

ASCE STANDARD

ASCE/SEI

7-16

Minimum Design Loads and Associated Criteria for Buildings and Other Structures

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS



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Associated Criteria for Buildings
and Other Structures**



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Tips for Using This Standard

The **standard provisions** are contained in chapters 1 to 31. Standard provisions are mandatory.

CHAPTER 8 RAIN LOADS

The **standard commentary** is contained in chapters C1 to C31. Standard commentary is intended to help you understand how the provisions were determined and how to apply them.

8.1 DEFINITIONS AND SYMBOLS

8.1.1 Definitions

CONTROLLED DRAINAGE: System intentionally regulating the rate of flow through the primary drains.

PONDING: The accumulation of water caused by the deflection of the roof structure, resulting in added load.

PONDING INSTABILITY: Member instability caused by progressive deflection due to ponding on roofs.

PRIMARY DRAINAGE SYSTEM: Roof drainage system through which water is normally conveyed off the roof.

PRIMARY MEMBERS: For the purposes of determining a susceptible bay, structural members having direct connection to the columns, including girders, beams, and trusses.

PARAPET: An opening in the side of a building (typically parapet wall) for the purpose of draining water off the roof.

SECONDARY DRAINAGE SYSTEM: Roof drainage system higher than the primary drainage system, through which water is conveyed off the roof when the primary system is blocked.

8.3 DESIGN RAIN LOADS

Each portion of a roof shall be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow.

$$R = 5.2(d_s + d_p) \quad (8.3-1)$$

$$R = 0.0098(d_s + d_p) \quad (8.3-1.si)$$

If the secondary drainage systems contain drain lines, such lines and their point of discharge shall be separate from the primary drain lines. Rain loads shall be based on the total head (static head plus hydraulic head $[d_p]$) associated with the design flow rate of the specified secondary drains and drainage system corresponding to the design flow rate for the specified secondary drainage system based on hydraulic test data.

Gray bars down the side in the provisions (but not the commentary) indicate sections with substantive changes from the previous edition of this standard, ASCE/SEI 7-10, Third Printing.

CHAPTER C8 RAIN LOADS

This standard uses both **customary and metric (S.I.) units**. Customary units appear first, followed by S.I. units in parentheses.

When numbered display equations have customary and S.I. versions, the one in customary units is numbered like this: (Eq. 8.3-1). The one in S.I. units is numbered like this: (Eq. 8.3-1.si).

8.1 DEFINITIONS AND SYMBOLS

A = Tributary roof area, plus one-half the wall area that diverts rainwater onto the roof, serviced by a single drain outlet in the secondary drainage system, in ft² (m²).

D = Drain bowl diameter for a primary roof drain, or overflow dam or standpipe diameter for a secondary roof drain, in in. (mm).
Design rainfall intensity, in/h (mm/h).

Rate out of a single drainage system, in gal./min (m³/s).

Height of level roof edge that allows for free overflow drainage of water when the roof edge is acting as the secondary drainage system, in ft (m).

DRAINAGE

Roofs are not always designed to sustain the flow of short-duration rainfall. For example, the International Building Code (ICC 2012) has a 1-h duration storm period for the design of roofs with the primary drainage system.

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Precipitation Frequency Atlas (PFA) and the National Hydrological Design Studies Center provide data in inches per hour for the 15-min duration/15-min return interval. http://hdsc.nws.noaa.gov/hdsc/plots/precipitation_intensity/ (i in Eq. [C8.3.1]) is in the units of inches per hour. If precipitation depth is provided, a conversion to intensity is required.

The following roof conditions adversely affect the critical duration, or increase the peak flow rate, and should be avoided or appropriately considered by the designer when determining the design rain load:

1. Roofs with internal gutters that have limited storage capacity and quickly fill with rainwater. Gutters are typically sized for 2- to 5-min duration storms since their storage capacity is much shorter than the critical duration of the roof drains, scuppers or internal drains.
2. Architecturally complex roofs with internal gutters and significant gutter slopes. Significant gutter slopes can cause water to pool in the gutters.

Referenced consensus standards are listed at the end of each chapter of provisions, where they are listed by number with title, publisher, year of publication (and the sections that cite them). In text, they are mentioned only by number: ACI 318, ANSI/AISI S100, ASTM D1536.

Reference citations are listed at the end of each chapter of commentary, where they are listed by author and date with accompanying bibliographic information. In the text, these references are called out by author and date: ASHRAE (2000); Bachman and Dowty (2008); NEHRP (2009).

CONSENSUS STANDARDS AND OTHER REFERENCED DOCUMENTS

This section lists the consensus standards and other documents that shall be considered part of this standard to the extent referenced in this chapter.

