

An ACI Standard

Building Code Requirements for Structural Concrete (ACI 318-19)

Commentary on Building Code Requirements for Structural Concrete (ACI 318R-19)

Reported by ACI Committee 318

ACI 318-19



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Building Code Requirements for Structural Concrete (ACI 318-19)

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An ACI Standard

Commentary on Building Code Requirements for Structural Concrete (ACI 318R-19)

Reported by ACI Committee 318

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Building Code Requirements for Structural Concrete and Commentary

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PREFACE TO ACI 318-19

The “Building Code Requirements for Structural Concrete” (“Code”) provides minimum requirements for the materials, design, and detailing of structural concrete buildings and, where applicable, nonbuilding structures. This Code was developed by an ANSI-approved consensus process and addresses structural systems, members, and connections, including cast-in-place, precast, shotcrete, plain, nonprestressed, prestressed, and composite construction. Among the subjects covered are: design and construction for strength, serviceability, and durability; load combinations, load factors, and strength reduction factors; structural analysis methods; deflection limits; mechanical and adhesive anchoring to concrete; development and splicing of reinforcement; construction document information; field inspection and testing; and methods to evaluate the strength of existing structures.

The Code was substantially reorganized and reformatted in 2014, and this Code continues and expands that same organizational philosophy. The principal objectives of the reorganization were to present all design and detailing requirements for structural systems or for individual members in chapters devoted to those individual subjects, and to arrange the chapters in a manner that generally follows the process and chronology of design and construction. Information and procedures that are common to the design of multiple members are located in utility chapters. Additional enhancements implemented in this Code to provide greater clarity and ease of use include the first use of color illustrations and the use of color to help the user navigate the Code and quickly find the information they need. Special thanks to Bentley Systems, Incorporated, for use of their ProConcrete software to produce many of the figures found in the Commentary.

Uses of the Code include adoption by reference in a general building code, and earlier editions have been widely used in this manner. The Code is written in a format that allows such reference without change to its language. Therefore, background details or suggestions for carrying out the requirements or intent of the Code provisions cannot be included within the Code itself. The Commentary is provided for this purpose.

Some considerations of the committee in developing the Code are discussed in the Commentary, with emphasis given to the explanation of new or revised provisions. Much of the research data referenced in preparing the Code is cited for the user desiring to study individual questions in greater detail. Other documents that provide suggestions for carrying out the requirements of the Code are also cited.

Technical changes from ACI 318-14 to ACI 318-19 are outlined in the August 2019 issue of *Concrete International* and are marked in the text of this Code with change bars in the margins.

KEYWORDS

admixtures; aggregates; anchorage (structural); beam-column frame; beams (supports); caissons; cements; cold weather; columns (supports); combined stress; composite construction (concrete to concrete); compressive strength; concrete; construction documents; construction joints; continuity (structural); contraction joints; cover; curing; deep beams; deep foundations; deflections; drilled piers; earthquake-resistant structures; flexural strength; floors; footings; formwork (construction); hot weather; inspection; isolation joints; joints (junctions); joists; lightweight concretes; load tests (structural); loads (forces); mixture proportioning; modulus of elasticity; moments; piles; placing; plain concrete; precast concrete; prestressed concrete; prestressing steels; quality control; reinforced concrete; reinforcing steels; roofs; serviceability; shear strength; shotcrete; spans; splicing; strength analysis; stresses; structural analysis; structural design; structural integrity; structural walls; T-beams; torsion; walls; water; welded wire reinforcement.

INTRODUCTION

ACI 318-19, “Building Code Requirements for Structural Concrete,” hereinafter called the Code or the 2019 Code, and ACI 318R-19, “Commentary,” are presented in a side-by-side column format. These are two separate but coordinated documents, with Code text placed in the left column and the corresponding Commentary text aligned in the right column. Commentary section numbers are preceded by an “R” to further distinguish them from Code section numbers. The two documents are bound together solely for the user’s convenience. Each document carries a separate enforceable and distinct copyright.

As the name implies, “Building Code Requirements for Structural Concrete” is meant to be used as part of a legally adopted building code and as such must differ in form and substance from documents that provide detailed specifications, recommended practice, complete design procedures, or design aids.

The Code is intended to cover all buildings of the usual types, both large and small. Requirements more stringent than the Code provisions may be desirable for unusual construction. The Code and Commentary cannot replace sound engineering knowledge, experience, and judgment.

A building code states only the minimum requirements necessary to provide for public health and safety. The Code is based on this principle. For any structure, the owner or the licensed design professional may require the quality of materials and construction to be higher than the minimum requirements necessary to protect the public as stated in the Code. However, lower standards are not permitted.

The Code has no legal status unless it is adopted by the government bodies having the police power to regulate building design and construction. Where the Code has not been adopted, it may serve as a reference to good practice even though it has no legal status.

The Code and Commentary are not intended for use in settling disputes between the owner, engineer, architect, contractor, or their agents, subcontractors, material suppliers, or testing agencies. Therefore, the Code cannot define the contract responsibility of each of the parties in usual construction. General references requiring compliance with the Code in the project specifications should be avoided because the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on a detailed knowledge of the design. Design-build construction contractors, however, typically combine the design and construction responsibility. Generally, the contract documents should contain all of the necessary requirements to ensure compliance with the Code. In part, this can be accomplished by reference to specific Code sections in the project specifications. Other ACI publications, such as “Specifications for Structural Concrete (ACI 301M)” are written specifically for use as contract documents for construction.

The Commentary discusses some of the considerations of Committee 318 in developing the provisions contained in the Code. Emphasis is given to the explanation of new or revised provisions that may be unfamiliar to Code users. In addition, comments are included for some items contained in previous editions of the Code to make the present Commentary independent of the previous editions. Comments on specific provisions are made under the corresponding chapter and section numbers of the Code.

The Commentary is not intended to provide a complete historical background concerning the development of the Code, nor is it intended to provide a detailed résumé of the studies and research data reviewed by the committee in formulating the provisions of the Code. However, references to some of the research data are provided for those who wish to study the background material in depth.

The Commentary directs attention to other documents that provide suggestions for carrying out the requirements and intent of the Code. However, those documents and the Commentary are not a part of the Code.

The Commentary is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations, and who will accept responsibility for the application of the information it contains. ACI disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom. Reference to the Commentary shall not be made in construction documents. If items found in the Commentary are desired by the licensed design professional to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the licensed design professional.

It is recommended to have the materials, processes, quality control measures, and inspections described in this document tested, monitored, or performed by individuals holding the appropriate ACI Certification or equivalent, when available. The personnel certification programs of the American Concrete Institute and the Post-Tensioning Institute; the plant certification programs of the Precast/Prestressed Concrete Institute, the Post-Tensioning Institute, and the National Ready Mixed Concrete Association; and the Concrete Reinforcing Steel Institute’s Voluntary Certification Program for Fusion-Bonded Epoxy Coating Applicator Plants are available for this purpose. In addition, “Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection” (ASTM E329-18) specifies performance requirements for inspection and testing agencies.

Design reference materials illustrating applications of the Code requirements are listed and described in the back of this document.

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CHAPTER 1—GENERAL

CODE

COMMENTARY

1.1—Scope of ACI 318

1.1.1 This chapter addresses (a) through (h):

- (a) General requirements of this Code
- (b) Purpose of this Code
- (c) Applicability of this Code
- (d) Interpretation of this Code
- (e) Definition and role of the building official and the licensed design professional
- (f) Construction documents
- (g) Testing and inspection
- (h) Approval of special systems of design, construction, or alternative construction materials

1.2—General

1.2.1 ACI 318, “Building Code Requirements for Structural Concrete,” is hereafter referred to as “this Code.”

1.2.2 In this Code, the general building code refers to the building code adopted in a jurisdiction. When adopted, this Code forms part of the general building code.

1.2.3 The official version of this Code is the English language version, using inch-pound units, published by the American Concrete Institute.

1.2.4 In case of conflict between the official version of this Code and other versions of this Code, the official version governs.

1.2.5 This Code provides minimum requirements for the materials, design, construction, and strength evaluation of structural concrete members and systems in any structure designed and constructed under the requirements of the general building code.

1.2.6 Modifications to this Code that are adopted by a particular jurisdiction are part of the laws of that jurisdiction, but are not a part of this Code.

1.2.7 If no general building code is adopted, this Code provides minimum requirements for the materials, design, construction, and strength evaluation of members and systems in any structure within the scope of this Code.

1.3—Purpose

1.3.1 The purpose of this Code is to provide for public health and safety by establishing minimum requirements for

R1.1—Scope of ACI 318

R1.1.1 This Code includes provisions for the design of concrete used for structural purposes, including plain concrete; concrete containing nonprestressed reinforcement, prestressed reinforcement, or both; and anchoring to concrete. This chapter includes a number of provisions that explain where this Code applies and how it is to be interpreted.

R1.2—General

R1.2.2 The American Concrete Institute recommends that this Code be adopted in its entirety.

R1.2.3 Committee 318 develops the Code in English, using inch-pound units. Based on that version, Committee 318 approved three other versions:

- (a) In English using SI units (ACI 318M)
- (b) In Spanish using SI units (ACI 318S)
- (c) In Spanish using inch-pound units (ACI 318SUS).

Jurisdictions may adopt ACI 318, ACI 318M, ACI 318S, or ACI 318SUS.

R1.2.5 This Code provides minimum requirements and exceeding these minimum requirements is not a violation of the Code.

The licensed design professional may specify project requirements that exceed the minimum requirements of this Code.

R1.3—Purpose

R1.3.1 This Code provides a means of establishing minimum requirements for the design and construction of

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strength, stability, serviceability, durability, and integrity of concrete structures.

1.3.2 This Code does not address all design considerations.

1.3.3 Construction means and methods are not addressed in this Code.

1.4—Applicability

1.4.1 This Code shall apply to concrete structures designed and constructed under the requirements of the general building code.

1.4.2 Provisions of this Code shall be permitted to be used for the assessment, repair, and rehabilitation of existing structures.

1.4.3 Applicable provisions of this Code shall be permitted to be used for structures not governed by the general building code.

1.4.4 The design of thin shells and folded plate concrete structures shall be in accordance with [ACI 318.2](#), “Building Code Requirements for Concrete Thin Shells.”

1.4.5 This Code shall apply to the design of slabs cast on stay-in-place, noncomposite steel decks.

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structural concrete, as well as for acceptance of design and construction of concrete structures by the building officials or their designated representatives.

This Code does not provide a comprehensive statement of all duties of all parties to a contract or all requirements of a contract for a project constructed under this Code.

R1.3.2 The minimum requirements in this Code do not replace sound professional judgment or the licensed design professional’s knowledge of the specific factors surrounding a project, its design, the project site, and other specific or unusual circumstances to the project.

R1.4—Applicability

R1.4.2 Specific provisions for assessment, repair, and rehabilitation of existing concrete structures are provided in [ACI 562-19](#). Existing structures in ACI 562 are defined as structures that are complete and permitted for use.

R1.4.3 Structures such as arches, bins and silos, blast-resistant structures, chimneys, underground utility structures, gravity walls, and shielding walls involve design and construction requirements that are not specifically addressed by this Code. Many Code provisions, however, such as concrete quality and design principles, are applicable for these structures. Recommendations for design and construction of some of these structures are given in the following:

- “Code Requirements for Reinforced Concrete Chimneys and Commentary” ([ACI 307-08](#))
- “Standard Practice for Design and Construction of Concrete Silos and Stacking Tubes for Storing Granular Materials” ([ACI 313-97](#))
- “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary” ([ACI 349M](#))
- “Code for Concrete Containments” ([ACI 359](#))

R1.4.5 In its most basic application, the noncomposite steel deck serves as a form, and the concrete slab is designed to resist all loads, while in other applications the concrete slab may be designed to resist only the superimposed loads. The design of a steel deck in a load-resisting application is given in “Standard for Non-Composite Steel Deck and Concrete Slab Composite Action” ([ACI 308-10](#)).

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1.4.6 For one- and two-family dwellings, multiple single-family dwellings, townhouses, and accessory structures to these types of dwellings, the design and construction of cast-in-place footings, foundation walls, and slabs-on-ground in accordance with **ACI 332M** shall be permitted.

1.4.7 This Code does not apply to the design and installation of concrete piles, drilled piers, and caissons embedded in ground, except as provided in (a) through (c):

- (a) For portions of deep foundation members in air or water, or in soil incapable of providing adequate lateral restraint to prevent buckling throughout their length
- (b) For precast concrete piles supporting structures assigned to Seismic Design Categories A and B (**13.4**)
- (c) For deep foundation elements supporting structures assigned to Seismic Design Categories C, D, E, and F (**Ch. 13, 18.13**)

1.4.8 This Code does not apply to design and construction of slabs-on-ground, unless the slab transmits vertical loads or lateral forces from other portions of the structure to the soil.

1.4.9 This Code does not apply to the design and construction of tanks and reservoirs.

1.4.10 This Code does not apply to composite design slabs cast on stay-in-place composite steel deck. Concrete used in the construction of such slabs shall be governed by this Code, where applicable. Portions of such slabs designed as reinforced concrete are governed by this Code.

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(SDI NC). The SDI standard refers to this Code for the design and construction of the structural concrete slab.

