ACI Releases ACI 318-19

Building Code Requirements for Structural Concrete

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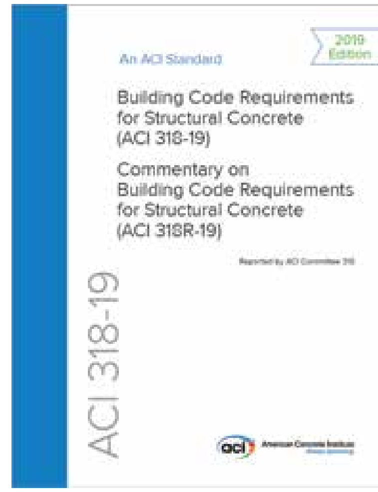

ACI 318-19 includes new and updated code provisions on one-way shear, two-way shear, shear wall drift capacity, seismic design, shotcrete, deep foundations, post-tensioning, precast, durability, lightweight concrete, and more.

The American Concrete Institute (ACI) published ACI 318-19, *Building Code Requirements for Structural Concrete*, in June 2019. This edition of ACI 318 is the first to be published since the format of ACI 318 was reorganized in 2014. It includes new and updated code provisions as well as color illustrations and interactive links in its online version.

ACI 318 includes the requirements for design and construction of structural concrete that are necessary to ensure public health and safety. It also addresses materials that have recently come into common use and incorporates calculations for now-common building types, such as tall structures. Seismic design is extensively addressed in ACI 318-19. The intended user of ACI 318 is the engineer or the building official who is responsible for the contract documents. It is anticipated that ACI 318-19 will be referenced in the 2021 *International Building Code* (IBC).

Materials

Current U.S. building codes limit rebar strength based on decades-old research and the assumption that most reinforcement used in concrete construction in the United States is Grade 60. Progress in metallurgy, however, has resulted in the production of rebar that is almost twice as strong as it was several decades ago. This stronger rebar can transfer much higher stresses; however, it also may lack benchmark properties of weaker steels, such as minimum strain-hardening and elongation. Recognizing these facts, ACI 318-19 includes new requirements for material properties of these higher-strength steels. Accompanying these are myriad changes related to strength reduction factors, minimum reinforcement, effective stiffness, and requirements for development and splice lengths of straight high-strength rebar as well as hooks and headed bars. These updates are expected to support the adoption of high-strength bars, which will, in turn, reduce congestion in heavily reinforced members, improve concrete placement, and save time and labor.

ACI 318-19 raises limits on the specified strength of reinforcement in shear wall and special moment frame systems. The new standard allows Grade 80 reinforcement for some special seismic systems and no longer allows Grade 40 rebar to be used in seismic applications. Shear walls can employ rebar in Grades 60, 80, or 100. Special moment frames can use Grades 60 or 80. Hoops and stirrups in special seismic systems used to support vertical reinforcing steel have a tighter specified spacing to prevent the vertical bars from buckling.

Shotcrete, a method of placing concrete by projecting it at high velocity, was not explicitly discussed in previous versions of ACI 318 but is now specifically included in ACI 318-19. This effort involved incorporating many IBC shotcrete provisions and updating them to current practice. The unification is expected to clarify both the design process and construction requirements for the use of shotcrete.

Seismic Requirements and PDB

With many new metrics for building performance – such as seismic resistance – now in place, performance-based design (PDB) is becoming common, especially in the western United States. Performance-based requirements set measurable objectives but allow freedom in design and construction for how the objectives are met. Performance-based seismic design is commonly done using nonlinear dynamic analysis. A new Appendix A in ACI 318-19 sets parameters for design verification of earthquake-resistant concrete structures using nonlinear response history analysis. Appendix A is intended to be used in conjunction with Chapter 16 of ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, which includes general requirements, ground motions, and load combinations. Appendix A is also compatible with *Guidelines for Performance-Based Seismic Design of Tall Buildings*, a document published by Pacific Earthquake Engineering Research (PEER) in conjunction with PEER's partners in the Tall Buildings Initiative. With the release of ACI 318-19, ACI becomes the primary resource for nonlinear dynamic analysis as it pertains to tall concrete buildings.

For the seismic design of structural walls, ACI 318-19 introduces several new design requirements. Whereas previous designs permitted the use of crossties with 90-degree hooks at one end, all crossties for special boundary elements now must have 135-degree hooks at both ends. New provisions also restrict the locations of lap splices near intended plastic hinge zones. Another new design provision provides a check that detailing is adequate for the calculated earthquake displacement demands. Perhaps most significantly, new provisions will now amplify wall design shears based on considerations of wall flexural overstrength and the effects of higher dynamic response modes, which may result in substantial increases in design shears for some walls.

ACI 318-19 also adopts the precast concrete diaphragm design procedure of ACI 550.5, *Code Requirements for the Design of Precast Concrete Diaphragms for Earthquake Motions*. The design method in ACI 550.5 gives designers connection options for selecting the target performance of a precast concrete diaphragm when subject to seismic forces. ACI 550.5 requires that connections be qualified in accordance with ACI 550.4, *Qualification of Precast Concrete Diaphragm Connections and Reinforcement at Joints for Earthquake Loading*.

