .
9. Response modification factor(s),  $R$ .
10. Analysis procedure used.

**1603.1.6 Flood load.** For buildings located in flood hazard areas as established in Section 1612.3, the following information, referenced to the datum on the community's Flood Insurance Rate Map (FIRM), shall be shown, regardless of whether flood loads govern the design of the building:

1. In flood hazard areas not subject to high-velocity wave action, the elevation of proposed lowest floor, including basement.
2. In flood hazard areas not subject to high-velocity wave action, the elevation to which any nonresidential building will be dry floodproofed.
3. In flood hazard areas subject to high-velocity wave action, the proposed elevation of the bottom of the lowest horizontal structural member of the lowest floor, including basement.

**1603.1.7 Special loads.** Special loads that are applicable to the design of the building, structure or portions thereof shall be indicated along with the specified section of this code that addresses the special loading condition.

**1603.1.8 System and components requiring special inspections for seismic resistance.** Construction documents or specifications shall be prepared for those systems and components requiring special inspection for seismic resistance as specified in Section 1707.1 by the registered design professional responsible for their design and shall be submitted for approval in accordance with Section 106.1. Reference to seismic standards in lieu of detailed drawings is acceptable.

**1603.2 Restrictions on loading.** It shall be unlawful to place, or cause or permit to be placed, on any floor or roof of a building, structure or portion thereof, a load greater than is permitted by these requirements.

**1603.3 Live loads posted.** Where the live loads for which each floor or portion thereof of a commercial or industrial building is or has been designed to exceed 50 psf (2.40 kN/m<sup>2</sup>), such design live loads shall be conspicuously posted by the owner in that part of each story in which they apply, using durable signs. It shall be unlawful to remove or deface such notices.

**1603.4 Occupancy permits for changed loads.** Construction documents for other than residential buildings filed with the building official with applications for permits shall show on each drawing the live loads per square foot (m<sup>2</sup>) of area covered for which the building is designed. Occupancy permits for buildings hereafter erected shall not be issued until the floor load signs, required by Section 1603.3, have been installed.

## SECTION 1604 GENERAL DESIGN REQUIREMENTS

**1604.1 General.** Building, structures and parts thereof shall be designed and constructed in accordance with strength design, load and resistance factor design, allowable stress design, empirical design or conventional construction methods, as permitted by the applicable material chapters.

**1604.2 Strength.** Buildings and other structures, and parts thereof, shall be designed and constructed to support safely the factored loads in load combinations defined in this code with-

out exceeding the appropriate strength limit states for the materials of construction. Alternatively, buildings and other structures, and parts thereof, shall be designed and constructed to support safely the nominal loads in load combinations defined in this code without exceeding the appropriate specified allowable stresses for the materials of construction.

Loads and forces for occupancies or uses not covered in this chapter shall be subject to the approval of the building official.

**1604.3 Serviceability.** Structural systems and members thereof shall be designed to have adequate stiffness to limit deflections and lateral drift. See Section 1617.3 for drift limits applicable to earthquake loading.

**1604.3.1 Deflections.** The deflections of structural members shall not exceed the more restrictive of the limitations of Sections 1604.3.2 through 1604.3.5 or that permitted by Table 1604.3.

**1604.3.2 Reinforced concrete.** The deflection of reinforced concrete structural members shall not exceed that permitted by ACI 318.

**1604.3.3 Steel.** The deflection of steel structural members shall not exceed that permitted by AISC LRFD, AISC HSS, AISC 335, AISI -NASPEC, AISI-General, AISI-Truss, ASCE 3, ASCE 8-SSD-LRFD/ASD, and the standard specifications of SJI Standard Specifications, Load Tables and Weight Tables for Steel Joists and Joist Girders as applicable.

**1604.3.4 Masonry.** The deflection of masonry structural members shall not exceed that permitted by ACI 530/ASCE 5/TMS 402.

**1604.3.5 Aluminum.** The deflection of aluminum structural members shall not exceed that permitted by AA-94.

**1604.3.6 Limits.** Deflection of structural members over span,  $l$ , shall not exceed that permitted by Table 1604.3.

**1604.4 Analysis.** Load effects on structural members and their connections shall be determined by methods of structural analysis that take into account equilibrium, general stability, geometric compatibility and both short- and long-term material properties.

Members that tend to accumulate residual deformations under repeated service loads shall have included in their analysis the added eccentricities expected to occur during their service life.

Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system that provides a complete load path capable of transferring loads from their point of origin to the load-resisting elements.

The total lateral force shall be distributed to the various vertical elements of the lateral-force-resisting system in proportion to their rigidities considering the rigidity of the horizontal bracing system or diaphragm. Rigid elements that are assumed not to be a part of the lateral-force-resisting system shall be permitted to be incorporated into buildings provided that their effect

on the action of the system is considered and provided for in design. Provisions shall be made for the increased forces induced on resisting elements of the structural system resulting from torsion due to eccentricity between the center of application of the lateral forces and the center of rigidity of the lateral-force-resisting system.

Every structure shall be designed to resist the overturning effects caused by the lateral forces specified in this chapter. See Section 1609 for wind, Section 1610 for lateral soil loads and Sections 1613 through 1623 for earthquake.

**TABLE 1604.3**  
**DEFLECTION LIMITS<sup>a, b, c, h, i</sup>**

CONSTRUCTION	$L$	$S$ or $W^f$	$D + L^{d,g}$
Roof members: <sup>e</sup>			
Supporting plaster ceiling	$l/360$	$l/360$	$l/240$
Supporting nonplaster ceiling	$l/240$	$l/240$	$l/180$
Not supporting ceiling	$l/180$	$l/180$	$l/120$
Floor members	$l/360$	—	$l/240$
Exterior walls and interior partitions:			
With brittle finishes	—	$l/240$	—
With flexible finishes	—	$l/120$	—
Farm buildings	—	—	$l/180$
Greenhouses	—	—	$l/120$

For SI: 1 foot = 304.8 mm.

