BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE (ACI 318-05) AND COMMENTARY (ACI 318R-05)

REPORTED BY ACI COMMITTEE 318

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Structural Building Code

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ACI 318-05 is deemed to satisfy ISO 19338, "Performance and Assessment Requirements for Design Standards on Structural Concrete," Reference Number ISO 19338.2003(E). Also Technical Corrigendum 1: 2004.

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PREFACE

The code portion of this document covers the design and construction of structural concrete used in buildings and where applicable in nonbuilding structures.

Among the subjects covered are: drawings and specifications; inspection; materials; durability requirements; concrete quality, mixing, and placing; formwork; embedded pipes; construction joints; reinforcement details; analysis and design; strength and serviceability; flexural and axial loads; shear and torsion; development and splices of reinforcement; slab systems; walls; footings; precast concrete; composite flexural members; prestressed concrete; shells and folded plate members; strength evaluation of existing structures; special provisions for seismic design; structural plain concrete; strut-and-tie modeling in Appendix A; alternative design provisions in Appendix B; alternative load and strength-reduction factors in Appendix C; and anchoring to concrete in Appendix D.

The quality and testing of materials used in construction are covered by reference to the appropriate ASTM standard specifications. Welding of reinforcement is covered by reference to the appropriate ANSI/AWS standard.

Uses of the code include adoption by reference in general building codes, 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 portion cannot be included. The commentary is provided for this purpose. Some of the considerations of the committee in developing the code portion are discussed within 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.

Keywords: admixtures; aggregates; anchorage (structural); beam-column frame; beams (supports); **building codes;** cements; cold weather construction; columns (supports); combined stress; composite construction (concrete and steel); composite construction (concrete to concrete); compressive strength; **concrete construction; concretes;** concrete slabs; construction joints; continuity (structural); contraction joints; cover; curing; deep beams; deflections; drawings; earthquake resistant structures; embedded service ducts; flexural strength; floors; folded plates; footings; formwork (construction); frames; hot weather construction; inspection; isolation joints; joints (junctions); joists; lightweight concretes; loads (forces); load tests (structural); materials; mixing; mix proportioning; modulus of elasticity; moments; pipe columns; pipes (tubing); placing; plain concrete; precast concrete; prestressed concrete; prestressing steels; quality control; **reinforced concrete**; reinforcing steels; roofs; serviceability; shear strength; shearwalls; shells (structural forms); spans; specifications; splicing; strength; strength analysis; stresses; **structural analysis; structural concrete; structural design;** structural integrity; T-beams; torsion; walls; water; welded wire reinforcement.

ACI 318-05 was adopted as a standard of the American Concrete Institute October 27, 2004 to supersede ACI 318-02 in accordance with the Institute's standardization procedure.

A complete metric companion to ACI 318/318R has been developed, 318M/318RM; therefore no metric equivalents are included in this document.

ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This 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 material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom. Reference to this commentary shall not be made in contract documents. If items found in this Commentary are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

CONTENTS

The ACI Building code and commentary are presented in a side-by-side column format, with code text placed in the left column and the corresponding commentary text aligned in the right column. To further distinguish the code from the commentary, the code has been printed in Helvetica, the same type face in which this paragraph is set.

This paragraph is set in Times Roman, and all portions of the text exclusive to the commentary are printed in this type face. Commentary section numbers are preceded by an "R" to further distinguish them from code section numbers.

Vertical lines in the margins indicate changes from the previous version. Changes to the notation and strictly editorial changes are not indicated with a vertical line.

INTRODUCTION

This commentary discusses some of the considerations of Committee 318 in developing the provisions contained in "Building Code Requirements for Structural Concrete (ACI 318-05)," hereinafter called the code or the 2005 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 ACI Building 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.

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 judgement.

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 structural designer 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 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 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 provides a means of establishing minimum standards for acceptance of designs and construction by legally appointed building officials or their designated representatives. 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 since 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 drawings, specifications and 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.

It is recommended to have testing and certification programs for the individual parties involved with the execution of work performed in accordance with this code. Available for this purpose are the plant certification programs of the Precast/Prestressed Concrete Institute, the Post-Tensioning Institute and the National Ready Mixed Concrete Association; the personnel certification programs of the American Concrete Institute and the Post-Tensioning Institute; and the Concrete Reinforcing Steel Institute's Voluntary Certification Program for Fusion-Bonded Epoxy Coating Applicator Plants. In addition, "Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction" (ASTM E 329-03) specifies performance requirements for inspection and testing agencies.

*For a history of the ACI Building Code see Kerekes, Frank, and Reid, Harold B., Jr., "Fifty Years of Development in Building Code Requirements for Reinforced Concrete," ACI JOURNAL, *Proceedings* V. 50, No. 6, Feb. 1954, p. 441. For a discussion of code philosophy, see Siess, Chester P., "Research, Building Codes, and Engineering Practice," ACI JOURNAL, *Proceedings* V. 56, No. 5, May 1960, p. 1105.