R1.4.6 **ACI 332M** addresses only the design and construction of cast-in-place footings, foundation walls supported on continuous footings, and slabs-on-ground for limited residential construction applications.

The **2015 IBC** requires design and construction of residential post-tensioned slabs on expansive soils to be in accordance with **PTI DC10.5-12**, which provides requirements for slab-on-ground foundations, including soil investigation, design, and analysis. Guidance for the design and construction of post-tensioned slabs-on-ground that are not on expansive soils can be found in **ACI 360R**. Refer to R1.4.8.

R1.4.7 The design and installation of concrete piles fully embedded in the ground is regulated by the general building code. The 2019 edition of the Code contains some provisions that previously were only available in the general building code. In addition to the provisions in this Code, recommendations for concrete piles are given in **ACI 543R**, recommendations for drilled piers are given in **ACI 336.3R**, and recommendations for precast prestressed concrete piles are given in “Recommended Practice for Design, Manufacture, and Installation of Prestressed Concrete Piling” (**PCI 1993**). Requirements for the design and construction of micropiles are not specifically addressed by this Code.

R1.4.8 Detailed recommendations for design and construction of slabs-on-ground and floors that do not transmit vertical loads or lateral forces from other portions of the structure to the soil are given in **ACI 360R**. This guide presents information on the design of slabs-on-ground, primarily industrial floors and the slabs adjacent to them. The guide addresses the planning, design, and detailing of the slabs. Background information on the design theories is followed by discussion of the soil support system, loadings, and types of slabs. Design methods are given for structural plain concrete, reinforced concrete, shrinkage-compensating concrete, and post-tensioned concrete slabs.

R1.4.9 Requirements and recommendations for the design and construction of tanks and reservoirs are given in **ACI 350M**, **ACI 334.1R**, and **ACI 372R**.

R1.4.10 In this type of construction, the steel deck serves as the positive moment reinforcement. The design and construction of concrete-steel deck slabs is described in “Standard for Composite Steel Floor Deck-Slabs” (**SDI C**). The standard refers to the appropriate portions of this Code for the design and construction of the concrete portion of the composite assembly. SDI C also provides guidance for design of composite-concrete-steel deck slabs. The design of negative moment reinforcement to be provided in the

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1.5—Interpretation

1.5.1 The principles of interpretation in this section shall apply to this Code as a whole unless otherwise stated.

1.5.2 This Code consists of chapters and appendixes, including text, headings, tables, figures, footnotes to tables and figures, and referenced standards.

1.5.3 The Commentary consists of a preface, introduction, commentary text, tables, figures, and cited publications. The Commentary is intended to provide contextual information, but is not part of this Code, does not provide binding requirements, and shall not be used to create a conflict with or ambiguity in this Code.

1.5.4 This Code shall be interpreted in a manner that avoids conflict between or among its provisions. Specific provisions shall govern over general provisions.

1.5.5 This Code shall be interpreted and applied in accordance with the plain meaning of the words and terms used. Specific definitions of words and terms in this Code shall be used where provided and applicable, regardless of whether other materials, standards, or resources outside of this Code provide a different definition.

1.5.6 The following words and terms in this Code shall be interpreted in accordance with (a) through (e):

- (a) The word “shall” is always mandatory.
- (b) Provisions of this Code are mandatory even if the word “shall” is not used.
- (c) Words used in the present tense shall include the future.
- (d) The word “and” indicates that all of the connected items, conditions, requirements, or events shall apply.
- (e) The word “or” indicates that the connected items, conditions, requirements, or events are alternatives, at least one of which shall be satisfied.

1.5.7 In any case in which one or more provisions of this Code are declared by a court or tribunal to be invalid, that ruling shall not affect the validity of the remaining provisions of this Code, which are severable. The ruling of a court or tribunal shall be effective only in that court’s jurisdiction, and shall not affect the content or interpretation of this Code in other jurisdictions.

1.5.8 If conflicts occur between provisions of this Code and those of standards and documents referenced in [Chapter 3](#), this Code shall apply.

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supports is a common example where a portion of the slab is designed in conformance with this Code.

R1.5—Interpretation

R1.5.4 General provisions are broad statements, such as a building needs to be serviceable. Specific provisions, such as explicit reinforcement distribution requirements for crack control, govern over the general provisions.

R1.5.5 [ACI Concrete Terminology \(2018\)](#) is the primary resource to help determine the meaning of words or terms that are not defined in the Code. Dictionaries and other reference materials commonly used by licensed design professionals may be used as secondary resources.

R1.5.7 This Code addresses numerous requirements that can be implemented fully without modification if other requirements in this Code are determined to be invalid. This severability requirement is intended to preserve this Code and allow it to be implemented to the extent possible following legal decisions affecting one or more of its provisions.

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1.6—Building official

1.6.1 All references in this Code to the building official shall be understood to mean persons who administer and enforce this Code.

1.6.2 Actions and decisions by the building official affect only the specific jurisdiction and do not change this Code.

1.6.3 The building official shall have the right to order testing of any materials used in concrete construction to determine if materials are of the quality specified.

1.7—Licensed design professional

1.7.1 All references in this Code to the licensed design professional shall be understood to mean the engineer in either 1.7.1.1 or 1.7.1.2.

1.7.1.1 The licensed design professional responsible for, and in charge of, the structural design work.

1.7.1.2 A specialty engineer to whom a specific portion of the structural design work has been delegated subject to the conditions of (a) and (b).

(a) The authority of the specialty engineer shall be explicitly limited to the delegated design work.

(b) The portion of design work delegated shall be well defined such that responsibilities and obligations of the parties are apparent.

1.8—Construction documents and design records

1.8.1 The licensed design professional shall provide in the construction documents the information required in **Chapter 26** and that required by the jurisdiction.

1.8.2 Calculations pertinent to design shall be filed with the construction documents if required by the building official. Analyses and designs using computer programs shall be permitted provided design assumptions, user input, and computer-generated output are submitted. Model analysis shall be permitted to supplement calculations.

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R1.6—Building official

R1.6.1 Building official is defined in **2.3**.

R1.6.2 Only the American Concrete Institute has the authority to alter or amend this Code.

R1.7—Licensed design professional

R1.7.1 Licensed design professional is defined in **2.3**.

R1.7.1.2(b) A portion of the design work may be delegated to a specialty engineer during the design phase or to the contractor in the construction documents. Examples of design work delegated to a specialty engineer or contractor include precast concrete and post-tensioned concrete design.

R1.8—Construction documents and design records

R1.8.1 The provisions of **Chapter 26** for preparing project drawings and specifications are, in general, consistent with those of most general building codes. Additional information may be required by the building official.

R1.8.2 Documented computer output is acceptable instead of manual calculations. The extent of input and output information required will vary according to the specific requirements of individual building officials. However, if a computer program has been used, only skeleton data should normally be required. This should consist of sufficient input and output data and other information to allow the building official to perform a detailed review and make comparisons using another program or manual calculations. Input data should be identified as to member designation, applied loads, and span lengths. The related output data should include member designation and the shears, moments, and reactions at key points in the span. For column design, it is desirable to include moment magnification factors in the output where applicable.

The Code permits model analysis to be used to supplement structural analysis and design calculations. Documentation

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of the model analysis should be provided with the related calculations. Model analysis should be performed by an individual having experience in this technique.

1.9—Testing and inspection

1.9.1 Concrete materials shall be tested in accordance with the requirements of **Chapter 26**.

1.9.2 Concrete construction shall be inspected in accordance with the general building code and in accordance with Chapter 26.

1.9.3 Inspection records shall include information in accordance with Chapter 26.

1.10—Approval of special systems of design, construction, or alternative construction materials

1.10.1 Sponsors of any system of design, construction, or alternative construction materials within the scope of this Code, the adequacy of which has been shown by successful use or by analysis or test, but which does not conform to or is not covered by this Code, shall have the right to present the data on which their design is based to the building official or to a board of examiners appointed by the building official. This board shall be composed of competent engineers and shall have authority to investigate the data so submitted, require tests, and formulate rules governing design and construction of such systems to meet the intent of this Code. These rules, when approved by the building official and promulgated, shall be of the same force and effect as the provisions of this Code.

R1.10—Approval of special systems of design, construction, or alternative construction materials

R1.10.1 New methods of design, new materials, and new uses of materials should undergo a period of development before being covered in a code. Hence, good systems or components might be excluded from use by implication if means were not available to obtain acceptance.

For special systems considered under this section, specific tests, load factors, deflection limits, and other pertinent requirements should be set by the board of examiners, and should be consistent with the intent of the Code.

The provisions of this section do not apply to model tests used to supplement calculations under 1.8.2 or to strength evaluation of existing structures under **Chapter 27**.

CHAPTER 2—NOTATION AND TERMINOLOGY

CODE COMMENTARY

2.1—Scope

2.1.1 This chapter defines notation and terminology used in this Code.

2.2—Notation

- a = depth of equivalent rectangular stress block, mm
- a_v = shear span, equal to distance from center of concentrated load to either: (a) face of support for continuous or cantilevered members, or (b) center of support for simply supported members, mm
- A_b = area of an individual bar or wire, mm²
- A_{bp} = area of the attachment base plate in contact with concrete or grout when loaded in compression, mm²
- A_{brg} = net bearing area of the head of stud, anchor bolt, or headed deformed bar, mm²
- A_c = area of concrete section resisting shear transfer, mm²
- A_{cf} = greater gross cross-sectional area of the two orthogonal slab-beam strips intersecting at a column of a two-way prestressed slab, mm²
- A_{ch} = cross-sectional area of a member measured to the outside edges of transverse reinforcement, mm²
- A_{cp} = area enclosed by outside perimeter of concrete cross section, mm²
- A_{cs} = cross-sectional area at one end of a strut in a strut-and-tie model, taken perpendicular to the axis of the strut, mm²
- A_{ct} = area of that part of cross section between the flexural tension face and centroid of gross section, mm²
- A_{cv} = gross area of concrete section bounded by web thickness and length of section in the direction of shear force considered in the case of walls, and gross area of concrete section in the case of diaphragms. Gross area is total area of the defined section minus area of any openings, mm²
- A_{cw} = area of concrete section of an individual pier, horizontal wall segment, or coupling beam resisting shear, mm²
- $A_{ef,sl}$ = effective bearing area of shear lug, mm²
- A_f = area of reinforcement in bracket or corbel resisting design moment, mm²
- A_g = gross area of concrete section, mm² For a hollow section, A_g is the area of the concrete only and does not include the area of the void(s)
- A_h = total area of shear reinforcement parallel to primary tension reinforcement in a corbel or bracket, mm²
- A_{hs} = total cross-sectional area of hooked or headed bars being developed at a critical section, mm²
- A_j = effective cross-sectional area within a joint in a plane parallel to plane of beam reinforcement generating shear in the joint, mm²
- A_ℓ = total area of longitudinal reinforcement to resist torsion, mm²
- $A_{\ell,min}$ = minimum area of longitudinal reinforcement to resist torsion, mm²

R2.2—Notation

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A_n	= area of reinforcement in bracket or corbel resisting factored restraint force N_{uc} , mm ²
A_{nz}	= area of a face of a nodal zone or a section through a nodal zone, mm ²
A_{Na}	= projected influence area of a single adhesive anchor or group of adhesive anchors, for calculation of bond strength in tension, mm ²
A_{Nao}	= projected influence area of a single adhesive anchor, for calculation of bond strength in tension if not limited by edge distance or spacing, mm ²
A_{Nc}	= projected concrete failure area of a single anchor or group of anchors, for calculation of strength in tension, mm ²
A_{Nco}	= projected concrete failure area of a single anchor, for calculation of strength in tension if not limited by edge distance or spacing, mm ²
A_o	= gross area enclosed by torsional shear flow path, mm ²
A_{oh}	= area enclosed by centerline of the outermost closed transverse torsional reinforcement, mm ²
A_{pd}	= total area occupied by duct, sheathing, and prestressing reinforcement, mm ²
A_{ps}	= area of prestressed longitudinal tension reinforcement, mm ²
A_{pt}	= total area of prestressing reinforcement, mm ²
A_s	= area of nonprestressed longitudinal tension reinforcement, mm ²
A_s'	= area of compression reinforcement, mm ²
A_{sc}	= area of primary tension reinforcement in a corbel or bracket, mm ²
$A_{se,N}$	= effective cross-sectional area of anchor in tension, mm ²
$A_{se,V}$	= effective cross-sectional area of anchor in shear, mm ²
A_{sh}	= total cross-sectional area of transverse reinforcement, including crossties, within spacing s and perpendicular to dimension b_c , mm ²
A_{si}	= total area of surface reinforcement at spacing s_i in the i -th layer crossing a strut, with reinforcement at an angle α_i to the axis of the strut, mm ²
$A_{s,min}$	= minimum area of flexural reinforcement, mm ²
A_{st}	= total area of nonprestressed longitudinal reinforcement including bars or steel shapes, and excluding prestressing reinforcement, mm ²
A_t	= area of one leg of a closed stirrup, hoop, or tie resisting torsion within spacing s , mm ²
A_{th}	= total cross-sectional area of ties or stirrups confining hooked bars, mm ²
A_{tp}	= area of prestressing reinforcement in a tie, mm ²
A_{tr}	= total cross-sectional area of all transverse reinforcement within spacing s that crosses the potential plane of splitting through the reinforcement being developed, mm ²
A_{ts}	= area of nonprestressed reinforcement in a tie, mm ²