- a. For structural roofing and siding made of formed metal sheets, the total load deflection shall not exceed  $l/60$ . For secondary roof structural members supporting formed metal roofing, the live load deflection shall not exceed  $l/150$ . For secondary wall members supporting formed metal siding, the design wind load deflection shall not exceed  $l/90$ . For roofs, this exception only applies when the metal sheets have no roof covering.
- b. Interior partitions not exceeding 6 feet in height and flexible, folding and portable partitions are not governed by the provisions of this section. The deflection criterion for interior partitions is based on the horizontal load defined in Section 1607.13.
- c. See Section 2403 for glass supports.
- d. For wood structural members having a moisture content of less than 16 percent at time of installation and used under dry conditions, the deflection resulting from  $L + 0.5D$  is permitted to be substituted for the deflection resulting from  $L + D$ .
- e. The above deflections do not ensure against ponding. Roofs that do not have sufficient slope or camber to assure adequate drainage shall be investigated for ponding. See Section 1611 for rain and ponding requirements and Section 1503.4 for roof drainage requirements.
- f. The wind load is permitted to be taken as 0.7 times the “component and cladding” loads for the purpose of determining deflection limits herein.
- g. For steel structural members, the dead load shall be taken as zero.
- h. For aluminum structural members or aluminum panels used in roofs or walls of sunroom additions or patio covers, not supporting edge of glass or aluminum sandwich panels, the total load deflection shall not exceed  $l/60$ . For aluminum sandwich panels used in roofs or walls of sunroom additions or patio covers, the total load deflection shall not exceed  $l/120$ .
- i. For cantilever members,  $l$  shall be taken as twice the length of the cantilever.

**1604.5 Importance factors.** The value for snow load, wind load and seismic load importance factors shall be determined in accordance with Table 1604.5.

**1604.6 In-situ load tests.** The building official is authorized to require an engineering analysis or a load test, or both, of any construction whenever there is reason to question the safety of the construction for the intended occupancy. Engineering analysis and load tests shall be conducted in accordance with Section 1710.

**TABLE 1604.5  
CLASSIFICATION OF BUILDINGS AND OTHER STRUCTURES FOR IMPORTANCE FACTORS**

CATEGORY <sup>a</sup>	NATURE OF OCCUPANCY	SEISMIC FACTOR $I_E$	SNOW FACTOR $I_S$	WIND FACTOR $I_W$
I	Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: <ul style="list-style-type: none"> <li>• Agricultural facilities</li> <li>• Certain temporary facilities</li> <li>• Minor storage facilities</li> </ul>	1.00	0.8	0.87 <sup>b</sup>
II	Buildings and other structures except those listed in Categories I, III and IV	1.00	1.0	1.00
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: <ul style="list-style-type: none"> <li>• Buildings and other structures where more than 300 people congregate in one area</li> <li>• Buildings and other structures with elementary school, secondary school or day care facilities with an occupant load greater than 250</li> <li>• Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities</li> <li>• Health care facilities with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities</li> <li>• Jails and detention facilities</li> <li>• Any other occupancy with an occupant load greater than 5,000</li> <li>• Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Category IV</li> <li>• Buildings and other structures not included in Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released</li> </ul>	1.25	1.1	1.15
IV	Buildings and other structures designated as essential facilities including, but not limited to: <ul style="list-style-type: none"> <li>• Hospitals and other health care facilities having surgery or emergency treatment facilities</li> <li>• Fire, rescue and police stations and emergency vehicle garages</li> <li>• Designated earthquake, hurricane or other emergency shelters</li> <li>• Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response</li> <li>• Power-generating stations and other public utility facilities required as emergency backup facilities for Category IV structures</li> <li>• Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.7(2)</li> <li>• Aviation control towers, air traffic control centers and emergency aircraft hangars</li> <li>• Buildings and other structures having critical national defense functions</li> <li>• Water treatment facilities required to maintain water pressure for fire suppression</li> </ul>	1.50	1.2	1.15

a. For the purpose of Section 1616.2, Categories I and II are considered Seismic Use Group I, Category III is considered Seismic Use Group II and Category IV is equivalent to Seismic Use Group III.

b. In hurricane-prone regions with  $V > 100$  miles per hour,  $I_w$  shall be 0.77.

**1604.7 Preconstruction load tests.** Materials and methods of construction that are not capable of being designed by approved engineering analysis or that do not comply with the applicable material design standards listed in Chapter 35, or alternative test procedures in accordance with Section 1711, shall be load tested in accordance with Section 1714.

**1604.8 Anchorage.**

**1604.8.1 General.** Anchorage of the roof to walls and columns, and of walls and columns to foundations, shall be provided to resist the uplift and sliding forces that result from the application of the prescribed loads.

**1604.8.2 Concrete and masonry walls.** Concrete and masonry walls shall be anchored to floors, roofs and other structural elements that provide lateral support for the wall. Such anchorage shall provide a positive direct connection capable of resisting the horizontal forces specified in this chapter but not less than a minimum strength design horizontal force of 280 plf (4.10 kN/m) of wall, substituted for “E” in the load combinations of Section 1605.2 or 1605.3. Walls shall be designed to resist bending between anchors where the anchor spacing exceeds 4 feet (1219 mm). Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall. See Sections 1609.6.2.2 and 1620 for wind and earthquake design requirements.

**1604.8.3 Decks.** Where supported by attachment to an exterior wall, decks shall be positively anchored to the primary structure and designed for both vertical and lateral loads as applicable. Such attachment shall not be accomplished by the use of toenails or nails subject to withdrawal. Where positive connection to the primary building structure cannot be verified during inspection, decks shall be self-supporting. For decks with cantilevered framing members, connections to exterior walls or other framing members shall be designed and constructed to resist uplift resulting from the full live load specified in Table 1607.1 acting on the cantilevered portion of the deck.

**SECTION 1605  
LOAD COMBINATIONS**

**1605.1 General.** Buildings and other structures and portions thereof shall be designed to resist the load combinations specified in Section 1605.2 or 1605.3 and Chapters 18 through 23, and the special seismic load combinations of Section 1605.4 where required by Section 1620.2.6, 1620.2.9 or 1620.4.4 or Section 9.5.2.6.2.11 or 9.5.2.6.3.1 of ASCE 7. Applicable loads shall be considered, including both earthquake and wind, in accordance with the specified load combinations. Each load combination shall also be investigated with one or more of the variable loads set to zero.