Design reference materials illustrating applications of the code requirements may be found in the following documents. The design aids listed may be obtained from the sponsoring organization.

Design aids:

"ACI Design Handbook," ACI Committee 340, Publication SP-17(97), American Concrete Institute, Farmington Hills, MI, 1997, 482 pp. (Provides tables and charts for design of eccentrically loaded columns by the Strength Design Method. Provides design aids for use in the engineering design and analysis of reinforced concrete slab systems carrying loads by two-way action. Design aids are also provided for the selection of slab thickness and for reinforcement required to control deformation and assure adequate shear and flexural strengths.)

"ACI Detailing Manual—2004," ACI Committee 315, Publication SP-66(04), American Concrete Institute, Farmington Hills, MI, 2004, 212 pp. (Includes the standard, ACI 315-99, and report, ACI 315R-04. Provides recommended methods and standards for preparing engineering drawings, typical details, and drawings placing reinforcing steel in reinforced concrete structures. Separate sections define responsibilities of both engineer and reinforcing bar detailer.)

"Guide to Durable Concrete (ACI 201.2R-92)," ACI Committee 201, American Concrete Institute, Farmington Hills, MI, 1992, 41 pp. (Describes specific types of concrete deterioration. It contains a discussion of the mechanisms involved in deterioration and the recommended requirements for individual components of the concrete, quality considerations for concrete mixtures, construction procedures, and influences of the exposure environment. Section R4.4.1 discusses the difference in chloride-ion limits between ACI 201.2R-92 and the code.)

"Guide for the Design of Durable Parking Structures (362.1R-97 (Reapproved 2002))," ACI Committee 362, American Concrete Institute, Farmington Hills, MI, 1997, 40 pp. (Summarizes practical information regarding design of parking structures for durability. It also includes information about design issues related to parking structure construction and maintenance.)

"CRSI Handbook," Concrete Reinforcing Steel Institute, Schaumburg, IL, 9th Edition, 2002, 648 pp. (Provides tabulated designs for structural elements and slab systems. Design examples are provided to show the basis of and use of the load tables. Tabulated designs are given for beams; square, round and rectangular columns; one-way slabs; and one-way joist construction. The design tables for two-way slab systems include flat plates, flat slabs and waffle slabs. The chapters on foundations provide design tables for square footings, pile caps, drilled piers (caissons) and cantilevered retaining walls. Other design aids are presented for crack control; and development of reinforcement and lap splices.)

"Reinforcement Anchorages and Splices," Concrete Reinforcing Steel Institute, Schaumberg, IL, 4th Edition, 1997, 100 pp. (Provides accepted practices in splicing reinforcement. The use of lap splices, mechanical splices, and welded splices are described. Design data are presented for development and lap splicing of reinforcement.)

"Structural Welded Wire Reinforcement Manual of Standard Practice," Wire Reinforcement Institute, Hartford, CT, 6th Edition, Apr. 2001, 38 pp. (Describes welded wire reinforcement material, gives nomenclature and wire size and weight tables. Lists specifications and properties and manufacturing limitations. Book has latest code requirements as code affects welded wire. Also gives development length and splice length tables. Manual contains customary units and soft metric units.)

"Structural Welded Wire Reinforcement Detailing Manual," Wire Reinforcement Institute, Hartford, CT, 1994, 252 pp. (Updated with current technical fact sheets inserted.) The manual, in addition to including ACI 318 provisions and design aids, also includes: detailing guidance on welded wire reinforcement in one-way and two-way slabs; precast/prestressed concrete components; columns and beams; cast-in-place walls; and slabs-on-ground. In addition, there are tables to compare areas and spacings of high-strength welded wire with conventional reinforcing.

"Strength Design of Reinforced Concrete Columns," Portland Cement Association, Skokie, IL, 1978, 48 pp. (Provides design tables of column strength in terms of load in kips versus moment in ft-kips for concrete strength of 5000 psi and Grade 60 reinforcement. Design examples are included. Note that the PCA design tables do not include the strength reduction factor ϕ in the tabulated values; M_u/ϕ and P_u/ϕ must be used when designing with this aid.

"PCI Design Handbook—Precast and Prestressed Concrete," Precast/Prestressed Concrete Institute, Chicago, IL, 5th Edition, 1999, 630 pp. (Provides load tables for common industry products, and procedures for design and analysis of precast and prestressed elements and structures composed of these elements. Provides design aids and examples.)

"Design and Typical Details of Connections for Precast and Prestressed Concrete," Precast/Prestressed Concrete Institute, Chicago, IL, 2nd Edition, 1988, 270 pp. (Updates available information on design of connections for both structural and architectural products, and presents a full spectrum of typical details. Provides design aids and examples.)

"Post-Tensioning Manual," Post-Tensioning Institute, Phoenix, AZ, 5th Edition, 1990, 406 pp. (Provides comprehensive coverage of post-tensioning systems, specifications, and design aid construction concepts.)