Chapter 16: Structural Design

General Comments

This chapter contains the commentary for the following structural topics: definitions of structural terms, construction document requirements, load combinations, dead loads, live loads, snow loads, wind loads, soil lateral loads, rain loads, flood loads and earthquake loads. This chapter provides minimum design requirements so that all buildings and structures are proportioned to resist the loads and forces that are likely to be encountered. The loads specified herein have been established through research and service performance of buildings and structures. The application of these loads and adherence to the serviceability criteria will enhance the protection of life and property. The earthquake loads, wind loads and snow loads in this chapter are based on the 2005 edition of ASCE 7. The earthquake criteria and ASCE 7 load requirements are based on the National Earthquake Hazards Reduction Program's (NEHRP) *Recommended Provisions for Seismic Regulations for New Buildings and other Structures* (FEMA 450). The NEHRP provisions were prepared by the Building Seismic Safety Council (BSSC) for the Federal Emergency Management Agency (FEMA).

Purpose

The purpose of this chapter is to prescribe minimum structural loading requirements for use in the design and construction of buildings and structures with the intent to minimize hazard to life and improve the occupancy capability of essential facilities after a design level event or occurrence.

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.

❖ While a significant portion of Chapter 16 is dedicated to the determination of minimum design loads, it also includes other important criteria that impact the design of structures, such as the permitted design methodologies, as well as the combinations of design loads used to establish the required minimum strength of structural members. Unless stated otherwise, the criteria found in this chapter are applicable to all buildings and structures. See Chapter 34 for application of these requirements to alterations, additions or repairs to existing structures.

SECTION 1602 DEFINITIONS AND NOTATIONS

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

❖ Certain terms are used in the code to describe something very specific to the related subject matter while other terms may have multiple meanings that can vary based on the subject matter and context. To avoid misunderstandings, it is preferable to reach a consensus on the meaning of these terms. Definitions are intended to facilitate the understanding of code provisions and to minimize potential confusion.

This section contains definitions of terms associated with structural design and minimum load criteria. Note that these terms are also listed in Chapter 2 with a cross reference to this section. Definitions that pertain primarily to structural design loads are included within this chapter to provide convenient access to them without having to refer back to Chapter 2. The use and application of all defined terms, including those defined herein, as well as undefined terms are set forth in Section 201.

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").

❖ This definition describes the allowable stress design method, which is one of the design approaches recognized under the code in Section 1604.1. In this approach, the computed stresses determined from the unfactored, or "nominal loads" (see definition on page 16-4) cannot exceed allowable stresses, which provide a factor of safety. The material chapters of the code specify either the allowable stresses for a given material or, in some cases, provide allowable capacities of specific assemblies, such as the wood structural panel shear wall capacities specified in Chapter 23.

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 the weight of fixed service equipment, such as cranes, plumbing stacks and risers, electrical feeders, heating, ventilating and air-conditioning systems and automatic sprinkler systems.

❖ The definition of "Dead loads" identifies the type of items that must be accounted for (also see Section 1607.11.3 for inclusion of items on landscaped roofs). This definition is necessary to distinguish dead loads from other loads, and for use in load combinations, as specified by Section 1605. Dead loads are considered permanent in the load combinations. The nominal dead load is to be determined in accordance with Section 1606.

The weights of service equipment, such as plumbing stacks and risers; heating, ventilating and air-conditioning (HVAC) equipment; elevators and elevator machinery; fire protection systems and similar fixed equipment are to be included in the dead load. For the most part, tracking the weights of each utility system is not practical and the structural design is therefore based on a dead load allowance for these items. At times the actual weight of equipment to be installed is unknown during the design phase of a building because the supplier of the equipment has yet to be determined. The structural design must often proceed based on an estimated equipment dead load. For additional comments on dead load estimates, see the commentary to Section 1606.2.

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

❖ This definition is needed to apply the strength design requirements in the code. The design strength is the nominal strength multiplied by a resistance or strength reduction factor that is less than one. The design strength and corresponding strength reduction factors are specified in the applicable material chapter of the code or a standard that is referenced therein.

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.

❖ Floor and roof diaphragms act to transfer the lateral forces, such as wind or seismic loads, to the vertical-resisting elements (e.g., shear walls, braced frames, moment frames, etc.) supporting them at their perimeter or intermittent locations.

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.

❖ Blocked diaphragms are horizontal or nearly horizontal assemblies designed to resist high shear forces in light-frame construction. Diaphragm sheathing may be applied with its long dimension either perpendicular or parallel to the main framing members. When the edge of the sheathing is not supported by the main framing member, it is considered to be unblocked. Blocking is accomplished by installing a framing member parallel to the otherwise unsupported edge of the sheathing. In some cases, the code may require blocking, while in other cases, the capacity of a diaphragm assembly will vary based on whether it is blocked or unblocked.