**1605.2 Load combinations using strength design or load and resistance factor design.**

**1605.2.1 Basic load combinations.** Where strength design or load and resistance factor design is used, structures and portions thereof shall resist the most critical effects from the following combinations of factored loads:

1.4D (Equation 16-1)

1.2D + 1.6L + 0.5(L<sub>r</sub> or S or R) (Equation 16-2)

1.2D + 1.6(L<sub>r</sub> or S or R) + (f<sub>1</sub>L or 0.8W) (Equation 16-3)

1.2D + 1.6W + f<sub>1</sub>L + 0.5(L<sub>r</sub> or S or R) (Equation 16-4)

1.2D + 1.0E + f<sub>1</sub>L + f<sub>2</sub>S (Equation 16-5)

0.9D + (1.0E or 1.6W) (Equation 16-6)

where:

f<sub>1</sub> = 1.0 for floors in places of public assembly, for live loads in excess of 100 pounds per square foot (4.79 kN/m<sup>2</sup>), and for parking garage live load.

f<sub>1</sub> = 0.5 for other live loads.

f<sub>2</sub> = 0.7 for roof configurations (such as saw tooth) that do not shed snow off the structure.

f<sub>2</sub> = 0.2 for other roof configurations.

**Exception:** Where other factored load combinations are specifically required by the provisions of this code, such combinations shall take precedence.

**1605.2.2 Other loads.** Where F, H, P or T is to be considered in design, each applicable load shall be added to the above combinations in accordance with Section 2.3.2 of ASCE 7. Where F<sub>a</sub> is to be considered in design, the load combinations of Section 2.3.3 of ASCE 7 shall be used.

**1605.3 Load combinations using allowable stress design.**

**1605.3.1 Basic load combinations.** Where allowable stress design (working stress design), as permitted by this code, is used, structures and portions thereof shall resist the most critical effects resulting from the following combinations of loads:

D (Equation 16-7)

D + L (Equation 16-8)

D + L + (L<sub>r</sub> or S or R) (Equation 16-9)

D + (W or 0.7E) + L + (L<sub>r</sub> or S or R) (Equation 16-10)

0.6D + W (Equation 16-11)

0.6D + 0.7E (Equation 16-12)

**Exceptions:**

1. Crane hook loads need not be combined with roof live load or with more than three-fourths of the snow load or one-half of the wind load.
2. Flat roof snow loads of 30 psf (1.44 kN/m<sup>2</sup>) or less need not be combined with seismic loads. Where flat roof snow loads exceed 30 psf (1.44 kN/m<sup>2</sup>), 20 percent shall be combined with seismic loads.

**1605.3.1.1 Load reduction.** It is permitted to multiply the combined effect of two or more variable loads by 0.75 and add to the effect of dead load. The combined load used in design shall not be less than the sum of the effects of dead load and any one of the variable loads. The 0.7 factor on E does not apply for this provision.

Increases in allowable stresses specified in the appropriate materials section of this code or referenced standard shall not be used with the load combinations of Section 1605.3.1 except that a duration of load increase shall be permitted in accordance with Chapter 23.

**1605.3.1.2 Other loads.** Where  $F$ ,  $H$ ,  $P$  or  $T$  are to be considered in design, the load combinations of Section 2.4.1 of ASCE 7 shall be used. Where  $F_a$  is to be considered in design, the load combinations of Section 2.4.2 of ASCE 7 shall be used.

**1605.3.2 Alternative basic load combinations.** In lieu of the basic load combinations specified in Section 1605.3.1, structures and portions thereof shall be permitted to be designed for the most critical effects resulting from the following combinations. 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 material section of this code or referenced standard. Where wind loads are calculated in accordance with Section 1609.6 or Section 6 of ASCE 7, the coefficient  $\omega$  in the following equations shall be taken as 1.3. For other wind loads  $\omega$  shall be taken as 1.0.

$$D + L + (L_r \text{ or } S \text{ or } R) \quad \text{(Equation 16-13)}$$

$$D + L + (\omega W) \quad \text{(Equation 16-14)}$$

$$D + L + \omega W + S/2 \quad \text{(Equation 16-15)}$$

$$D + L + S + \omega W/2 \quad \text{(Equation 16-16)}$$

$$D + L + S + E/1.4 \quad \text{(Equation 16-17)}$$

$$0.9D + E/1.4 \quad \text{(Equation 16-18)}$$

**Exceptions:**

1. Crane hook loads need not be combined with roof live load or with more than three-fourths of the snow load or one-half of the wind load.
2. Flat roof snow loads of 30 pounds per square foot (1.44 kN/m<sup>2</sup>) or less need not be combined with seismic loads. Where flat roof snow loads exceed 30 psf (1.44 kN/m<sup>2</sup>), 20 percent shall be combined with seismic loads.

**1605.3.2.1 Other loads.** Where  $F$ ,  $H$ ,  $P$  or  $T$  are to be considered in design, 1.0 times each applicable load shall be added to the combinations specified in Section 1605.3.2.

**1605.4 Special seismic load combinations.** For both allowable stress design and strength design methods, where specifically required by Sections 1613 through 1622 or by Chapters 18 through 23, elements and components shall be designed to resist the forces calculated using Equation 16-19 when the effects of the seismic ground motion are additive to gravity forces and those calculated using Equation 16-20 when the effects of the seismic ground motion counteract gravity forces.

$$1.2D + f_i L + E_m \quad \text{(Equation 16-19)}$$

$$0.9D + E_m \quad \text{(Equation 16-20)}$$

where:

$E_m$  = The maximum effect of horizontal and vertical forces as set forth in Section 1617.1.

$f_i$  = 1.0 for floors in places of public assembly, for live loads in excess of 100 psf (4.79 kN/m<sup>2</sup>) and for parking garage live load.

$f_i$  = 0.5 for other live loads.

**1605.5 Heliports and helistops.** Heliport and helistop landing or touchdown areas shall be designed for the following loads, combined in accordance with Section 1605:

1. Dead load,  $D$ , plus the gross weight of the helicopter,  $D_h$ , plus snow load,  $S$ .
2. Dead load,  $D$ , plus two single concentrated impact loads,  $L$ , approximately 8 feet (2438 mm) apart applied anywhere on the touchdown pad (representing each of the helicopter's two main landing gear, whether skid type or wheeled type), having a magnitude of 0.75 times the gross weight of the helicopter. Both loads acting together total 1.5 times the gross weight of the helicopter.
3. Dead load,  $D$ , plus a uniform live load,  $L$ , of 100 psf (4.79 kN/m<sup>2</sup>).