ACI 318, *Building code requirements for structural concrete and commentary*. American Concrete Institute, 2014.

ANSI/AISI S100, *North American specification for the design of cold-formed steel structural members*. American Iron and Steel Institute, 2009.

ASTM D1536, *Method of test for color difference using the colormaster differential calorimeter*, 1964.

REFERENCES

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). (2000). *Practical guide to seismic restraint, RP-812*. ASHRAE, Atlanta, GA.

Bachman, R. E., and Dowty, S. M. (2008). "Nonstructural component or nonbuilding structure?" *Bldg. Safety J.* (April-May).

National Earthquake Hazards Reduction Program (NEHRP). (2009). NEHRP recommended provisions for seismic regulations for new buildings and other structures, NEHRP, Washington, DC.

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This revision of the standard began in 2011 and incorporates information as described in the commentary.

This standard was prepared through the consensus standards process by balloting in compliance with procedures of ASCE's Codes and Standards Activities Committee. The individuals who serve on the Standards Committee are listed as follows.

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IN MEMORIAM

Robert B. Paullus Jr., P.E., S.E., F.SEI, F.ASCE

1959–2015

Mr. Paullus served on the ASCE/SEI 7 Minimum Design Loads for Buildings and Other Structures Standard Committee for several cycles. During the 2017 cycle, he served on the Main Committee, the Subcommittee on Seismic Loads, and the Subcommittee on Wind Loads. Mr. Paullus was a tireless advocate for improvement of seismic design practices and requirements in Tennessee and surrounding regions at risk from severe shaking from the New Madrid fault zone.

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CHAPTER 1 GENERAL

1.1 SCOPE

This standard provides minimum loads, hazard levels, associated criteria, and intended performance goals for buildings, other structures, and their nonstructural components that are subject to building code requirements. The loads, load combinations, and associated criteria provided herein are to be used with design strengths or allowable stress limits contained in design specifications for conventional structural materials. Used together, they are deemed capable of providing the intended performance levels for which the provisions of this standard have been developed. Procedures for applying alternative means to demonstrate acceptable performance are also described.

1.2 DEFINITIONS AND SYMBOLS

1.2.1 Definitions. The following definitions apply to the provisions of the entire standard.

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”).

AUTHORITY HAVING JURISDICTION: The organization, political subdivision, office, or individual charged with the responsibility of administering and enforcing the provisions of this standard.

BUILDINGS: Structures, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended occupancy.

DESIGN STRENGTH: The product of the nominal strength and a resistance factor.

DESIGNATED NONSTRUCTURAL SYSTEM: A non-structural component or system that is essential to the intended function of a Risk Category IV structure or that is essential to Life Safety in structures assigned to other Risk Categories.

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 the nominal load and a load factor.

HIGHLY TOXIC SUBSTANCE: As defined in 29 CFR 1910.1200, Appendix A, with Amendments as of February 1, 2000.

IMPORTANCE FACTOR: A factor that accounts for the degree of risk to human life, health, and welfare associated with damage to property or loss of use or functionality.

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

LOAD EFFECTS: Forces and deformations produced in structural members by the applied loads.

LOAD FACTOR: A factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transform 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 all building materials, occupants and their possessions, environmental effects, differential movement, and restrained dimensional changes. Permanent loads are loads in which variations over time are rare or of small magnitude. All other loads are variable loads (see also “nominal loads”).

NOMINAL LOADS: The magnitudes of the loads specified in this standard for dead, live, soil, wind, snow, rain, flood, and earthquake loads.

NOMINAL STRENGTH: The capacity of a structure or member to resist the effects of loads, as determined by computations using specified material strengths and dimensions and formulas 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.

OCCUPANCY: The purpose for which a building or other structure, or part thereof, is used or intended to be used.

OTHER STRUCTURES: Structures, other than buildings, for which loads are specified in this standard.

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

PERFORMANCE-BASED PROCEDURES: An alternative to the prescriptive procedures in this standard characterized by project-specific engineering analysis, optionally supplemented by limited testing, to determine the computed reliability of an individual building or structure.

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”).

RISK CATEGORY: A categorization of buildings and other structures for determination of flood, snow, ice, and earthquake loads based on the risk associated with unacceptable performance. See Table 1.5-1.

SERVICE LOADS: Loads imparted on a building or other structure because of (1) self-weight and superimposed dead load, (2) live loads assumed to be present during normal occupancy or use of the building or other structure, (3) environmental loads that are expected to occur during the defined service life of a building or other structure, and (4) self-straining forces and effects. Service live loads and environmental loads for a