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A_{tt}	= total cross-sectional area of ties or stirrups acting as parallel tie reinforcement for headed bars, mm^2
A_v	= area of shear reinforcement within spacing s , mm^2
A_{vd}	= total area of reinforcement in each group of diagonal bars in a diagonally reinforced coupling beam, mm^2
A_{vf}	= area of shear-friction reinforcement, mm^2
A_{vh}	= area of shear reinforcement parallel to flexural tension reinforcement within spacing s_2 , mm^2
$A_{v,min}$	= minimum area of shear reinforcement within spacing s , mm^2
A_{Vc}	= projected concrete failure area of a single anchor or group of anchors, for calculation of strength in shear, mm^2
A_{Vco}	= projected concrete failure area of a single anchor, for calculation of strength in shear, if not limited by corner influences, spacing, or member thickness, mm^2
A_1	= loaded area for consideration of bearing, strut, and node strength, mm^2
A_2	= area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge contained wholly within the support and having its upper base equal to the loaded area. The sides of the pyramid, cone, or tapered wedge shall be sloped one vertical to two horizontal, mm^2
b	= width of compression face of member, mm
b_c	= cross-sectional dimension of member core measured to the outside edges of the transverse reinforcement composing area A_{sh} , mm
b_f	= effective flange width, mm
b_o	= perimeter of critical section for two-way shear in slabs and footings, mm
b_s	= width of strut, mm
b_{sl}	= width of shear lug, mm
b_{slab}	= effective slab width, mm
b_t	= width of that part of cross section containing the closed stirrups resisting torsion, mm
b_v	= width of cross section at contact surface being investigated for horizontal shear, mm
b_w	= web width or diameter of circular section, mm
b_1	= dimension of the critical section b_o measured in the direction of the span for which moments are determined, mm
b_2	= dimension of the critical section b_o measured in the direction perpendicular to b_1 , mm
B_n	= nominal bearing strength, N
B_u	= factored bearing load, N
c	= distance from extreme compression fiber to neutral axis, mm
c_{ac}	= critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting, mm

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$c_{a,max}$ = maximum distance from center of an anchor shaft to the edge of concrete, mm

$c_{a,min}$ = minimum distance from center of an anchor shaft to the edge of concrete, mm

c_{a1} = distance from the center of an anchor shaft to the edge of concrete in one direction, mm. If shear is applied to anchor, c_{a1} is taken in the direction of the applied shear. If tension is applied to the anchor, c_{a1} is the minimum edge distance. Where anchors subject to shear are located in narrow sections of limited thickness, see R17.7.2.1.2

c'_{a1} = limiting value of c_{a1} where anchors are located less than $1.5c_{a1}$ from three or more edges, mm; see Fig. R17.7.2.1.2

c_{a2} = distance from center of an anchor shaft to the edge of concrete in the direction perpendicular to c_{a1} , mm

c_b = lesser of: (a) the distance from center of a bar or wire to nearest concrete surface, and (b) one-half the center-to-center spacing of bars or wires being developed, mm

c_c = clear cover of reinforcement, mm

c_{Na} = projected distance from center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor, mm

c_{sl} = distance from the centerline of the row of anchors in tension nearest the shear lug to the centerline of the shear lug measured in the direction of shear, mm

c_t = distance from the interior face of the column to the slab edge measured parallel to c_1 , but not exceeding c_1 , mm

c_1 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direction of the span for which moments are being determined, mm

c_2 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direction perpendicular to c_1 , mm

C_m = factor relating actual moment diagram to an equivalent uniform moment diagram

d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, mm

d' = distance from extreme compression fiber to centroid of longitudinal compression reinforcement, mm

d_a = outside diameter of anchor or shaft diameter of headed stud, headed bolt, or hooked bolt, mm

d'_a = value substituted for d_a if an oversized anchor is used, mm

d_{agg} = nominal maximum size of coarse aggregate, mm

d_b = nominal diameter of bar, wire, or prestressing strand, mm

d_p = distance from extreme compression fiber to centroid of prestressed reinforcement, mm

C = compressive force acting on a nodal zone, N

d_{burst} = distance from the anchorage device to the centroid of the bursting force, T_{burst} , mm

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d_{pile} = diameter of pile at footing base, mm
 D = effect of service dead load
 D_s = effect of superimposed dead load
 D_w = effect of self-weight dead load of the concrete structural system

e_{anc} = eccentricity of the anchorage device or group of devices with respect to the centroid of the cross section, mm

e_h = distance from the inner surface of the shaft of a J- or L-bolt to the outer tip of the J- or L-bolt, mm
 e'_N = distance between resultant tension load on a group of anchors loaded in tension and the centroid of the group of anchors loaded in tension, mm; e'_N is always positive
 e'_V = distance between resultant shear load on a group of anchors loaded in shear in the same direction, and the centroid of the group of anchors loaded in shear in the same direction, mm; e'_V is always positive
 E = effect of horizontal and vertical earthquake-induced forces
 E_c = modulus of elasticity of concrete, MPa
 E_{cb} = modulus of elasticity of beam concrete, MPa
 E_{cs} = modulus of elasticity of slab concrete, MPa
 EI = flexural stiffness of member, N·mm²
 $(EI)_{eff}$ = effective flexural stiffness of member, N·mm²
 E_p = modulus of elasticity of prestressing reinforcement, MPa
 E_s = modulus of elasticity of reinforcement and structural steel, excluding prestressing reinforcement, MPa
 f'_c = specified compressive strength of concrete, MPa
 $\sqrt{f'_c}$ = square root of specified compressive strength of concrete, MPa
 f'_{ci} = specified compressive strength of concrete at time of initial prestress, MPa
 $\sqrt{f'_{ci}}$ = square root of specified compressive strength of concrete at time of initial prestress, MPa
 f_{ce} = effective compressive strength of the concrete in a strut or a nodal zone, MPa
 f_d = stress due to unfactored dead load, at extreme fiber of section where tensile stress is caused by externally applied loads, MPa
 f_{dc} = decompression stress; stress in the prestressed reinforcement if stress is zero in the concrete at the same level as the centroid of the prestressed reinforcement, MPa
 f_{pc} = compressive stress in concrete, after allowance for all prestress losses, at centroid of cross section resisting externally applied loads or at junction of web and flange where the centroid lies within the flange, MPa. In a composite member, f_{pc} is the resultant compressive stress at centroid of composite section, or at junction of web and flange where the centroid lies within the flange, due to both prestress

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and moments resisted by precast member acting alone

f_{pe} = compressive stress in concrete due only to effective prestress forces, after allowance for all prestress losses, at extreme fiber of section if tensile stress is caused by externally applied loads, MPa

f_{ps} = stress in prestressed reinforcement at nominal flexural strength, MPa

f_{pu} = specified tensile strength of prestressing reinforcement, MPa

f_{py} = specified yield strength of prestressing reinforcement, MPa

f_r = modulus of rupture of concrete, MPa

f_s = tensile stress in reinforcement at service loads, excluding prestressed reinforcement, MPa

f'_s = compressive stress in reinforcement under factored loads, excluding prestressed reinforcement, MPa

f_{se} = effective stress in prestressed reinforcement, after allowance for all prestress losses, MPa

f_{si} = stress in the i -th layer of surface reinforcement, MPa

f_t = extreme fiber stress in the precompressed tension zone calculated at service loads using gross section properties after allowance of all prestress losses, MPa

f_{uta} = specified tensile strength of anchor steel, MPa

f_y = specified yield strength for nonprestressed reinforcement, MPa

f_{ya} = specified yield strength of anchor steel, MPa

f_{yt} = specified yield strength of transverse reinforcement, MPa

F = effect of service load due to fluids with well-defined pressures and maximum heights

F_{nn} = nominal strength at face of a nodal zone, N

F_{ns} = nominal strength of a strut, N

F_{nt} = nominal strength of a tie, N

F_{un} = factored force on the face of a node, N

F_{us} = factored compressive force in a strut, N

F_{ut} = factored tensile force in a tie, N

h = overall thickness, height, or depth of member, mm

h_a = thickness of member in which an anchor is located, measured parallel to anchor axis, mm

h_{ef} = effective embedment depth of anchor, mm

h_{anc} = dimension of anchorage device or single group of closely spaced devices in the direction of bursting being considered, mm

h'_{ef} = limiting value of h_{ef} where anchors are located less than $1.5h_{ef}$ from three or more edges, mm; refer to Fig. R17.6.2.1.2

$h_{ef,sl}$ = effective embedment depth of shear lug, mm

h_{sl} = embedment depth of shear lug, mm

h_{sx} = story height for story x , mm

h_u = laterally unsupported height at extreme compression fiber of wall or wall pier, mm, equivalent to ℓ_u for compression members

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h_w	= height of entire wall from base to top, or clear height of wall segment or wall pier considered, mm
h_{wcs}	= height of entire structural wall above the critical section for flexural and axial loads, mm
h_x	= maximum center-to-center spacing of longitudinal bars laterally supported by corners of crossties or hoop legs around the perimeter of a column or wall boundary element, mm
H	= effect of service load due to lateral earth pressure, ground water pressure, or pressure of bulk materials, N
I	= moment of inertia of section about centroidal axis, mm ⁴
I_b	= moment of inertia of gross section of beam about centroidal axis, mm ⁴
I_{cr}	= moment of inertia of cracked section transformed to concrete, mm ⁴
I_e	= effective moment of inertia for calculation of deflection, mm ⁴
I_g	= moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement, mm ⁴
I_s	= moment of inertia of gross section of slab about centroidal axis, mm ⁴
I_{se}	= moment of inertia of reinforcement about centroidal axis of member cross section, mm ⁴
k	= effective length factor for compression members
k_c	= coefficient for basic concrete breakout strength in tension
k_{cp}	= coefficient for pryout strength
k_f	= concrete strength factor
k_n	= confinement effectiveness factor
K_{tr}	= transverse reinforcement index, mm
ℓ	= span length of beam or one-way slab; clear projection of cantilever, mm
ℓ_a	= additional embedment length beyond centerline of support or point of inflection, mm
ℓ_{be}	= length of boundary element from compression face of member, mm
ℓ_c	= length of compression member, measured center-to-center of the joints, mm
ℓ_{cb}	= arc length of bar bend along centerline of bar, mm
ℓ_d	= development length in tension of deformed bar, deformed wire, plain and deformed welded wire reinforcement, or pretensioned strand, mm
ℓ_{dc}	= development length in compression of deformed bars and deformed wire, mm
ℓ_{db}	= debonded length of prestressed reinforcement at end of member, mm

K_t = torsional stiffness of member; moment per unit rotation

K_{05} = coefficient associated with the 5 percent fractile

ℓ_{anc} = length along which anchorage of a tie must occur, mm

ℓ_b = width of bearing, mm



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ℓ_{dh} = development length in tension of deformed bar or deformed wire with a standard hook, measured from outside end of hook, point of tangency, toward critical section, mm

ℓ_{dt} = development length in tension of headed deformed bar, measured from the bearing face of the head toward the critical section, mm

ℓ_e = load bearing length of anchor for shear, mm

ℓ_{ext} = straight extension at the end of a standard hook, mm

ℓ_n = length of clear span measured face-to-face of supports, mm

ℓ_o = length, measured from joint face along axis of member, over which special transverse reinforcement must be provided, mm

ℓ_{sc} = compression lap splice length, mm

ℓ_{st} = tension lap splice length, mm

ℓ_t = span of member under load test, taken as the shorter span for two-way slab systems, mm. Span is the lesser of: (a) distance between centers of supports, and (b) clear distance between supports plus thickness h of member. Span for a cantilever shall be taken as twice the distance from face of support to cantilever end

ℓ_{tr} = transfer length of prestressed reinforcement, mm

ℓ_u = unsupported length of column or wall, mm

ℓ_w = length of entire wall, or length of wall segment or wall pier considered in direction of shear force, mm

ℓ_1 = length of span in direction that moments are being determined, measured center-to-center of supports, mm

ℓ_2 = length of span in direction perpendicular to ℓ_1 , measured center-to-center of supports, mm

L = effect of service live load

L_r = effect of service roof live load

M = moment acting on anchor or anchor group, mm-N

M_a = maximum moment in member due to service loads at stage deflection is calculated, N·mm

M_c = factored moment amplified for the effects of member curvature used for design of compression member, N·mm

M_{cr} = cracking moment, N·mm

M_{cre} = moment causing flexural cracking at section due to externally applied loads, N·mm

M_{max} = maximum factored moment at section due to externally applied loads, N·mm

M_n = nominal flexural strength at section, N·mm

M_{nb} = nominal flexural strength of beam including slab where in tension, framing into joint, N·mm

M_{nc} = nominal flexural strength of column framing into joint, calculated for factored axial force, consistent with the direction of lateral forces considered, resulting in lowest flexural strength, N·mm

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at joint faces assuming a tensile

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stress in the longitudinal bars of at least $1.25f_y$ and a strength reduction factor ϕ of 1.0, N·mm