**SECTION 1606  
DEAD LOADS**

**1606.1 Weights of materials and construction.** In determining dead loads for purposes of design, the actual weights of materials and construction shall be used. In the absence of definite information, values used shall be subject to the approval of the building official.

**1606.2 Weights of fixed service equipment.** In determining dead loads for purposes of design, the weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, heating, ventilating and air-conditioning systems (HVAC) and fire sprinkler systems, shall be included.

**SECTION 1607  
LIVE LOADS**

**1607.1 General.** Live loads are those loads defined in Section 1602.1.

**1607.2 Loads not specified.** For occupancies or uses not designated in Table 1607.1, the live load shall be determined in accordance with a method approved by the building official.

**1607.3 Uniform live loads.** The live loads used in the design of buildings and other structures shall be the maximum loads expected by the intended use or occupancy but shall in no case be less than the minimum uniformly distributed unit loads required by Table 1607.1.

**1607.4 Concentrated loads.** Floors and other similar surfaces shall be designed to support the uniformly distributed live loads prescribed in Section 1607.3 or the concentrated load, in pounds (kilonewtons), given in Table 1607.1, whichever produces the greater load effects. Unless otherwise specified, the indicated concentration shall be assumed to be uniformly distributed over an area 2.5 feet by 2.5 feet [6.25 ft<sup>2</sup> (0.58 m<sup>2</sup>)] and shall be located so as to produce the maximum load effects in the structural members.

**TABLE 1607.1  
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS AND MINIMUM CONCENTRATED LIVE LOADS<sup>9</sup>**

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)	OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
1. Apartments (see residential)	—	—	25. Office buildings		
2. Access floor systems			File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Office use	50	2,000	Lobbies and first-floor corridors	100	2,000
Computer use	100	2,000	Offices	50	2,000
3. Armories and drill rooms	150	—	Corridors above first floor	80	2,000
4. Assembly areas and theaters			26. Penal institutions		
Fixed seats (fastened to floor)	60		Cell blocks	40	—
Lobbies	100		Corridors	100	—
Movable seats	100	—	27. Residential		
Stages and platforms	125		One- and two-family dwellings		
Follow spot, projections and control rooms	50		Uninhabitable attics without storage	10	
Catwalks	40		Uninhabitable attics with storage	20	
5. Balconies (exterior)	100		Habitable attics and sleeping areas	30	
On one- and two-family residences only, and not exceeding 100 ft. <sup>2</sup>	60	—	All other areas except balconies and decks	40	—
6. Decks	Same as occupancy served <sup>h</sup>	—	Hotels and multifamily dwellings		
7. Bowling alleys	75	—	Private rooms and corridors serving them	40	
8. Cornices	60	—	Public rooms and corridors serving them	100	
9. Corridors, except as otherwise indicated	100	—	28. Reviewing stands, grandstands and bleachers	Note c	—
10. Dance halls and ballrooms	100	—	29. Roofs	See Section 1607.11	
11. Dining rooms and restaurants	100	—	30. Schools		
12. Dwellings (see residential)	—	—	Classrooms	40	1,000
13. Elevator machine room grating (on area of 4 in. <sup>2</sup> )	—	300	Corridors above first floor	80	1,000
14. Finish light floor plate construction (on area of 1 in. <sup>2</sup> )	—	200	First-floor corridors	100	1,000
15. Fire escapes	100		31. Scuttles, skylight ribs and accessible ceilings	—	200
On single-family dwellings only	40	—	32. Sidewalks, vehicular driveways and yards, subject to trucking	250 <sup>d</sup>	8,000 <sup>e</sup>
16. Garages (passenger vehicles only)	40	Note a	33. Skating rinks	100	—
Trucks and buses	See Section 1607.6		34. Stadiums and arenas		
17. Grandstands (see stadium and arena bleachers)	—	—	Bleachers	100 <sup>c</sup>	—
18. Gymnasiums, main floors and balconies	100	—	Fixed seats (fastened to floor)	60 <sup>c</sup>	
19. Handrails, guards and grab bars	See Section 1607.7		35. Stairs and exits		
20. Hospitals			One- and two-family dwellings	100	Note f
Operating rooms, laboratories	60	1,000	All other	40	
Private rooms	40	1,000	36. Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Wards	40	1,000	Light	125	—
Corridors above first floor	80	1,000	Heavy	250	
21. Hotels (see residential)	—	—	37. Stores		
22. Libraries			Retail		
Reading rooms	60	1,000	First floor	100	1,000
Stack rooms	150 <sup>b</sup>	1,000	Upper floors	75	1,000
Corridors above first floor	80	1,000	Wholesale, all floors	125	1,000
23. Manufacturing			38. Vehicle barriers	See Section 1607.7	
Light	125	2,000	39. Walkways and elevated platforms (other than exitways)	60	—
Heavy	250	3,000	40. Yards and terraces, pedestrians	100	—
24. Marquees	75	—			

(continued)

**Notes to Table 1607.1**

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm<sup>2</sup>, 1 pound per square foot = 0.0479 kN/m<sup>2</sup>, 1 pound = 0.004448 kN.

1 pound per cubic foot = 16 kg/m<sup>3</sup>

- a. Floors in garages or portions of buildings used for the storage of motor vehicles shall be designed for the uniformly distributed live loads of Table 1607.1 or the following concentrated loads: (1) for garages restricted to vehicles accommodating not more than nine passengers, 3,000 pounds acting on an area of 4.5 inches by 4.5 inches; (2) for mechanical parking structures without slab or deck which are used for storing passenger vehicles only, 2,250 pounds per wheel.
- b. The loading applies to stack room floors that support nonmobile, double-faced library bookstacks, subject to the following limitations:
  - 1. The nominal bookstack unit height shall not exceed 90 inches;
  - 2. The nominal shelf depth shall not exceed 12 inches for each face; and
  - 3. Parallel rows of double-faced bookstacks shall be separated by aisles not less than 36 inches wide.
- c. Design in accordance with the ICC *Standard on Bleachers, Folding and Telescopic Seating and Grandstands*.
- d. Other uniform loads in accordance with an approved method which contains provisions for truck loadings shall also be considered where appropriate.
- e. The concentrated wheel load shall be applied on an area of 20 square inches.
- f. Minimum concentrated load on stair treads (on area of 4 square inches) is 300 pounds.
- g. Where snow loads occur that are in excess of the design conditions, the structure shall be designed to support the loads due to the increased loads caused by drift buildup or a greater snow design determined by the building official (see Section 1608). For special-purpose roofs, see Section 1607.11.2.2.
- h. See Section 1604.8.3 for decks attached to exterior walls.

