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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

American Concrete Institute
Always advancing

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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 301)" 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

### 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

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### 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. | structural concrete, as well as for acceptance of design and construction of concrete structures by the building officials or their designated representatives.<br>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. |
| **1.3.2** This Code does not address all design considerations. | **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. |
| **1.3.3** Construction means and methods are not addressed in this Code. | |
| **1.4—Applicability** | **R1.4—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. | **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. |
| **1.4.3** Applicable provisions of this Code shall be permitted to be used for structures not governed by the general building code. | **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:<br>• "Code Requirements for Reinforced Concrete Chimneys and Commentary" (ACI 307-08)<br>• "Standard Practice for Design and Construction of Concrete Silos and Stacking Tubes for Storing Granular Materials" (ACI 313-97)<br>• "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary" (ACI 349)<br>• "Code for Concrete Containments" (ACI 359) |
| **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. | **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 Floor Deck" |

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

**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 332 shall be permitted.

**R1.4.6** ACI 332 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.

**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)

**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.

**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.

**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.

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

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

**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.

**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 create continuity at

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

### 1.5—Interpretation

### R1.5—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.

**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.

**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.

**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.

**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.

**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.

**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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### 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.