M_{sa} = maximum moment in wall due to service loads, excluding $P\Delta$ effects, N·mm

M_{sc} = factored slab moment that is resisted by the column at a joint, N·mm

M_u = factored moment at section, N·mm

M_{ua} = moment at midheight of wall due to factored lateral and eccentric vertical loads, not including $P\Delta$ effects, N·mm

M_1 = lesser factored end moment on a compression member, N·mm

M_{1ns} = factored end moment on a compression member at the end at which M_1 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis, N·mm

M_{1s} = factored end moment on compression member at the end at which M_1 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame analysis, N·mm

M_2 = greater factored end moment on a compression member. If transverse loading occurs between supports, M_2 is taken as the largest moment occurring in member. Value of M_2 is always positive, N·mm

$M_{2,min}$ = minimum value of M_2 , N·mm

M_{2ns} = factored end moment on compression member at the end at which M_2 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis, N·mm

M_{2s} = factored end moment on compression member at the end at which M_2 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame analysis, N·mm

n = number of items, such as, bars, wires, monostrand anchorage devices, or anchors

n_ℓ = number of longitudinal bars around the perimeter of a column core with rectilinear hoops that are laterally supported by the corner of hoops or by seismic hooks. A bundle of bars is counted as a single bar

n_s = number of stories above the critical section

N_a = nominal bond strength in tension of a single adhesive anchor, N

N_{ag} = nominal bond strength in tension of a group of adhesive anchors, N

N_b = basic concrete breakout strength in tension of a single anchor in cracked concrete, N

N_{ba} = basic bond strength in tension of a single adhesive anchor, N

N_c = resultant tensile force acting on the portion of the concrete cross section that is subjected to tensile stresses due to the combined effects of service loads and effective prestress, N

n_t = number of threads per mm

N = tension force acting on anchor or anchor group, N



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COMMENTARY

N_{cb}	= nominal concrete breakout strength in tension of a single anchor, N
N_{cbg}	= nominal concrete breakout strength in tension of a group of anchors, N
N_{cp}	= basic concrete pryout strength of a single anchor, N
N_{cpg}	= basic concrete pryout strength of a group of anchors, N
N_n	= nominal strength in tension, N
N_p	= pullout strength in tension of a single anchor in cracked concrete, N
N_{pn}	= nominal pullout strength in tension of a single anchor, N
N_{sa}	= nominal strength of a single anchor or individual anchor in a group of anchors in tension as governed by the steel strength, N
N_{sb}	= side-face blowout strength of a single anchor, N
N_{sbg}	= side-face blowout strength of a group of anchors, N
N_u	= factored axial force normal to cross section occurring simultaneously with V_u or T_u ; to be taken as positive for compression and negative for tension, N
N_{ua}	= factored tensile force applied to anchor or individual anchor in a group of anchors, N
$N_{ua,g}$	= total factored tensile force applied to anchor group, N
$N_{ua,i}$	= factored tensile force applied to most highly stressed anchor in a group of anchors, N
$N_{ua,s}$	= factored sustained tension load, N
N_{uc}	= factored restraint force applied to a bearing connection acting perpendicular to and simultaneously with V_u , to be taken as positive for tension, N
$N_{uc,max}$	= maximum restraint force that can be transmitted through the load path of a bearing connection multiplied by the load factor used for live loads in combinations with other factored load effects
p_{cp}	= outside perimeter of concrete cross section, mm
p_h	= perimeter of centerline of outermost closed transverse torsional reinforcement, mm
P_a	= maximum allowable compressive strength of a deep foundation member, N
P_c	= critical buckling load, N
P_n	= nominal axial compressive strength of member, N
$P_{n,max}$	= maximum nominal axial compressive strength of a member, N
P_{nt}	= nominal axial tensile strength of member, N
$P_{nt,max}$	= maximum nominal axial tensile strength of member, N
P_o	= nominal axial strength at zero eccentricity, N
P_{pu}	= factored prestressing force at anchorage device, N
P_s	= unfactored axial load at the design, midheight section including effects of self-weight, N
P_u	= factored axial force; to be taken as positive for compression and negative for tension, N

$P\delta$ = secondary moment due to individual member second order effects, N·mm

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COMMENTARY

$P\Delta$	= secondary moment due to lateral deflection, N·mm
q_u	= factored load per unit area, N/m ²
Q	= stability index for a story
r	= radius of gyration of cross section, mm
r_b	= bend radius at the inside of a bar, mm
R	= cumulative load effect of service rain load
s	= center-to-center spacing of items, such as longitudinal reinforcement, transverse reinforcement, tendons, or anchors, mm
s_i	= center-to-center spacing of reinforcement in the i -th direction adjacent to the surface of the member, mm
s_o	= center-to-center spacing of transverse reinforcement within the length ℓ_o , mm
s_s	= sample standard deviation, MPa
s_w	= clear distance between adjacent webs, mm
s_2	= center-to-center spacing of longitudinal shear or torsional reinforcement, mm
S	= effect of service snow load
S_{DS}	= 5 percent damped, spectral response acceleration parameter at short periods determined in accordance with the general building code
S_e	= moment, shear, or axial force at connection corresponding to development of probable strength at intended yield locations, based on the governing mechanism of inelastic lateral deformation, considering both gravity and earthquake effects
S_m	= elastic section modulus, mm ³
S_n	= nominal moment, shear, axial, torsion, or bearing strength
S_y	= yield strength of connection, based on f_y of the connected part, for moment, shear, torsion, or axial force, MPa
t	= wall thickness of hollow section, mm
t_f	= thickness of flange, mm
t_{sl}	= thickness of shear lug, mm
T	= cumulative effects of service temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete
T_{cr}	= cracking torsional moment, N·mm
T_t	= total test load, N
T_{th}	= threshold torsional moment, N·mm
T_n	= nominal torsional moment strength, N·mm
T_u	= factored torsional moment at section, N·mm
U	= strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as stipulated in this Code
v_c	= stress corresponding to nominal two-way shear strength provided by concrete, MPa

R = reaction, N

T = tension force acting on a nodal zone in a strut-and-tie model, N (T is also used to define the cumulative effects of service temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete in the load combinations defined in 5.3.6.)

T_{burst} = tensile force in general zone acting ahead of the anchorage device caused by spreading of the anchorage force, N

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COMMENTARY

- v_n = equivalent concrete stress corresponding to nominal two-way shear strength of slab or footing, MPa
- v_s = equivalent concrete stress corresponding to nominal two-way shear strength provided by reinforcement, MPa
- v_u = maximum factored two-way shear stress calculated around the perimeter of a given critical section, MPa
- v_{uv} = factored shear stress on the slab critical section for two-way action, from the controlling load combination, without moment transfer, MPa

- V_b = basic concrete breakout strength in shear of a single anchor in cracked concrete, N
- $V_{brg,sl}$ = nominal bearing strength of a shear lug in direction of shear, N
- V_c = nominal shear strength provided by concrete, N
- V_{cb} = nominal concrete breakout strength in shear of a single anchor, N
- V_{cbg} = nominal concrete breakout strength in shear of a group of anchors, N
- $V_{cb,sl}$ = nominal concrete breakout strength in shear of attachment with shear lugs, N
- V_{ci} = nominal shear strength provided by concrete where diagonal cracking results from combined shear and moment, N
- V_{cp} = nominal concrete pryout strength of a single anchor, N
- V_{cpg} = nominal concrete pryout strength of a group of anchors, N
- V_{cw} = nominal shear strength provided by concrete where diagonal cracking results from high principal tensile stress in web, N
- V_d = shear force at section due to unfactored dead load, N
- V_e = design shear force for load combinations including earthquake effects, N
- V_i = factored shear force at section due to externally applied loads occurring simultaneously with M_{max} , N
- V_n = nominal shear strength, N
- V_{nh} = nominal horizontal shear strength, N
- V_p = vertical component of effective prestress force at section, N
- V_s = nominal shear strength provided by shear reinforcement, N
- V_{sa} = nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength, N
- V_u = factored shear force at section, N
- V_{ua} = factored shear force applied to a single anchor or group of anchors, N

- V = shear force acting on anchor or anchor group, N
- $V_{||}$ = maximum shear force that can be applied parallel to the edge, N
- $V_{\perp}$ = maximum shear force that can be applied perpendicular to the edge, N

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- $V_{ua,g}$ = total factored shear force applied to anchor group, N
 $V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors, N
 V_{uh} = factored shear force along contact surface in composite concrete flexural member, N
 V_{us} = factored horizontal shear in a story, N
 $V_{u,x}$ = factored shear force at section in the x-direction, N
 $V_{u,y}$ = factored shear force at section in the y-direction, N
 $V_{n,x}$ = shear strength in the x-direction
 $V_{n,y}$ = shear strength in the y-direction
 w_c = density, unit weight, of normalweight concrete or equilibrium density of lightweight concrete, kg/m³

w_t = effective tie width in a strut-and-tie model, mm

- w_u = factored load per unit length of beam or one-way slab, N/mm
 w/cm = water-cementitious materials ratio
 W = effect of wind load

- y_t = distance from centroidal axis of gross section, neglecting reinforcement, to tension face, mm
 α = angle defining the orientation of reinforcement
 α_c = coefficient defining the relative contribution of concrete strength to nominal wall shear strength
 α_f = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by centerlines of adjacent panels, if any, on each side of the beam

α_{fm} = average value of α_f for all beams on edges of a panel

α_s = constant used to calculate V_c in slabs and footings

α_1 = minimum angle between unidirectional distributed reinforcement and a strut

β = ratio of long to short dimensions: clear spans for two-way slabs, sides of column, concentrated load or reaction area; or sides of a footing

β_b = ratio of area of reinforcement cut off to total area of tension reinforcement at section

β_c = confinement modification factor for struts and nodes in a strut-and-tie model

β_{dns} = ratio used to account for reduction of stiffness of columns due to sustained axial loads

β_{ds} = the ratio of maximum factored sustained shear within a story to the maximum factored shear in that story associated with the same load combination

β_n = factor used to account for the effect of the anchorage of ties on the effective compressive strength of a nodal zone

β_s = factor used to account for the effect of cracking and confining reinforcement on the effective compressive strength of the concrete in a strut

w_s = width of a strut perpendicular to the axis of the strut, mm

w_t = effective height of concrete concentric with a tie, used to dimension nodal zone, mm

$w_{t,max}$ = maximum effective height of concrete concentric with a tie, mm

W_a = service-level wind load, N

$\alpha_f = E_{cb}I_b/E_{cs}I_s$



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- β_1 = factor relating depth of equivalent rectangular compressive stress block to depth of neutral axis
- γ_f = factor used to determine the fraction of M_{sc} transferred by slab flexure at slab-column connections
- γ_p = factor used for type of prestressing reinforcement
- γ_s = factor used to determine the portion of reinforcement located in center band of footing
- γ_v = factor used to determine the fraction of M_{sc} transferred by eccentricity of shear at slab-column connections

δ = moment magnification factor used to reflect effects of member curvature between ends of a compression member

δ_c = wall displacement capacity at top of wall, mm

δ_s = moment magnification factor used for frames not braced against sidesway, to reflect lateral drift resulting from lateral and gravity loads

δ_u = design displacement, mm

Δ_{cr} = calculated out-of-plane deflection at midheight of wall corresponding to cracking moment M_{cr} , mm

Δ_n = calculated out-of-plane deflection at midheight of wall corresponding to nominal flexural strength M_n , mm

Δ_o = relative lateral deflection between the top and bottom of a story due to V_{us} , mm

Δf_p = increase in stress in prestressed reinforcement due to factored loads, MPa

Δf_{ps} = stress in prestressed reinforcement at service loads less decompression stress, MPa

Δf_{pt} = difference between the stress that can be developed in the prestressed reinforcement at the section under consideration and the stress required to resist factored bending moment at section, M_u/ϕ , MPa

Δ_r = residual deflection measured 24 hours after removal of the test load. For the first load test, residual deflection is measured relative to the position of the structure at the beginning of the first load test. For the second load test, residual deflection is measured relative to the position of the structure at the beginning of the second load test, mm

Δ_s = out-of-plane deflection due to service loads, mm

Δ_u = calculated out-of-plane deflection at midheight of wall due to factored loads, mm

Δ_x = design story drift of story x , mm

Δ_1 = maximum deflection, during first load test, measured 24 hours after application of the full test load, mm

Δ_2 = maximum deflection, during second load test, measured 24 hours after application of the full test load. Deflection is measured relative to the position of the structure at the beginning of the second load test, mm

ϵ_{cu} = maximum usable strain at extreme concrete compression fiber

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ε_t = net tensile strain in extreme layer of longitudinal tension reinforcement at nominal strength, excluding strains due to effective prestress, creep, shrinkage, and temperature

ε_{ty} = value of net tensile strain in the extreme layer of longitudinal tension reinforcement used to define a compression-controlled section

θ = angle between axis of strut, compression diagonal, or compression field and the tension chord of the members

λ = modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength

λ_a = modification factor to reflect the reduced mechanical properties of lightweight concrete in certain concrete anchorage applications

λ_s = factor used to modify shear strength based on the effects of member depth, commonly referred to as the size effect factor.