**1607.5 Partition loads.** In office buildings and in other buildings where partition locations are subject to change, provision for partition weight shall be made, whether or not partitions are shown on the construction documents, unless the specified live load exceeds 80 psf (3.83 kN/m<sup>2</sup>). Such partition load shall not be less than a uniformly distributed live load of 20 psf (0.96kN/m<sup>2</sup>).

**1607.6 Truck and bus garages.** Minimum live loads for garages having trucks or buses shall be as specified in Table 1607.6, but shall not be less than 50 psf (2.40 kN/m<sup>2</sup>), unless other loads are specifically justified and approved by the building official. Actual loads shall be used where they are greater than the loads specified in the table. Plazas subject to emergency vehicle traffic shall be designed for the worst case of either 250 psf (12kN/m<sup>2</sup>) or a fire truck with a wheel base of 230 inches (5842 mm) with the following weight distribution: 20,000 pounds (89 kN) on the front axle and 30,000 pounds (134 kN) on each of the two tandem rear axles. Basement and retaining walls adjacent to these areas shall also be designed for these loads as a surcharge.

**1607.6.1 Truck and bus garage live load application.** The concentrated load and uniform load shall be uniformly distributed over a 10-foot (3048 mm) width on a line normal to the centerline of the lane placed within a 12-foot-wide (3658 mm) lane. The loads shall be placed within their individual lanes so as to produce the maximum stress in each structural member. Single spans shall be designed for the uniform load in Table 1607.6 and one simultaneous concentrated load positioned to produce the maximum effect. Multiple spans shall be designed for the uniform load in Table 1607.6 on the spans and two simultaneous concentrated loads in two spans positioned to produce the maximum negative moment effect. Multiple span design loads, for other effects, shall be the same as for single spans.

**1607.7 Loads on handrails, guards, grab bars and vehicle barriers.** Handrails, guards, grab bars as designed in ICC

A117.1 and vehicle barriers shall be designed and constructed to the structural loading conditions set forth in this section.

**TABLE 1607.6  
UNIFORM AND CONCENTRATED LOADS**

LOADING CLASS <sup>a</sup>	UNIFORM LOAD (pounds/linear foot of lane)	CONCENTRATED LOAD (pounds) <sup>b</sup>	
		For moment design	For shear design
H20-44 and HS20-44	640	18,000	26,000
H15-44 and HS15-44	480	13,500	19,500

For SI: 1 pound per linear foot = 0.01459 kN/m, 1 pound = 0.004448 kN, 1 ton = 8.90 kN.

- a. An H loading class designates a two-axle truck with a semitrailer. An HS loading class designates a tractor truck with a semitrailer. The numbers following the letter classification indicate the gross weight in tons of the standard truck and the year the loadings were instituted.
- b. See Section 1607.6.1 for the loading of multiple spans.

**1607.7.1 Handrails and guards.** Handrail assemblies and guards shall be designed to resist a load of 50 plf (0.73 kN/m) applied in any direction at the top and to transfer this load through the supports to the structure.

**Exceptions:**

- 1. For one- and two-family dwellings, only the single, concentrated load required by Section 1607.7.1.1 shall be applied.
- 2. In Group I-3, F, H and S occupancies, for areas that are not accessible to the general public and that have an occupant load no greater than 50, the minimum load shall be 20 pounds per foot (0.29 kN/m).

**1607.7.1.1 Concentrated load.** Handrail assemblies and guards shall be able to resist a single concentrated load of 200 pounds (0.89 kN), applied in any direction at any point along the top, and have attachment devices and supporting structure to transfer this loading to appropriate structural elements of the building. This load need not be assumed to act concurrently with the loads specified in the preceding paragraph.

**1607.7.1.2 Components.** Intermediate rails (all those except the handrail), balusters and panel fillers shall be designed to withstand a horizontally applied normal load of 50 pounds (0.22 kN) on an area equal to 1 square foot (0.093m<sup>2</sup>), including openings and space between rails. Reactions due to this loading are not required to be superimposed with those of Section 1607.7.1 or 1607.7.1.1.

**1607.7.1.3 Stress increase.** Where handrails and guards are designed in accordance with the provisions for allowable stress design (working stress design) exclusively for the loads specified in Section 1607.7.1, the allowable stress for the members and their attachments are permitted to be increased by one-third.

**1607.7.2 Grab bars, shower seats and dressing room bench seats.** Grab bars, shower seats and dressing room bench seat systems shall be designed to resist a single concentrated load of 250 pounds (1.11 kN) applied in any direction at any point.

**1607.7.3 Vehicle barriers.** Vehicle barrier systems for passenger cars shall be designed to resist a single load of 6,000 pounds (26.70 kN) applied horizontally in any direction to

the barrier system and shall have anchorage or attachment capable of transmitting this load to the structure. For design of the system, the load shall be assumed to act at a minimum height of 1 foot, 6 inches (457 mm) above the floor or ramp surface on an area not to exceed 1 square foot (305 mm<sup>2</sup>), and is not required to be assumed to act concurrently with any handrail or guard loadings specified in the preceding paragraphs of Section 1607.7.1. Garages accommodating trucks and buses shall be designed in accordance with an approved method that contains provision for traffic railings.

**1607.8 Impact loads.** The live loads specified in Section 1607.2 include allowance for impact conditions. Provisions shall be made in the structural design for uses and loads that involve unusual vibration and impact forces.

**1607.8.1 Elevators.** Elevator loads shall be increased by 100 percent for impact and the structural supports shall be designed within the limits of deflection prescribed by ASME A17.1.