ACI 318-19 clarifies the application and effect of the vertical ground component on earthquake load. There were numerous clarifications and additions to the requirements for column tie spacing in special moment frames; this included clarifications of tie spacings for columns that are not considered part of the earthquake-resisting system. Intermediate moment frame requirements for tie spacing were also reduced.

ACI 318-19 also made numerous miscellaneous clarifications and simplifications. The column-to-beam flexural strength ratio was adjusted for roof-level connections where the column axial load is low, for example. The shear area of concrete walls, A_{cv}, was clarified so that it is clear it does not include the area of wall openings.

Additional Changes to ACI 318-19

ACI 318-19 addresses concerns in the industry that previous shear provisions were inadequate for the design of thick slabs or deep beams. As more large structures are designed to include thick slabs that support upper floors, these updates are timely. ACI 318-19 sections on one-way shear and two-way shear (that is, punching shear) consolidate what was previously a wide range of equations They also provide a method to include size effect in shear design to avoid issues wherein increasing a member's size can reduce the design unit shear strength of a section. The new shear equations also allow the design engineer to take the effect of reinforcement ratio into consideration.

ACI 318-19 includes revisions and additions aimed at eliminating conflicting provisions in ACI 318, ASCE 7, and IBC regarding the design of deep foundations for earthquake-resistant structures. For some time, these differences have been a source of confusion for both engineers and code officials. The purpose of the code change is to have all the pertinent concrete related design and detailing provisions for the seismic design of deep foundations contained in ACI 318-19.

A variety of other industry needs are now addressed in ACI 318-19. Updates were made to provisions on post-tensioning, precast concrete, concrete durability, lightweight concrete, and strut-and-tie methodology (STM).

- Post-tensioning updates included clarifications of the construction requirements regarding loss of prestress, use of a new reference document for determining prestress losses, deformed and bonded reinforcement spacing limitations, and several clarifications to requirements for anchorage zone reinforcement.
- Precast concrete received several clarifications with specific attention on bearing connections.
- Numerous changes were made to the durability of concrete sections, including additional requirements for sulfate exposure classes and concrete exposed to water.
- Lightweight concrete provisions throughout the code received numerous changes and clarifications based on the new method for determining λ, the lightweight modification factor.
- Updates to STM included the removal of bottle-shaped struts from the code and the inclusion of minimum reinforcing requirements in STM. Other STM improvements included curved-bar nodes and knee joints.

Additional changes include:

- Shrinkage and temperature reinforcement requirements were simplified.
- Load testing provisions were modified to become more consistent with other ACI standards.
- Addition of commentary language allowing ACI 318-19 to be used for analysis, repair, and rehabilitation of existing structures and to recognize ACI 562, *Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures.*

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Several analysis clarifications and additions were made. Commentary language regarding vibration analysis was added to help the user find guidance for designing a structure when vibrations are design criteria. Calculations of the effective moment of inertia, I_e, were adjusted for nonprestressed reinforced concrete based on more accurate estimated deflection calculation results in both the laboratory and the field.

Code Integration and Reorganization

In addition to its compatibility with the ASCE 7 requirements for design verification using nonlinear dynamic analysis, ACI 318-19 achieves code integration by incorporating information from the IBC and modernizing those provisions. ACI 318-19 also identifies areas where personnel are required to be certified and references appropriate certification requirements. By referencing certification requirements directly in the code and commentary, the information becomes more easily accessible to engineers.

Two chapters of ACI 318-19 have been reorganized. Chapter 17, which covers anchor design, was reformatted to match the format of other chapters initially adopted for ACI 318-14. It now includes screw anchors and shear lugs. ACI 318.2-14, "Building Code Requirements for Concrete Thin Shells and Commentary," which replaced ACI 318-11 Chapter 19, was also reorganized to have consistency with the rest of ACI 318-19.

Chapter 26, "Construction Documents and Inspection," has seen significant updates since ACI 318-14. Inspection requirements are unified in this chapter, including the relocation of anchor inspection requirements from Chapter 17. The chapter now recognizes that projects may have roles for multiple design engineers and provides a framework for their coordination of work. As higher strength concretes have been developed over time, using the standard definition of modulus of elasticity may not be adequate for certain projects (such as tall buildings). Therefore, the definition for modulus of elasticity was updated using data from external documents and best practices. For certain materials that are becoming commonplace in the industry (such as alternative cements, crushed hydraulic-cement concrete, or recycled aggregates), ACI 318-19 Chapter 26 outlines precautions for designers who are considering their use. Additionally, an alternative method for defining λ – which is a modification factor for adjusting tensile strength when using lightweight concrete – was added to ACI 318-19. This new method calculates λ based on concrete mixture proportions, allowing λ to be defined as early as the project design stage.

Printed and digital formats of ACI 318-19 are available at **concrete.org**. Versions are available in inch-pound units and SI units. ACI 318-19 is also available to subscribers of the online ACI Collection of Concrete Codes, Specifications, and Practices. Additionally, the Institute is hosting public and in-house seminars to introduce users to ACI 318-19 – visit the website for locations and to learn more.▪

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