λ_Δ = multiplier used for additional deflection due to long-term effects

μ = coefficient of friction

ξ = time-dependent factor for sustained load

ρ = ratio of A_s to bd

ρ' = ratio of A_s' to bd

ρ_ℓ = ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement

ρ_p = ratio of A_{ps} to bd_p

ρ_s = ratio of volume of spiral reinforcement to total volume of core confined by the spiral, measured out-to-out of spirals

ρ_t = ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement

ρ_v = ratio of tie reinforcement area to area of contact surface

ρ_w = ratio of A_s to $b_w d$

ϕ = strength reduction factor

ϕ_p = strength reduction factor for moment in pretensioned member at cross section closest to the end of the member where all strands are fully developed

τ_{cr} = characteristic bond stress of adhesive anchor in cracked concrete, MPa

λ = in most cases, the reduction in mechanical properties is caused by the reduced ratio of tensile-to-compressive strength of lightweight concrete compared to normalweight concrete. There are instances in the Code where λ is used as a modifier to reduce expected performance of lightweight concrete where the reduction is not related directly to tensile strength.

ζ = exponent symbol in tensile/shear force interaction equation

ϕ_K = stiffness reduction factor

σ = wall boundary extreme fiber concrete nominal compressive stress, MPa

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τ_{uncr}	= characteristic bond stress of adhesive anchor in uncracked concrete, MPa
$\psi_{brg,sl}$	= shear lug bearing factor used to modify bearing strength of shear lugs based on the influence of axial load
ψ_c	= factor used to modify development length based on concrete strength
$\psi_{c,N}$	= breakout cracking factor used to modify tensile strength of anchors based on the influence of cracks in concrete
$\psi_{c,P}$	= pullout cracking factor used to modify pullout strength of anchors based on the influence of cracks in concrete
$\psi_{c,V}$	= breakout cracking factor used to modify shear strength of anchors based on the influence of cracks in concrete and presence or absence of supplementary reinforcement
$\psi_{cp,N}$	= breakout splitting factor used to modify tensile strength of post-installed anchors intended for use in uncracked concrete without supplementary reinforcement to account for the splitting tensile stresses
$\psi_{cp,Na}$	= bond splitting factor used to modify tensile strength of adhesive anchors intended for use in uncracked concrete without supplementary reinforcement to account for the splitting tensile stresses due to installation
ψ_e	= factor used to modify development length based on reinforcement coating
$\psi_{ec,N}$	= breakout eccentricity factor used to modify tensile strength of anchors based on eccentricity of applied loads
$\psi_{ec,Na}$	= breakout eccentricity factor used to modify tensile strength of adhesive anchors based on eccentricity of applied loads
$\psi_{ec,V}$	= breakout eccentricity factor used to modify shear strength of anchors based on eccentricity of applied loads
$\psi_{ed,N}$	= breakout edge effect factor used to modify tensile strength of anchors based on proximity to edges of concrete member
$\psi_{ed,Na}$	= breakout edge effect factor used to modify tensile strength of adhesive anchors based on proximity to edges of concrete member
$\psi_{ed,V}$	= breakout edge effect factor used to modify shear strength of anchors based on proximity to edges of concrete member
ψ_g	= factor used to modify development length based on grade of reinforcement
$\psi_{h,V}$	= breakout thickness factor used to modify shear strength of anchors located in concrete members with $h_a < 1.5c_{a1}$
ψ_o	= factor used to modify development length of hooked and headed bars based on side cover and confinement

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ψ_p	= factor used to modify development length for headed reinforcement based on parallel tie reinforcement
ψ_r	= factor used to modify development length based on confining reinforcement
ψ_s	= factor used to modify development length based on reinforcement size
ψ_t	= factor used to modify development length for casting location in tension
ψ_w	= factor used to modify development length for welded deformed wire reinforcement in tension
Ω_o	= amplification factor to account for overstrength of the seismic-force-resisting system determined in accordance with the general building code
Ω_v	= overstrength factor equal to the ratio of M_{pr}/M_u at the wall critical section
ω_v	= factor to account for dynamic shear amplification

2.3—Terminology

adhesive—chemical components formulated from organic polymers, or a combination of organic polymers and inorganic materials that cure if blended together.

admixture—material other than water, aggregate, cementitious materials, and fiber reinforcement used as an ingredient, which is added to grout, mortar, or concrete, either before or during its mixing, to modify the freshly mixed, setting, or hardened properties of the mixture.

aggregate—granular material, such as sand, gravel, crushed stone, iron blast-furnace slag, or recycled aggregates including crushed hydraulic cement concrete, used with a cementing medium to form concrete or mortar.

aggregate, lightweight—aggregate meeting the requirements of [ASTM C330](#) and having a loose bulk density of 1120 kg/m³ or less, determined in accordance with [ASTM C29](#).

alternative cement—an inorganic cement that can be used as a complete replacement for portland cement or blended hydraulic cement, and that is not covered by applicable specifications for portland or blended hydraulic cements.

anchor—a steel element either cast into concrete or post-installed into a hardened concrete member and used to transmit applied loads to the concrete.

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R2.3—Terminology

aggregate—The use of recycled aggregate is addressed in the Code in 2019. The definition of recycled materials in [ASTM C33](#) is very broad and is likely to include materials that would not be expected to meet the intent of the provisions of this Code for use in structural concrete. Use of recycled aggregates including crushed hydraulic-cement concrete in structural concrete requires additional precautions. See [26.4.1.2.1\(c\)](#).

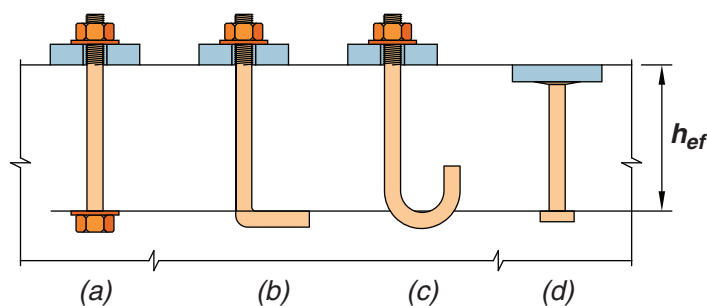
aggregate, lightweight—In some standards, the term “lightweight aggregate” is being replaced by the term “low-density aggregate.”

alternative cements—Alternative cements are described in the references listed in [R26.4.1.1.1\(b\)](#). Refer to [26.4.1.1.1\(b\)](#) for precautions when using these materials in concrete covered by this Code.

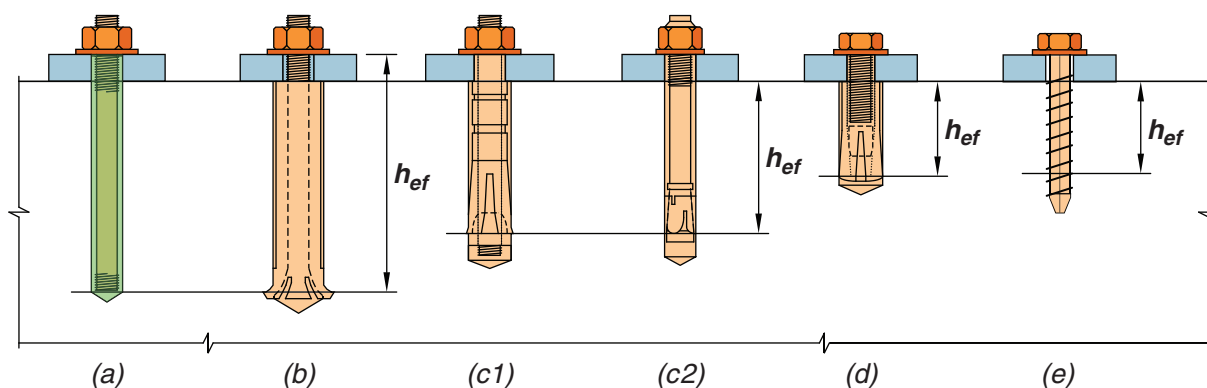
anchor—Cast-in anchors include headed bolts, hooked bolts (J- or L-bolt), and headed studs. Post-installed anchors include expansion anchors, undercut anchors, screw anchors, and adhesive anchors; steel elements for adhesive anchors include threaded rods, deformed reinforcing bars, or internally threaded steel sleeves with external deformations. Anchor types are shown in Fig. R2.1.

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COMMENTARY



(A) Cast-in anchors: (a) hex head bolt with washer;
(b) L-bolt; (c) J-bolt; and (d) welded headed stud.



(B) Post-installed anchors: (a) adhesive anchor; (b) undercut anchor;
(c) torque-controlled expansion anchors [(c1) sleeve-type and (c2) stud-type];
(d) drop-in type displacement-controlled expansion anchor; and (e) screw anchor.

Fig. R2.1—Types of anchors.

anchor, adhesive—a post-installed anchor, inserted into hardened concrete with an anchor hole diameter not greater than 1.5 times the anchor diameter, that transfers loads to the concrete by bond between the anchor and the adhesive, and bond between the adhesive and the concrete.

anchor, cast-in—headed bolt, headed stud, or hooked bolt installed before placing concrete.

anchor, expansion—post-installed anchor, inserted into hardened concrete that transfers loads to or from the concrete by direct bearing or friction, or both.

anchor, adhesive—The design model included in Chapter 17 for adhesive anchors is based on the behavior of anchors with hole diameters not exceeding 1.5 times the anchor diameter. Anchors with hole diameters exceeding 1.5 times the anchor diameter behave differently and are therefore excluded from the scope of Chapter 17 and ACI 355.4M. To limit shrinkage and reduce displacement under load, most adhesive anchor systems require the annular gap to be as narrow as practical while still maintaining sufficient clearance for insertion of the anchor element in the adhesive filled hole and ensuring complete coverage of the bonded area over the embedded length. The annular gap for reinforcing bars is generally greater than that for threaded rods. The required hole size is provided in the Manufacturer's Printed Installation Instructions (MPII).

anchor, expansion—Expansion anchors may be torque-controlled, where the expansion is achieved by a torque acting on the screw or bolt; or displacement controlled, where the expansion is achieved by impact forces acting on a sleeve or plug and the expansion is controlled by limiting the travel of the sleeve or plug.

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anchor, horizontal or upwardly inclined—Anchor installed in a hole drilled horizontally or in a hole drilled at any orientation above horizontal.

anchor, post-installed—anchor installed in hardened concrete; adhesive, expansion, screw, and undercut anchors are examples of post-installed anchors.

anchor, screw—a post-installed threaded, mechanical anchor inserted into hardened concrete that transfers loads to the concrete by engagement of the hardened threads of the screw with the grooves that the threads cut into the sidewall of a predrilled hole during anchor installation.

anchor, undercut—post-installed anchor that develops its tensile strength from the mechanical interlock provided by undercutting of the concrete at the embedded end of the anchor. Undercutting is achieved with a special drill before installing the anchor or alternatively by the anchor itself during its installation.

anchor group—a number of similar anchors having approximately equal effective embedment depths with spacing s between adjacent anchors such that the projected areas overlap.

anchor pullout strength—the strength corresponding to the anchoring device or a major component of the device sliding out from the concrete without breaking out a substantial portion of the surrounding concrete.

anchorage device—in post-tensioned members, the hardware used to transfer force from prestressed reinforcement to the concrete.

anchorage device, basic monostrand—anchorage device used with any single strand or a single 15 mm or smaller diameter bar that is in accordance with 25.8.1, 25.8.2, and 25.9.3.1(a).

anchorage device, basic multistrand—anchorage device used with multiple strands, bars, or wires, or with single bars larger than 15 mm diameter that satisfies 25.8.1, 25.8.2 and 25.9.3.1(b).

COMMENTARY

anchor, horizontal or upwardly inclined—Figure R2.2 illustrates the potential hole orientations for horizontal or upwardly inclined anchors.

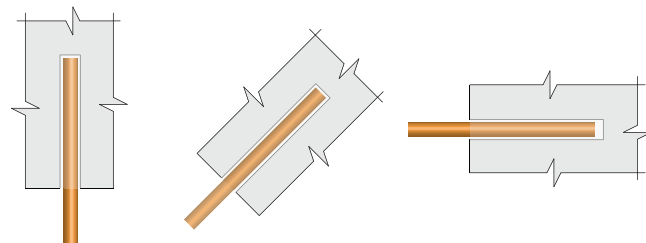


Fig. R2.2—Possible orientations of overhead, upwardly inclined, or horizontal anchors.

anchor, screw—The required predrilled hole size for a screw anchor is provided by the anchor manufacturer.

anchor group—For all potential failure modes (steel, concrete breakout, pullout, side-face blowout, and pryout), only those anchors susceptible to a particular failure mode should be considered when evaluating the strength associated with that failure mode.

anchorage device—Most anchorage devices for post-tensioning are standard manufactured devices available from commercial sources. In some cases, non-standard details or assemblages are developed that combine various wedges and wedge plates for anchoring prestressed reinforcement. Both standard and non-standard anchorage devices may be classified as basic anchorage devices or special anchorage devices as defined in this Code and AASHTO LRFDUS-US.

anchorage device, basic—Devices that are so proportioned that they can be checked analytically for compliance with bearing stress and stiffness requirements without having to undergo the acceptance-testing program required of special anchorage devices.