**1607.8.2 Machinery.** For the purpose of design, the weight of machinery and moving loads shall be increased as follows to allow for impact: (1) elevator machinery, 100 percent; (2) light machinery, shaft- or motor-driven, 20 percent; (3) reciprocating machinery or power-driven units, 50 percent; (4) hangers for floors or balconies, 33 percent. Percentages shall be increased where specified by the manufacturer.

**1607.9 Reduction in live loads.** The minimum uniformly distributed live loads,  $L_o$ , in Table 1607.1 are permitted to be reduced according to the following provisions.

**1607.9.1 General.** Subject to the limitations of Sections 1607.9.1.1 through 1607.9.1.4, members for which a value of  $K_{LL}A_T$  is 400 square feet (37.16 m<sup>2</sup>) or more are permitted to be designed for a reduced live load in accordance with the following equation:

$$L = L_o \left( 0.25 + \frac{15}{\sqrt{K_{LL} A_T}} \right) \quad \text{(Equation 16-21)}$$

$$\text{For SI: } L = L_o \left( 0.25 + \frac{4.57}{\sqrt{K_{LL} A_T}} \right)$$

where:

$L$  = Reduced design live load per square foot (meter) of area supported by the member.

$L_o$  = Unreduced design live load per square foot (meter) of area supported by the member (see Table 1607.1).

$K_{LL}$  = Live load element factor (see Table 1607.9.1).

$A_T$  = Tributary area, in square feet (square meters).  $L$  shall not be less than  $0.50L_o$  for members supporting one floor and  $L$  shall not be less than  $0.40L_o$  for members supporting two or more floors.

**TABLE 1607.9.1  
LIVE LOAD ELEMENT FACTOR,  $K_{LL}$**

ELEMENT	$K_{LL}$
Interior columns	4
Exterior columns without cantilever slabs	4
Edge columns with cantilever slabs	3
Corner columns with cantilever slabs	2
Edge beams without cantilever slabs	2
Interior beams	2
All other members not identified above including: Edge beams with cantilever slabs Cantilever beams Two-way slabs Members without provisions for continuous shear transfer normal to their span	1

**1607.9.1.1 Heavy live loads.** Live loads that exceed 100 psf (4.79 kN/m<sup>2</sup>) shall not be reduced except the live loads for members supporting two or more floors are permitted to be reduced by a maximum of 20 percent, but the live load shall not be less than  $L$  as calculated in Section 1607.9.1.

**1607.9.1.2 Passenger vehicle garages.** The live loads shall not be reduced in passenger vehicle garages except the live loads for members supporting two or more floors are permitted to be reduced by a maximum of 20 percent, but the live load shall not be less than  $L$  as calculated in Section 1607.9.1.

**1607.9.1.3 Special occupancies.** Live loads of 100 psf (4.79 kN/m<sup>2</sup>) or less shall not be reduced in public assembly occupancies.

**1607.9.1.4 Special structural elements.** Live loads shall not be reduced for one-way slabs except as permitted in Section 1607.9.1.1. Live loads of 100 psf (4.79 kN/m<sup>2</sup>) or less shall not be reduced for roof members except as specified in Section 1607.11.2.

**1607.9.2 Alternate floor live load reduction.** As an alternative to Section 1607.9.1, floor live loads are permitted to be reduced in accordance with the following provisions. Such reductions shall apply to slab systems, beams, girders, columns, piers, walls and foundations.

1. A reduction shall not be permitted in Group A occupancies.
2. A reduction shall not be permitted when the live load exceeds 100 psf (4.79 kN/m<sup>2</sup>) except that the design live load for columns may be reduced by 20 percent.
3. For live loads not exceeding 100 psf (4.79 kN/m<sup>2</sup>), the design live load for any structural member supporting 150 square feet (13.94 m<sup>2</sup>) or more is permitted to be reduced in accordance with the following equation:

$$R = r(A - 150) \quad \text{(Equation 16-22)}$$

$$\text{For SI: } R = r(A - 13.94)$$

Such reduction shall not exceed 40 percent for horizontal members, 60 percent for vertical members, nor  $R$  as determined by the following equation:

$$R = 23.1 (1 + D/L_o) \quad \text{(Equation 16-23)}$$

where:

$A$  = Area of floor or roof supported by the member, square feet ( $m^2$ ).

$D$  = Dead load per square foot ( $m^2$ ) of area supported.

$L_o$  = Unreduced live load per square foot ( $m^2$ ) of area supported.

$R$  = Reduction in percent.

$r$  = Rate of reduction equal to 0.08 percent for floors.

**1607.10 Distribution of floor loads.** Where uniform floor live loads are involved in the design of structural members arranged so as to create continuity, the minimum applied loads shall be the full dead loads on all spans in combination with the floor live loads on spans selected to produce the greatest effect at each location under consideration. It shall be permitted to reduce floor live loads in accordance with Section 1607.9.

**1607.11 Roof loads.** The structural supports of roofs and marquees shall be designed to resist wind and, where applicable, snow and earthquake loads, in addition to the dead load of construction and the appropriate live loads as prescribed in this section, or as set forth in Table 1607.1. The live loads acting on a sloping surface shall be assumed to act vertically on the horizontal projection of that surface.

**1607.11.1 Distribution of roof loads.** Where uniform roof live loads are involved in the design of structural members arranged so as to create continuity, the minimum applied loads shall be the full dead loads on all spans in combination with the roof live loads on adjacent spans or on alternate spans, whichever produces the greatest effect. See Section 1607.11.2 for minimum roof live loads and Section 1608.5 for partial snow loading.

**1607.11.2 Minimum roof live loads.** Minimum roof loads shall be determined for the specific conditions in accordance with Sections 1607.11.2.1 through 1607.11.2.4.

**1607.11.2.1 Flat, pitched and curved roofs.** Ordinary flat, pitched and curved roofs shall be designed for the live loads specified in the following equation or other controlling combinations of loads in Section 1605, whichever produces the greater load. In structures where special scaffolding is used as a work surface for workers and materials during maintenance and repair operations, a lower roof load than specified in the following equation shall not be used unless approved by the building official. Greenhouses shall be designed for a minimum roof live load of 10 psf (0.479 kN/m<sup>2</sup>).

$$L_r = 20R_1R_2 \quad \text{(Equation 16-24)}$$

where:  $12 \leq L_r \leq 20$

For SI:  $L_r = 0.96 R_1R_2$

where:  $0.58 \leq L_r \leq 0.96$

$L_r$  = Roof live load per square foot ( $m^2$ ) of horizontal projection in pounds per square foot (kN/m<sup>2</sup>).