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 boundary is typically the connection between the floor or roof sheathing and the band board surrounding the diaphragm.

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

❖ A diaphragm acts as a deep horizontal beam. The chords of the beam are the elements at the boundary of the diaphragm that are perpendicular to the direction of the applied load.

Diaphragm flexible. A diaphragm is flexible for the purpose of distribution of story shear and torsional moment where so indicated in Section 12.3.1 of ASCE 7, as modified in Section 1613.6.1.

❖ Because analysis requirements in Section 1604.4 depend on the type of diaphragm, it is necessary to distinguish a rigid diaphragm from a flexible diaphragm. A flexible diaphragm deforms more than a rigid diaphragm when subjected to the same load. Where the diaphragm is determined to be flexible, the effect of diaphragm rigidity on the distribution of lateral forces is negligible and it need not be considered in the structural analysis. Load distribution from a flexible diaphragm to vertical supporting elements need not include torsional effects and is usually based on the tributary area associated with those elements.

This definition facilitates the classification of the diaphragm. While these diaphragm definitions apply to lateral loads in general, this definition makes a direct reference to the ASCE 7 earthquake provision that addresses the classification of diaphragms. That provision prescribes diaphragm construction that can be assumed to be flexible without the need of a substantiating calculation. Similarly, it prescribes diaphragm construction that can be assumed to be rigid.

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.

❖ This definition facilitates the classification of a diaphragm. A rigid diaphragm deforms less than a flexible diaphragm when subjected to the same load. Load distribution from a rigid diaphragm is based on the stiffness of the vertical-resisting elements. Because they act as rigid bodies, torsion is also a consideration (see Section 1604.4 for analysis requirements).

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

❖ An understanding of duration of load is necessary since the allowable design stresses for wood members and fasteners must be modified by a duration of load factor that is a function of the length of time that the wood member must resist an applied load. See Section 4.3 of the NDS for discussion of the load duration factor for wood structures. Note that it can be applied in the basic allowable stress load combinations of Section 1605.3.1 even though traditional allowable stress increases are not permitted.

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.

❖ This definition is needed to facilitate identification of Occupancy Category IV buildings under Section 1604.5. This is critical in determining the design earthquake, flood, snow and wind load criteria that apply to the facility.

FABRIC PARTITION. A partition consisting of a finished surface made of fabric, without a continuous rigid backing, that is directly attached to a framing system in which the vertical framing members are spaced greater than 4 feet (1219 mm) on center.

❖ This definition identifies which assemblies are considered fabric partitions for the purpose of applying the specific load criteria that is given in Section 1607.13.1. They are typically for uses such as office furniture panel systems, for open floor plans in offices and similar occupancies.

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

❖ This definition explains the term "Factored loads" so that the loads to be applied are clear. Factored loads are determined for strength design (for load and resistance factor design) by multiplying nominal load (see definition) by a load factor, as in the load combinations of Section 1605.2. While this definition is applicable to most loads, the exception would be the earthquake load effect, E, determined in Section 1613, which is considered a strength level load without applying a load factor. This is based on the approach taken in the 1997 NEHRP provisions (see FEMA 302) and is evidenced by a load factor of 1.0 being applied to E in the strength load combinations given by Equations 16-5 and 16-7.

GUARD. See Section 1002.1.

❖ This is simply a cross reference to the section where the complete definition is located. It is listed here since guard loads are addressed in this chapter.

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.

❖ This definition identifies the scope of the type of loading addressed in Section 1607.8. The effect of impact loads on a structure can be significantly higher than the weight of the impacting elements because of their movement or vibration.

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).

❖ This definition is needed for a clear understanding of the load and resistance factor design methodology.

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.

❖ This definition identifies the scope of the type of loading included Section 1607. Generally, live loads are not environmental loads or dead loads, but are transient in nature and will vary in magnitude over the life of a structure.

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.

❖ This definition is needed for the proper application of the load combinations in this chapter. This definition clarifies that roof loads, such as snow loads, are not live loads.

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.

❖ This definition describes the load and resistance factor design method, which is one of the design approaches recognized under the code in Section 1604.1. It is needed for the proper application of the steel design requirements in Chapter 22 and the wood design requirements in Chapter 23.

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

❖ This definition is needed to properly apply the structural load requirements in this chapter. "Load effects" is a collective term used to refer to the internal member forces and member deformations that result from the applied loads.