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anchorage device, special—anchorage device that satisfies tests required in 25.9.3.1(c).

anchorage zone—in post-tensioned members, portion of the member through which the concentrated prestressing force is transferred to concrete and distributed more uniformly across the section; its extent is equal to the largest dimension of the cross section; for anchorage devices located away from the end of a member, the anchorage zone includes the disturbed regions ahead of and behind the anchorage device.

attachment—structural assembly, external to the surface of the concrete, that transmits loads to or receives loads from the anchor.

B-region—portion of a member in which it is reasonable to assume that strains due to flexure vary linearly through section.

base of structure—level at which horizontal earthquake ground motions are assumed to be imparted to a building. This level does not necessarily coincide with the ground level.

beam—member subjected primarily to flexure and shear, with or without axial force or torsion; beams in a moment frame that forms part of the lateral-force-resisting system are predominantly horizontal members; a girder is a beam.

boundary element—portion along wall and diaphragm edge, including edges of openings, strengthened by longitudinal and transverse reinforcement.

breakout strength, concrete—strength corresponding to a volume of concrete surrounding the anchor or group of anchors separating from the member.

building official—term used to identify the Authority having jurisdiction or individual charged with administration and enforcement of provisions of the building code. Such terms as building commissioner or building inspector are variations of the title, and the term “building official” as used in this Code, is intended to include those variations, as well as others that are used in the same sense.

caisson—see drilled pier.

cementitious materials—materials that have cementing value if used in grout, mortar, or concrete, including portland cement, blended hydraulic cements, expansive cement, fly ash, raw or calcined natural pozzolan, slag cement, and silica fume, but excluding alternative cements.

collector—element that acts in axial tension or compression to transmit forces between a diaphragm and a vertical element of the lateral-force-resisting system.

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anchorage device, special—Special anchorage devices are any devices (monostrand or multistrand) that do not meet the relevant PTI or AASHTO LFRDUS bearing stress and, where applicable, stiffness requirements. Most commercially marketed multi-bearing surface anchorage devices are special anchorage devices. As provided in 25.9.3, such devices can be used only if they have been shown experimentally to be in compliance with the AASHTO requirements. This demonstration of compliance will ordinarily be furnished by the device manufacturer.

anchorage zone—In post-tensioned members, the portion of the member through which the concentrated prestressing force is transferred to the concrete and distributed more uniformly across the section. Its extent is equal to the largest dimension of the cross section. For anchorage devices located away from the end of a member, the anchorage zone includes the disturbed regions ahead of and behind the anchorage devices. Refer to Fig. R25.9.1.1b.

cementitious materials—Cementitious materials permitted for use in this Code are addressed in 26.4.1.1. Fly ash, raw or calcined natural pozzolan, slag cement, and silica fume are considered supplementary cementitious materials.

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column—member, usually vertical or predominantly vertical, used primarily to support axial compressive load, but that can also resist moment, shear, or torsion. Columns used as part of a lateral-force-resisting system resist combined axial load, moment, and shear. See also **moment frame**.

column capital—enlargement of the top of a concrete column located directly below the slab or drop panel that is cast monolithically with the column.

compliance requirements—construction-related code requirements directed to the contractor to be incorporated into construction documents by the licensed design professional, as applicable.

composite concrete flexural members—concrete flexural members of precast or cast-in-place concrete elements, constructed in separate placements but connected so that all elements respond to loads as a unit.

compression-controlled section—cross section in which the net tensile strain in the extreme tension reinforcement at nominal strength is less than or equal to the compression-controlled strain limit.

compression-controlled strain limit—net tensile strain at balanced strain conditions.

concrete—mixture of portland cement or any other cementitious material, fine aggregate, coarse aggregate, and water, with or without admixtures.

concrete, all-lightweight—lightweight concrete containing only lightweight coarse and fine aggregates that conform to **ASTM C330**.

concrete, lightweight—concrete containing lightweight aggregate and having an equilibrium density, as determined by **ASTM C567**, between 1440 and 2160 kg/m³.

concrete, nonprestressed—reinforced concrete with at least the minimum amount of nonprestressed reinforcement and no prestressed reinforcement; or for two-way slabs, with less than the minimum amount of prestressed reinforcement.

concrete, normalweight—concrete containing only coarse and fine aggregates that conform to **ASTM C33** and having a density greater than 2160 kg/m³.

concrete, plain—structural concrete with no reinforcement or with less than the minimum amount of reinforcement specified for reinforced concrete.

concrete, precast—structural concrete element cast elsewhere than its final position in the structure.

concrete, prestressed—reinforced concrete in which internal stresses have been introduced by prestressed reinforcement to reduce potential tensile stresses in concrete resulting from loads, and for two-way slabs, with at least the minimum amount of prestressed reinforcement.

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compliance requirements—Although primarily directed to the contractor, the compliance requirements are also commonly used by others involved with the project.

concrete, nonprestressed—Nonprestressed concrete usually contains no prestressed reinforcement. Prestressed two-way slabs require a minimum level of compressive stress in the concrete due to effective prestress in accordance with **8.6.2.1**. Two-way slabs with less than this minimum level of precompression are required to be designed as nonprestressed concrete.

concrete, normalweight—Normalweight concrete typically has a density (unit weight) between 2160 and 2560 kg/m³, and is normally taken as 2320 to 2400 kg/m³.

concrete, plain—The presence of reinforcement, nonprestressed or prestressed, does not exclude the member from being classified as plain concrete, provided all requirements of **Chapter 14** are satisfied.

concrete, prestressed—Classes of prestressed flexural members are defined in **24.5.2.1**. Prestressed two-way slabs require a minimum level of compressive stress in the concrete due to effective prestress in accordance with **8.6.2.1**. Although the behavior of a prestressed member with unbonded tendons may vary from that of a member with continuously bonded prestressing reinforcement, bonded

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concrete, reinforced—structural concrete reinforced with at least the minimum amounts of nonprestressed reinforcement, prestressed reinforcement, or both, as specified in this Code.

concrete, sand-lightweight—lightweight concrete containing only normalweight fine aggregate that conforms to **ASTM C33** and lightweight coarse aggregate that conforms to **ASTM C330**.

concrete, steel fiber-reinforced—concrete containing a prescribed amount of dispersed, randomly oriented, discontinuous deformed steel fibers.

concrete-filled pipe piles—steel pipe with a closed end that is driven for its full length in contact with the surrounding soil, or a steel pipe with an open end that is driven for its full length and the soil cleaned out; for both installation procedures, the pipe is subsequently filled with reinforcement and concrete.

concrete strength, specified compressive, (f'_c)—compressive strength of concrete used in design and evaluated in accordance with provisions of this Code, MPa; wherever the quantity f'_c is under a radical sign, the square root of numerical value only is intended, and the result has units of MPa.

connection—region of a structure that joins two or more members; a connection also refers to a region that joins members of which one or more is precast.

connection, ductile—connection between one or more precast elements that experiences yielding as a result of the earthquake design displacements.

connection, strong—connection between one or more precast elements that remains elastic while adjoining members experience yielding as a result of earthquake design displacements.

construction documents—written and graphic documents and specifications prepared or assembled for describing the location, design, materials, and physical characteristics of the elements of a project necessary for obtaining a building permit and construction of the project.

contraction joint—formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.

cover, specified concrete—distance between the outermost surface of embedded reinforcement and the closest outer surface of the concrete.

and unbonded prestressed concrete are combined with nonprestressed concrete under the generic term “reinforced concrete.” Provisions common to both prestressed and nonprestressed concrete are integrated to avoid overlapping and conflicting provisions.

concrete, reinforced—Includes members satisfying the requirements for nonprestressed and prestressed concrete.

concrete, sand-lightweight—By Code terminology, sand-lightweight concrete is lightweight concrete with all of the fine aggregate replaced by sand. This definition may not be in agreement with usage by some material suppliers or contractors where the majority, but not all, of the lightweight fines are replaced by sand. For proper application of the Code provisions, the replacement limits should be stated, with interpolation if partial sand replacement is used.

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crosstie—a continuous reinforcing bar having a seismic hook at one end and a hook not less than 90 degrees with at least a $6d_b$ extension at the other end. The hooks shall engage peripheral longitudinal bars. The 90-degree hooks of two successive crossties engaging the same longitudinal bars shall be alternated end for end.

cutoff point—point where reinforcement is terminated.

D-region—portion of a member within a distance h of a force discontinuity or a geometric discontinuity.

design displacement—total calculated lateral displacement expected for the design-basis earthquake.

design information—project-specific information to be incorporated into construction documents by the licensed design professional, as applicable.

design load combination—combination of factored loads and forces.

design story drift ratio—relative difference of design displacement between the top and bottom of a story, divided by the story height.

development length—length of embedded reinforcement, including pretensioned strand, required to develop the design strength of reinforcement at a critical section.

discontinuity—abrupt change in geometry or loading.

distance sleeve—sleeve that encases the center part of an undercut anchor, a torque-controlled expansion anchor, or a displacement-controlled expansion anchor, but does not expand.

drilled piers or caissons—cast-in-place concrete foundation elements with or without an enlarged base (bell), constructed by excavating a hole in the ground and filling with reinforcement and concrete. Drilled piers or caissons are considered as uncased cast-in-place concrete drilled or augered piles, unless they have permanent steel casing, in which case they are considered as metal cased concrete piles.

drop panel—projection below the slab used to reduce the amount of negative reinforcement over a column or the minimum required slab thickness, and to increase the slab shear strength.

duct—conduit, plain or corrugated, to accommodate prestressing reinforcement for post-tensioning applications.

ductile coupled structural wall—see **structural wall**, **ductile coupled**.

durability—ability of a structure or member to resist deterioration that impairs performance or limits service life

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design displacement—The design displacement is an index of the maximum lateral displacement expected in design for the design-basis earthquake. In documents such as **ASCE/SEI 7** and the International Building Code, the design displacement is calculated using static or dynamic linear elastic analysis under code-specified actions considering effects of cracked sections, effects of torsion, effects of vertical forces acting through lateral displacements, and modification factors to account for expected inelastic response. The design displacement generally is greater than the displacement calculated from design-level forces applied to a linear-elastic model of the building.

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of the structure in the relevant environment considered in design.

edge distance—distance from the edge of the concrete surface to the center of the nearest anchor.

effective depth of section—distance measured from extreme compression fiber to centroid of longitudinal tension reinforcement.

effective embedment depth—overall depth through which the anchor transfers force to or from the surrounding concrete; effective embedment depth will normally be the depth of the concrete failure surface in tension applications; for cast-in headed anchor bolts and headed studs, the effective embedment depth is measured from the bearing contact surface of the head.

effective prestress—stress remaining in prestressed reinforcement after losses in 20.3.2.6 have occurred.

effective stiffness—stiffness of a structural member accounting for cracking, creep, and other nonlinear effects.

embedments—items embedded in concrete, excluding reinforcement as defined in Chapter 20 and anchors as defined in Chapter 17. Reinforcement or anchors welded, bolted or otherwise connected to the embedded item to develop the strength of the assembly, are considered to be part of the embedment.

embedments, pipe—embedded pipes, conduits, and sleeves.

embedment length—length of embedded reinforcement provided beyond a critical section.

equilibrium density—density of lightweight concrete determined in accordance with ASTM C567.

expansion sleeve—outer part of an expansion anchor that is forced outward by the center part, either by applied torque or impact, to bear against the sides of the predrilled hole. See also **anchor, expansion**.

extreme tension reinforcement—layer of prestressed or nonprestressed reinforcement that is the farthest from the extreme compression fiber.

finite element analysis—a numerical modeling technique in which a structure is divided into a number of discrete elements for analysis.

five percent fractile—statistical term meaning 90 percent confidence that there is 95 percent probability of the actual strength exceeding the nominal strength.

foundation seismic ties—elements used to sufficiently interconnect foundations to act as a unit. Elements may consist of grade beams, slabs-on-ground, or beams within a slab-on-ground.

headed deformed bars—deformed bars with heads attached at one or both ends.

effective embedment depth—Effective embedment depths for a variety of anchor types are shown in Fig. R2.1. For post-installed mechanical anchors, the value h_{ef} is obtained from the ACI 355.2 product evaluation report provided by the manufacturer.

five percent fractile—The determination of the coefficient K_{05} associated with the 5 percent fractile, $\bar{x} - K_{05}s$, depends on the number of tests, n , used to calculate the sample mean, $\bar{x}$, and sample standard deviation, s . Values of K_{05} range, for example, from 1.645 for $n = \infty$, to 2.010 for $n = 40$, and 2.568 for $n = 10$. With this definition of the 5 percent fractile, the nominal strength in Chapter 17 is the same as the characteristic strength in ACI 355.2 and ACI 355.4M.

headed deformed bars—The bearing area of a headed deformed bar is, for the most part, perpendicular to the axis. In contrast, the bearing area of the head of headed

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headed bolt—cast-in steel anchor that develops its tensile strength from the mechanical interlock provided by either a head or nut at the embedded end of the anchor.

headed stud—a steel anchor conforming to the requirements of **AWS D1.1** and affixed to a plate or similar steel attachment by the stud arc welding process before casting; also referred to as a **welded headed stud**.