The reduction factors  $R_1$  and  $R_2$  shall be determined as follows:

$$R_1 = 1 \quad \text{for } A_t \leq 200 \text{ square feet (18.58 } m^2) \quad \text{(Equation 16-25)}$$

$$R_1 = 1.2 - 0.001A_t \quad \text{for } 200 \text{ square feet} < A_t < 600 \text{ square feet} \quad \text{(Equation 16-26)}$$

For SI:  $1.2 - 0.011A_t$  for 18.58 square meters  $< A_t < 55.74$  square meters

$$R_1 = 0.6 \quad \text{for } A_t \geq 600 \text{ square feet (55.74 } m^2) \quad \text{(Equation 16-27)}$$

where:

$A_t$  = Tributary area (span length multiplied by effective width) in square feet ( $m^2$ ) supported by any structural member, and

$F$  = for a sloped roof, the number of inches of rise per foot (for SI:  $F = 0.12 \times$  slope, with slope expressed in percentage points), and

$F$  = for an arch or dome, rise-to-span ratio multiplied by 32, and

$$R_2 = 1 \quad \text{for } F \leq 4 \quad \text{(Equation 16-28)}$$

$$R_2 = 1.2 - 0.05 F \quad \text{for } 4 < F < 12 \quad \text{(Equation 16-29)}$$

$$R_2 = 0.6 \quad \text{for } F \geq 12 \quad \text{(Equation 16-30)}$$

**1607.11.2.2 Special-purpose roofs.** Roofs used for promenade purposes shall be designed for a minimum live load of 60 psf (2.87 kN/m<sup>2</sup>). Roofs used for roof gardens or assembly purposes shall be designed for a minimum live load of 100 psf (4.79 kN/m<sup>2</sup>). Roofs used for other special purposes shall be designed for appropriate loads, as directed or approved by the building official.

**1607.11.2.3 Landscaped roofs.** Where roofs are to be landscaped, the uniform design live load in the landscaped area shall be 20 psf (0.958 kN/m<sup>2</sup>). The weight of the landscaping materials shall be considered as dead load and shall be computed on the basis of saturation of the soil.

**1607.11.2.4 Awnings.** Awnings shall be designed for a uniform live load of 5 psf (0.240 kN/m<sup>2</sup>) as well as for snow loads and wind loads as specified in Sections 1608 and 1609.

**1607.11.2.5 Shade structures, canopies and membrane structures.** The live load for shade structures, canopies and membrane structures shall be a minimum 10 psf (0.48 kN/m<sup>2</sup>). Frame elements shall support a minimum concentrated load of 200 pounds (890 N) at any point that results in greatest stress on the member or its connection.

**1607.12 Crane loads.** The crane live load shall be the rated capacity of the crane. Design loads for the runway beams, including connections and support brackets, of moving bridge cranes and monorail cranes shall include the maximum wheel loads of the crane and the vertical impact, lateral and longitudinal forces induced by the moving crane.

**1607.12.1 Maximum wheel load.** The maximum wheel loads shall be the wheel loads produced by the weight of the bridge, as applicable, plus the sum of the rated capacity and the weight of the trolley with the trolley positioned on its runway at the location where the resulting load effect is maximum.

**1607.12.2 Vertical impact force.** The maximum wheel loads of the crane shall be increased by the percentages shown below to determine the induced vertical impact or vibration force:

- Monorail cranes (powered) . . . . . 25 percent
- Cab-operated or remotely operated bridge cranes (powered) . . . . . 25 percent
- Pendant-operated bridge cranes (powered) . . . . . 10 percent
- Bridge cranes or monorail cranes with hand-gear bridge, trolley and hoist . . . . . 0 percent

**1607.12.3 Lateral force.** The lateral force on crane runway beams with electrically powered trolleys shall be calculated as 20 percent of the sum of the rated capacity of the crane and the weight of the hoist and trolley. The lateral force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction perpendicular to the beam, and shall be distributed according to the lateral stiffness of the runway beam and supporting structure.

**1607.12.4 Longitudinal force.** The longitudinal force on crane runway beams, except for bridge cranes with hand-gear bridges, shall be calculated as 10 percent of the maximum wheel loads of the crane. The longitudinal force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction parallel to the beam.

**1607.13 Interior walls and partitions.** Interior walls and partitions that exceed 6 feet (1829 mm) in height, including their

finish materials, shall have adequate strength to resist the loads to which they are subjected but not less than a horizontal load of 5 psf (0.240 kN/m<sup>2</sup>).

**SECTION 1608  
SNOW LOADS**

**1608.1 General.** Design snow loads shall be determined in accordance with Section 7 of ASCE 7, but the design roof load shall not be less than that determined by Section 1607.

**1608.2 Ground snow loads.** The ground snow loads to be used in determining the design snow loads for roofs are given in Figure 1608.2 for the contiguous United States and Table 1608.2 for Alaska. Site-specific case studies shall be made in areas designated CS in Figure 1608.2. Ground snow loads for sites at elevations above the limits indicated in Figure 1608.2 and for all sites within the CS areas shall be approved. Ground snow load determination for such sites shall be based on an extreme value statistical analysis of data available in the vicinity of the site using a value with a 2-percent annual probability of being exceeded (50-year mean recurrence interval). Snow loads are zero for Hawaii, except in mountainous regions as approved by the building official.

**1608.3 Flat roof snow loads.** The flat roof snow load,  $p_f$ , on a roof with a slope equal to or less than 5 degrees (0.09 rad) (1 inch per foot = 4.76 degrees) shall be calculated in accordance with Section 7.3 of ASCE 7.

**1608.3.1 Exposure factor.** The value for the snow exposure factor,  $C_e$ , used in the calculation of  $p_f$  shall be determined from Table 1608.3.1.