headed shear stud reinforcement—reinforcement consisting of individual headed studs or groups of studs, with anchorage provided by a head at each end, or by a head at one end and a common base rail consisting of a steel plate or shape at the other end.

hooked bolt—cast-in anchor anchored mainly by bearing of the 90-degree bend (L-bolt) or 180-degree bend (J-bolt) against the concrete, at its embedded end, and having a minimum e_h equal to $3d_a$.

hoop—closed tie or continuously wound tie, made up of one or several reinforcement elements, each having seismic hooks at both ends. A closed tie shall not be made up of interlocking headed deformed bars. See **25.7.4**.

inspection—observation, verification, and required documentation of the materials, installation, fabrication, erection, or placement of components and connections to determine compliance with construction documents and referenced standards.

inspection, continuous—the full-time observation, verification, and required documentation of work in the area where the work is being performed.

inspection, periodic—the part-time or intermittent observation, verification, and required documentation of work in the area where the work is being performed.

isolation joint—separation between adjoining parts of a concrete structure, usually a vertical plane at a designed location such as to interfere least with performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete, and through which all or part of the bonded reinforcement is interrupted.

jacking force—in prestressed concrete, temporary force exerted by a device that introduces tension into prestressing reinforcement.

joint—portion of structure common to intersecting members.

licensed design professional—an individual who is licensed to practice structural design as defined by the statutory requirements of the professional licensing laws of the

stud reinforcement is a nonplanar spatial surface of revolution, as shown in Fig. R20.4.1. The two types of reinforcement differ in other ways. The shanks of headed studs are smooth, not deformed as with headed deformed bars. The minimum net bearing area of the head of a headed deformed bar is permitted to be as small as four times the bar area. In contrast, the minimum stud head area is not specified in terms of the bearing area, but by the total head area which must be at least 10 times the area of the shank.

joint—The effective cross-sectional area of a joint of a special moment frame, A_j , for shear strength calculations is given in **15.4.2.4**.

licensed design professional—May also be referred to as “registered design professional” in other jurisdictions; a licensed design professional in responsible charge of the

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state or jurisdiction in which the project is to be constructed, and who is in responsible charge for all or part of the structural design.

load—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 those loads in which variations over time are rare or of small magnitude; all other loads are variable loads.

load, dead—(a) the weights of the members, supported structure, and permanent attachments or accessories that are likely to be present on a structure in service; or (b) loads meeting specific criteria found in the general building code; without load factors.

load, factored—load, multiplied by appropriate load factors.

load, live—(a) load that is not permanently applied to a structure, but is likely to occur during the service life of the structure (excluding environmental loads); or (b) loads meeting specific criteria found in the general building code; without load factors.

load, roof live—a load on a roof produced: (a) during maintenance by workers, equipment, and materials, and (b) during the life of the structure by movable objects, such as planters or other similar small decorative appurtenances that are not occupancy related; or loads meeting specific criteria found in the general building code; without load factors.

load, self-weight dead—weight of the structural system, including the weight of any bonded concrete topping.

load, service—all loads, static or transitory, imposed on a structure or element thereof, during the operation of a facility, without load factors.

load, superimposed dead—dead loads other than the self-weight that are present or are considered in the design.

load effects—forces and deformations produced in structural members by applied loads or restrained volume changes.

load path—sequence of members and connections designed to transfer the factored loads and forces in such combinations as are stipulated in this Code, from the point of application or origination through the structure to the final support location or the foundation.

Manufacturer's Printed Installation Instructions (MPII)—published instructions for the correct installation of an adhesive anchor under all covered installation conditions as supplied in the product packaging.

metal cased concrete piles—thin-walled steel pipe, steel shell, or spiral-welded metal casing with a closed end that is driven for its full length in contact with the surrounding soil, left permanently in place, and subsequently filled with reinforcement and concrete.

modulus of elasticity—ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material.

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design work is often referred to as the “engineer of record” (EOR).

loads—A number of definitions for loads are given as the Code contains requirements that are to be met at various load levels. The terms “dead load” and “live load” refer to the unfactored, sometimes called “service” loads specified or defined by the general building code. Service loads (loads without load factors) are to be used where specified in this Code to proportion or investigate members for adequate serviceability. Loads used to proportion a member for adequate strength are defined as factored loads. Factored loads are service loads multiplied by the appropriate load factors for required strength except wind and earthquake which are already specified as strength loads in [ASCE/SEI 7](#). The factored load terminology clarifies where the load factors are applied to a particular load, moment, or shear value as used in the Code provisions.

load effects—Stresses and strains are directly related to forces and deformations and are considered as load effects.

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moment frame—frame in which beams, slabs, columns, and joints resist forces predominantly through flexure, shear, and axial force; beams or slabs are predominantly horizontal or nearly horizontal; columns are predominantly vertical or nearly vertical.

moment frame, intermediate—cast-in-place beam-column frame or two-way slab-column frame without beams complying with 18.4.

moment frame, ordinary—cast-in-place or precast concrete beam-column or slab-column frame complying with 18.3.

moment frame, special—cast-in-place beam-column frame complying with 18.2.3 through 18.2.8; and 18.6 through 18.8. A precast beam-column frame complying with 18.2.3 through 18.2.8 and 18.9.

net tensile strain—the tensile strain at nominal strength exclusive of strains due to effective prestress, creep, shrinkage, and temperature.

nodal zone—volume of concrete around a node that is assumed to transfer strut-and-tie forces through the node.

node—point in a strut-and-tie model where the axes of the struts, ties, and concentrated forces acting on the joint intersect.

node, curved bar—the bend region of a continuous reinforcing bar (or bars) that defines a node in a strut-and-tie model.

one-way construction—members designed to be capable of supporting all loads through bending in a single direction; see also **two-way construction**.

panel, shotcrete mockup—a shotcrete specimen that simulates the size and detailing of reinforcement in a proposed structural member for preconstruction evaluation of the nozzle operator's ability to encase the reinforcement.

panel, shotcrete test—a shotcrete specimen prepared in accordance with ASTM C1140 for evaluation of shotcrete.

pedestal—member with a ratio of height-to-least lateral dimension less than or equal to 3 used primarily to support axial compressive load; for a tapered member, the least lateral dimension is the average of the top and bottom dimensions of the smaller side.

plastic hinge region—length of frame element over which flexural yielding is intended to occur due to earthquake design displacements, extending not less than a distance h from the critical section where flexural yielding initiates.

post-tensioning—method of prestressing in which prestressing reinforcement is tensioned after concrete has hardened.

precast concrete piles—driven piles that may be either prestressed concrete or conventionally reinforced concrete.

precompressed tension zone—portion of a prestressed member where flexural tension, calculated using gross section properties, would occur under service loads if the prestress force was not present.

one-way construction—Joists, beams, girders, and some slabs and foundations are considered one-way construction.

panel, shotcrete mockup—Shotcrete mockup panels are used for preconstruction evaluation and are either sawed or cored, or both, to evaluate if the reinforcement has been adequately encased.

panel, shotcrete test—Shotcrete test panels are typically used to evaluate a shotcrete mixture, to qualify a nozzle operator, to verify surface finish, and to provide specimens for compressive or flexural strength testing.

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pretensioning—method of prestressing in which prestressing reinforcement is tensioned before concrete is cast.

projected area—area on the free surface of the concrete member that is used to represent the greater base of the assumed rectilinear failure surface.

projected influence area—rectilinear area on the free surface of the concrete member that is used to calculate the bond strength of adhesive anchors.

pryout strength, concrete—strength corresponding to formation of a concrete spall behind short, stiff anchors displaced in the direction opposite to the applied shear force.

reinforcement—steel element or elements embedded in concrete and conforming to 20.2 through 20.4. Prestressed reinforcement in external tendons is also considered reinforcement.

reinforcement, anchor—reinforcement used to transfer the design load from the anchors into the structural member.

reinforcement, bonded prestressed—pretensioned reinforcement or prestressed reinforcement in a bonded tendon.

reinforcement, deformed—deformed bars, welded bar mats, deformed wire, and welded wire reinforcement conforming to 20.2.1.3, 20.2.1.5, or 20.2.1.7, excluding plain wire.

reinforcement, nonprestressed—bonded reinforcement that is not prestressed.

reinforcement, plain—bars or wires conforming to 20.2.1.4 or 20.2.1.7 that do not conform to definition of deformed reinforcement.

reinforcement, prestressed—prestressing reinforcement that has been tensioned to impart forces to concrete.

reinforcement, prestressing—high-strength reinforcement such as strand, wire, or bar conforming to 20.3.1.

reinforcement, supplementary—reinforcement that acts to restrain the potential concrete breakout but is not designed to transfer the design load from the anchors into the structural member.

reinforcement, welded deformed steel bar mat—mat conforming to 20.2.1.5 consisting of two layers of deformed bars at right angles to each other welded at the intersections.

reinforcement, welded wire—plain or deformed wire fabricated into sheets or rolls conforming to 20.2.1.7.

Seismic Design Category—classification assigned to a structure based on its occupancy category and the severity of the design earthquake ground motion at the site, as defined

reinforcement, anchor—Anchor reinforcement is designed and detailed specifically for the purpose of transferring anchor loads from the anchors into the member. Hairpins are generally used for this purpose (refer to 17.5.2.1(a) and 17.5.2.1(b)); however, other configurations that can be shown to effectively transfer the anchor load are acceptable.

reinforcement, deformed—Deformed reinforcement is defined as that meeting the reinforcement specifications in this Code. No other reinforcement qualifies. This definition permits accurate statement of development lengths. Bars or wire not meeting the deformation requirements or welded wire reinforcement not meeting the spacing requirements are “plain reinforcement,” for code purposes, and may be used only for spirals.

reinforcement, supplementary—Supplementary reinforcement has a configuration and placement similar to anchor reinforcement but is not specifically designed to transfer loads from the anchors into the member. Stirrups, as used for shear reinforcement, may fall into this category.

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by the general building code. Also denoted by the abbreviation SDC.

seismic-force-resisting system—portion of the structure designed to resist earthquake effects required by the general building code using the applicable provisions and load combinations.

seismic hook—hook on a stirrup, hoop, or crosstie having a bend not less than 135 degrees, except that circular hoops shall have a bend not less than 90 degrees; hooks shall have an extension of at least $6d_b$, but not less than 75 mm. The hooks shall engage the longitudinal reinforcement and the extension shall project into the interior of the stirrup or hoop.

shear cap—projection below the slab used to increase the slab shear strength.

shear lug—a steel element welded to an attachment base plate to transfer shear to concrete by bearing.

sheathing—material encasing prestressing reinforcement to prevent bonding of the prestressing reinforcement with the surrounding concrete, to provide corrosion protection, and to contain the corrosion-inhibiting coating.

shotcrete—mortar or concrete placed pneumatically by high velocity projection from a nozzle onto a surface.

shotcrete, dry-mix—shotcrete in which most of the mixing water is added to the concrete ingredients at the nozzle.

shotcrete, wet-mix—shotcrete in which the concrete ingredients, including water, are mixed before introduction into the delivery hose.

side-face blowout strength, concrete—strength of anchors with deep embedment and thin side-face cover such that spalling occurs on the side face around the embedded head without breakout occurring at the top concrete surface.

slab-beam strip—in two-way prestressed slabs, the width of the floor system, including both the slab and beam if applicable, bounded laterally by adjacent panel centerlines for an interior slab-beam strip, or by adjacent panel centerline and slab edge for an exterior slab-beam strip.

spacing, clear—least dimension between the outermost surfaces of adjacent items.

span length—distance between supports.

special seismic systems—structural systems that use special moment frames, special structural walls, or both.

specialty engineer—a licensed design professional to whom a specific portion of the design work has been delegated.

specialty insert—predesigned and prefabricated cast-in anchors specifically designed for attachment of bolted or slotted connections.

spiral reinforcement—continuously wound reinforcement in the form of a cylindrical helix.

steel element, brittle—element with a tensile test elongation of less than 14 percent, or reduction in area of less than 30 percent at failure.

steel element, ductile—element with a tensile test elongation of at least 14 percent and reduction in area of at

sheathing—Typically, sheathing is a continuous, seamless, high-density polyethylene material extruded directly on the coated prestressing reinforcement.

shotcrete—Terms such as gunite and sprayed concrete are sometimes used to refer to shotcrete.

specialty insert—Specialty inserts are devices often used for handling, transportation, erection, and anchoring elements; specialty inserts are not within the scope of this Code.

steel element, brittle—The 14 percent elongation should be measured over the gauge length specified in the appropriate ASTM standard for the steel.

steel element, ductile—The 14 percent elongation should be measured over the gauge length specified in the

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least 30 percent; steel element meeting the requirements of **ASTM A307** shall be considered ductile; except as modified by for earthquake effects, deformed reinforcing bars meeting the requirements of **ASTM A615**, **A706**, or **A955** shall be considered as ductile steel elements.

stirrup—reinforcement used to resist shear and torsion forces in a member; typically deformed bars, deformed wires, or welded wire reinforcement either single leg or bent into L, U, or rectangular shapes and located perpendicular to, or at an angle to, longitudinal reinforcement. See also **tie**.

strength, design—nominal strength multiplied by a strength reduction factor ϕ .

strength, nominal—strength of a member or cross section calculated in accordance with provisions and assumptions of the strength design method of this Code before application of any strength reduction factors.

strength, required—strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as stipulated in this Code.

stretch length—length of anchor, extending beyond concrete in which it is anchored, subject to full tensile load applied to anchor, and for which cross-sectional area is minimum and constant.

structural concrete—concrete used for structural purposes, including plain and reinforced concrete.

structural diaphragm—member, such as a floor or roof slab, that transmits forces acting in the plane of the member to vertical elements of the lateral-force-resisting system. A structural diaphragm may include chords and collectors as part of the diaphragm.

structural integrity—ability of a structure through strength, redundancy, ductility, and detailing of reinforcement to redistribute stresses and maintain overall stability if localized damage or significant overstress occurs.

structural system—interconnected members designed to meet performance requirements.

structural truss—assemblage of reinforced concrete members subjected primarily to axial forces.

structural wall—wall proportioned to resist combinations of moments, shears, and axial forces in the plane of the wall; a shear wall is a structural wall.

structural wall, ductile coupled—a seismic-force-resisting-system complying with 18.10.9.

structural wall, ordinary reinforced concrete—a wall complying with Chapter 11.

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appropriate ASTM standard for steel. Due to concerns over fracture in cut threads, it should be verified that threaded deformed reinforcing bars satisfy the strength requirements of **25.5.7.1**.

stirrup—The term “stirrup” is usually applied to transverse reinforcement in beams or slabs and the term “ties” or “hoops” to transverse reinforcement in compression members.

strength, nominal—Nominal or specified values of material strengths and dimensions are used in the calculation of nominal strength. The subscript n is used to denote the nominal strengths; for example, nominal axial load strength P_n , nominal moment strength M_n , and nominal shear strength V_n . For additional discussion on the concepts and nomenclature for strength design, refer to the Commentary of **Chapter 22**.

strength, required—The subscript u is used only to denote the required strengths; for example, required axial load strength P_u , required moment strength M_u , and required shear strength V_u , calculated from the applied factored loads and forces. The basic requirement for strength design may be expressed as follows: design strength $\geq$ required strength; for example, $\phi P_n \geq P_u$; $\phi M_n \geq M_u$; $\phi V_n \geq V_u$. For additional discussion on the concepts and nomenclature for strength design, refer to the Commentary of Chapter 22.

stretch length—Length of an anchor over which inelastic elongations are designed to occur under earthquake loadings. Examples illustrating stretch length are shown in Fig. R17.10.5.3.

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structural wall, ordinary plain concrete—a wall complying with Chapter 14.

structural wall, intermediate precast—a wall complying with 18.5.

structural wall, special—a cast-in-place structural wall in accordance with 18.2.3 through 18.2.8 and 18.10; or a precast structural wall in accordance with 18.2.3 through 18.2.8 and 18.11.

strut—compression member in a strut-and-tie model representing the resultant of a parallel or a fan-shaped compression field.

strut, boundary—strut located along the boundary of a member or discontinuity region.

strut, interior—strut not located along the boundary of a member or discontinuity region.

strut-and-tie model—truss model of a member or of a D-region in such a member, made up of struts and ties connected at nodes and capable of transferring the factored loads to the supports or to adjacent B-regions.

tendon—in post-tensioned members, a tendon is a complete assembly consisting of anchorages, prestressing reinforcement, and sheathing with coating for unbonded applications or ducts filled with grout for bonded applications.

tendon, bonded—tendon in which prestressed reinforcement is continuously bonded to the concrete through grouting of ducts embedded within the concrete cross section.

tendon, external—a tendon external to the member concrete cross section in post-tensioned applications.

tendon, unbonded—tendon in which prestressed reinforcement is prevented from bonding to the concrete. The prestressing force is permanently transferred to the concrete at the tendon ends by the anchorages only.

tension-controlled section—a cross section in which the net tensile strain in the extreme tension steel at nominal strength is greater than or equal to $\epsilon_{ty} + 0.003$.

tie—(a) reinforcing bar or wire enclosing longitudinal reinforcement; a continuously wound transverse bar or wire in the form of a circle, rectangle, or other polygonal shape without reentrant corners enclosing longitudinal reinforcement; see also **stirrup**, **hoop**; (b) tension element in a strut-and-tie model.

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structural wall, intermediate precast—Requirements of 18.5 are intended to result in an intermediate precast structural wall having minimum strength and toughness equivalent to that for an ordinary reinforced concrete structural wall of cast-in-place concrete. A precast concrete wall not satisfying the requirements of 18.5 is considered to have ductility and structural integrity less than that for an intermediate precast structural wall.

structural wall, special—Requirements of 18.2.3 through 18.2.8 and 18.11 are intended to result in a special precast structural wall having minimum strength and toughness equivalent to that for a special reinforced concrete structural wall of cast-in-place concrete.

strut, boundary—A boundary strut is intended to apply to the flexural compression zone of a beam, wall, or other member. Boundary struts are not subject to transverse tension and are therefore stronger than interior struts (Fig. R23.2.1).

strut, interior—Interior struts are subject to tension, acting perpendicular to the strut in the plane of the model, from shear (Fig. R23.2.1).

tendon, external—In new or existing post-tensioned applications, a tendon totally or partially external to the member concrete cross section, or inside a box section, and attached at the anchor device and deviation points.

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transfer—act of transferring stress in prestressed reinforcement from jacks or pretensioning bed to concrete member.

transfer length—length of embedded pretensioned reinforcement required to transfer the effective prestress to the concrete.

two-way construction—members designed to be capable of supporting loads through bending in two directions; some slabs and foundations are considered two-way construction. See also **one-way construction**.

uncased cast-in-place concrete drilled or augered piles—piles with or without an enlarged base (bell) that are constructed by either drilling a hole in the ground, or by installing a temporary casing in the ground and cleaning out the soil, and subsequently filling the hole with reinforcement and concrete.

wall—a vertical element designed to resist axial load, lateral load, or both, with a horizontal length-to-thickness ratio greater than 3, used to enclose or separate spaces.

wall segment—portion of wall bounded by vertical or horizontal openings or edges.

wall segment, horizontal—segment of a structural wall, bounded vertically by two openings or by an opening and an edge.

wall segment, vertical—segment of a structural wall, bounded horizontally by two openings or by an opening and an edge; wall piers are vertical wall segments.

wall pier—a vertical wall segment within a structural wall, bounded horizontally by two openings or by an opening and an edge, with ratio of horizontal length to wall thickness (ℓ_w/b_w) less than or equal to 6.0, and ratio of clear height to horizontal length (h_w/ℓ_w) greater than or equal to 2.0.

water-cementitious materials ratio—ratio of mass of water, excluding that absorbed by the aggregate, to the mass of cementitious materials in a mixture, stated as a decimal.

work—the entire construction or separately identifiable parts thereof that are required to be furnished under the construction documents.

yield strength—specified minimum yield strength or yield point of reinforcement; yield strength or yield point shall be determined in tension according to applicable ASTM standards as modified by this Code.

wall segment, horizontal—A horizontal wall segment is shown in Fig. R18.10.4.5.

wall pier—Wall piers are vertical wall segments with dimensions and reinforcement intended to result in shear demand being limited by flexural yielding of the vertical reinforcement in the pier.

CHAPTER 3—REFERENCED STANDARDS

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3.1—Scope

3.1.1 Standards, or specific sections thereof, cited in this Code, including Annex, Appendixes, or Supplements where prescribed, are referenced without exception in this Code, unless specifically noted. Cited standards are listed in the following with their serial designations, including year of adoption or revision.

3.2—Referenced standards

3.2.1 *American Association of State Highway and Transportation Officials (AASHTO)*

LRFDUS-8—LRFD Bridge Design Specifications, 8th Edition, 2017, Articles 5.8.4.4.2, 5.8.4.4.3, and 5.8.4.5

LRFDCONS-4—LRFD Bridge Construction Specifications, Fourth Edition, 2017, Article 10.3.2.3

3.2.2 *American Concrete Institute (ACI)*

301M-16—Specifications for Structural Concrete, Article 4.2.3

318.2-19—Building Code Requirements for Concrete Thin Shells and Commentary

332M-14—Residential Code Requirements for Structural Concrete and Commentary

355.2-19—Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary

355.4M-11—Qualification of Post-Installed Adhesive Anchors in Concrete

369.1M-17—Standard Requirements for Seismic Evaluation and Retrofit of Existing Concrete Buildings (369.1M-17) and Commentary

374.1-05—Acceptance Criteria for Moment Frames Based on Structural Testing

423.7-14—Specification for Unbonded Single-Strand Tendon Materials

437.2M-13—Code Requirements for Load Testing of Existing Concrete Structures and Commentary

550.3M-13—Design Specification for Unbonded Post-Tensioned Precast Concrete Special Moment Frames Satisfying ACI 374.1 and Commentary

550.4M-18—Qualification of Precast Concrete Diaphragm Connections and Reinforcement at Joints for Earthquake Loading and Commentary

550.5M-18—Code Requirements for the Design of Precast Concrete Diaphragms for Earthquake Motions and Commentary

ITG-5.1M-07—Acceptance Criteria for Special Unbonded Post-Tensioned Precast Structural Walls Based on Validation Testing

ITG-5.2-09—Requirements for Design of a Special Unbonded Post-Tensioned Precast Wall Satisfying ACI ITG-5.1 and Commentary

R3.1—Scope

R3.1.1 In this Code, references to standard specifications or other material are to a specific edition of the cited document. This is done by using the complete serial designation for the referenced standard including the title that indicates the subject and year of adoption. All standards referenced in this Code are listed in this chapter, with the title and complete serial designation. In other sections of the Code, referenced standards are abbreviated to include only the serial designation without a title or date. These abbreviated references correspond to specific standards listed in this chapter.

R3.2—Referenced standards

R3.2.1 *American Association of State Highway and Transportation Officials (AASHTO)*

Three articles of the AASHTO LRFD Specifications for Highway Bridge Design (AASHTO LRFDUS) and one article of the AASHTO LRFD Construction Specifications (AASHTO LRFDCONS) are cited in [Chapters 2](#) and [25](#) of this Code.

R3.2.2 *American Concrete Institute (ACI)*

Article 4.2.3 of ACI 301M is referenced for the method of mixture proportioning cited in [26.4.3.1\(b\)](#).

Prior to 2014, the provisions of [ACI 318.2](#) were specified in Chapter 19 of the ACI 318 Building Code.

[ACI 355.2](#) contains qualification requirements for testing and evaluating post-installed expansion, screw, and undercut anchors for use in both cracked and uncracked concrete.

[ACI 355.4M](#) contains qualification requirements for testing and evaluating adhesive anchors for use in both cracked and uncracked concrete.

[ACI 423.7](#) requires the use of encapsulated tendon systems for applications subject to this Code.

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3.2.3 American Society of Civil Engineers (ASCE)

ASCE/SEI 7-16—Minimum Design Loads for Buildings and Other Structures, Sections 2.3.2, Load Combinations Including Flood Loads; and 2.3.3, Load Combinations Including Atmospheric Ice Loads

3.2.4 ASTM International

A184/A184M-17—Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement

A307-14^{e1}—Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 PSI Tensile Strength

A370-18—Standard Test Methods and Definitions for Mechanical Testing of Steel Products

A416/A416M-18—Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete

A421/A421M-15—Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete, including Supplementary Requirement SI, Low-Relaxation Wire and Relaxation Testing

A615/A615M-18^{e1}—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

A706/A706M-16—Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

A722/A722M-18—Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete

A767/A767M-16—Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

A775/A775M-17—Standard Specification for Epoxy-Coated Steel Reinforcing Bars

A820/A820M-16—Standard Specification for Steel Fibers for Fiber-Reinforced Concrete

A884/A884M-14—Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement

A934/A934M-16—Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

A955/A955M-18b—Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

A970/A970M-18—Standard Specification for Headed Steel Bars for Concrete Reinforcement, including Annex A1 Requirements for Class HA Head Dimensions

A996/A996M-16—Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

A1022/A1022M-16b—Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement

A1035/A1035M-16b—Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement

A1044/A1044M-16a—Standard Specification for Steel Stud Assemblies for Shear Reinforcement of Concrete

A1055/A1055M-16—Standard Specification for Zinc and Epoxy Dual-Coated Steel Reinforcing Bars

A1060/A1060M-16b—Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire Reinforcement, Plain and Deformed, for Concrete

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R3.2.3 American Society of Civil Engineers (ASCE)

The two specific sections of ASCE 7 are referenced for the purposes cited in 5.3.9 and 5.3.10.

R3.2.4 ASTM International

The ASTM standards listed are the latest editions at the time these code provisions were adopted. ASTM standards are revised frequently relative to the revision cycle for the Code. Current and historical editions of the referenced standards can be obtained from ASTM International. Use of an edition of a standard other than that referenced in the Code obligates the user to evaluate if any differences in the nonconforming edition are significant to use of the standard.

Many of the ASTM standards are combined standards as denoted by the dual designation, such as ASTM A36/A36M. For simplicity, these combined standards are referenced without the metric (M) designation within the text of the Code and Commentary. In this provision, however, the complete designation is given because that is the official designation for the standard.