**1608.3.2 Thermal factor.** The value for the thermal factor,  $C_t$ , used in the calculation of  $p_f$  shall be determined from Table 1608.3.2.

**TABLE 1608.2  
GROUND SNOW LOADS,  $p_g$ , FOR ALASKAN LOCATIONS**

LOCATION	POUNDS PER SQUARE FOOT	LOCATION	POUNDS PER SQUARE FOOT	LOCATION	POUNDS PER SQUARE FOOT
Adak	30	Galena	60	Petersburg	150
Anchorage	50	Gulkana	70	St. Paul Islands	40
Angoon	70	Homer	40	Seward	50
Barrow	25	Juneau	60	Shemya	25
Barter Island	35	Kenai	70	Sitka	50
Bethel	40	Kodiak	30	Talkeetna	120
Big Delta	50	Kotzebue	60	Unalakleet	50
Cold Bay	25	McGrath	70	Valdez	160
Cordova	100	Nenana	80	Whittier	300
Fairbanks	60	Nome	70	Wrangell	60
Fort Yukon	60	Palmer	50	Yakutat	150

For SI: 1 pound per square foot = 0.0479 kN/m<sup>2</sup>.



FIGURE 1608.2  
GROUND SNOW LOADS,  $p_g$ , FOR THE UNITED STATES (psf)



FIGURE 1608.2—continued  
GROUND SNOW LOADS,  $p_g$ , FOR THE UNITED STATES (psf)

TABLE 1608.3.1  
SNOW EXPOSURE FACTOR,  $C_e$

TERRAIN CATEGORY <sup>a</sup>	EXPOSURE OF ROOF <sup>a,b</sup>		
	Fully exposed <sup>c</sup>	Partially exposed	Sheltered
A (see Section 1609.4)	N/A	1.1	1.3
B (see Section 1609.4)	0.9	1.0	1.2
C (see Section 1609.4)	0.9	1.0	1.1
D (see Section 1609.4)	0.8	0.9	1.0
Above the treeline in windswept mountainous areas	0.7	0.8	N/A
In Alaska, in areas where trees do not exist within a 2-mile radius of the site	0.7	0.8	N/A

For SI: 1 mile = 1609 m.

- a. The terrain category and roof exposure condition chosen shall be representative of the anticipated conditions during the life of the structure. An exposure factor shall be determined for each roof of a structure.
- b. Definitions of roof exposure are as follows:
  1. Fully exposed shall mean roofs exposed on all sides with no shelter afforded by terrain, higher structures or trees. Roofs that contain several large pieces of mechanical equipment, parapets which extend above the height of the balanced snow load,  $h_b$ , or other obstructions are not in this category.
  2. Partially exposed shall include all roofs except those designated as “fully exposed” or “sheltered.”
  3. Sheltered roofs shall mean those roofs located tight in among conifers that qualify as “obstructions.”
- c. Obstructions within a distance of  $10 h_o$  provide “shelter,” where  $h_o$  is the height of the obstruction above the roof level. If the only obstructions are a few deciduous trees that are leafless in winter, the “fully exposed” category shall be used except for terrain category “A.” Note that these are heights above the roof. Heights used to establish the terrain category in Section 1609.4 are heights above the ground.

TABLE 1608.3.2  
THERMAL FACTOR,  $C_t$

THERMAL CONDITION <sup>a</sup>	$C_t$
All structures except as indicated below	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance ( $R$ -value) between the ventilated space and the heated space exceeds $25h \cdot \text{ft}^2 \cdot ^\circ\text{F}/\text{Btu}$	1.1
Unheated structures	1.2
Continuously heated greenhouses <sup>b</sup> with a roof having a thermal resistance ( $R$ -value) less than $2.0h \cdot \text{ft}^2 \cdot ^\circ\text{F}/\text{Btu}$	0.85

For SI:  $^\circ\text{C} = [(\text{°F}) - 32]/1.8$ , 1 British thermal unit per hour = 0.2931W.

- a. The thermal condition shall be representative of the anticipated conditions during winters for the life of the structure.
- b. A continuously heated greenhouse shall mean a greenhouse with a constantly maintained interior temperature of  $50^\circ\text{F}$  or more during winter months. Such greenhouse shall also have a maintenance attendant on duty at all times or a temperature alarm system to provide warning in the event of a heating system failure.

**1608.3.3 Snow load importance factor.** The value for the snow load importance factor,  $I_s$ , used in the calculation of  $p_f$  shall be determined in accordance with Table 1604.5. Greenhouses that are occupied for growing plants on production or research basis, without public access, shall be included in Importance Category I.

**1608.3.4 Rain-on-snow surcharge load.** Roofs with a slope less than  $1/2$  inch per foot (2.38 degrees) shall be designed for a rain-on-snow surcharge load determined in accordance with Section 7.10 of ASCE 7.

**1608.3.5 Ponding instability.** For roofs with a slope less than  $1/4$  inch per foot (1.19 degrees), the design calculations shall include verification of the prevention of ponding instability in accordance with Section 7.11 of ASCE 7.

**1608.4 Sloped roof snow loads.** The snow load,  $p_s$ , on a roof with a slope greater than 5 degrees (0.09 rad) (1 inch per foot = 4.76 degrees) shall be calculated in accordance with Section 7.4 of ASCE 7.

**1608.5 Partial loading.** The effect of not having the balanced snow load over the entire loaded roof area shall be analyzed in accordance with Section 7.5 of ASCE 7.

**1608.6 Unbalanced snow loads.** Unbalanced roof snow loads shall be determined in accordance with Section 7.6 of ASCE 7. Winds from all directions shall be accounted for when establishing unbalanced snow loads.

**1608.7 Drifts on lower roofs.** In areas where the ground snow load,  $p_g$ , as determined by Section 1608.2, is equal to or greater than 5 psf (0.240 kN/m<sup>2</sup>), roofs shall be designed to sustain localized loads from snow drifts in accordance with Section 7.7 of ASCE 7.

**1608.8 Roof projections.** Drift loads due to mechanical equipment, penthouses, parapets and other projections above the roof shall be determined in accordance with Section 7.8 of ASCE 7.

**1608.9 Sliding snow.** The extra load caused by snow sliding off a sloped roof onto a lower roof shall be determined in accordance with Section 7.9 of ASCE 7.