PREFACE TO ACI 318-14

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 addresses structural systems, members, and connections, including cast-in-place, precast, 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. “Building Code Requirements for Concrete Thin Shells” (ACI 318.2) is adopted by reference in this Code.

The Code user will find that ACI 318-14 has been substantially reorganized and reformatted from previous editions. The principal objectives of this reorganization are 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 members are located in utility chapters.

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 American Welding Society (AWS) standard.

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 of the considerations of the committee in developing the Code 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.

Technical changes from ACI 318-11 to ACI 318-14 are outlined in the May 2014 issue of Concrete International.

Transition keys showing how the code was reorganized are provided on the ACI website on the 318 Resource Page under Topics in Concrete.

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; concrete slabs; concretes; construction joints; continuity (structural); contract documents; contraction joints; cover; curing; deep beams; deflections; 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; load tests (structural); loads (forces); materials; mixing; mixture 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; shear walls; shells (structural forms); spans; splicing; strength; strength analysis; stresses; structural analysis; structural concrete; structural design; structural integrity; T-beams; torsion; walls; water; welded wire reinforcement.

NOTES FROM THE PUBLISHER

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This commentary (318R-14) 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 there from. Reference to this document shall not be made in contract documents. If items found in this document 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.

The materials, processes, quality control measures, and inspections described in this document should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI Certification or equivalent.

ACI 318-14, Building Code Requirements for Structural Concrete, and ACI 318R-14, 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.
INTRODUCTION

This Commentary discusses some of the considerations of Committee 318 in developing the provisions contained in “Building Code Requirements for Structural Concrete (ACI 318-14),” hereinafter called the Code or the 2014 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.

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 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 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 Construction Inspecting and/or Testing” (ASTM E329-09) specifies performance requirements for inspection and testing agencies.

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,” Publication SP-17(11), American Concrete Institute, Farmington Hills, MI, 2011, 539 pp. (This provides tables and charts for design of eccentrically loaded columns by the Strength Design Method of the 2009 Code. 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.)

“Guide to Durable Concrete (ACI 201.2R-08),” ACI Committee 201, American Concrete Institute, Farmington Hills, MI, 2008, 49 pp. (This 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.)

“Guide for the Design and Construction of Durable Parking Structures (362.1R-12),” ACI Committee 362, American Concrete Institute, Farmington Hills, MI, 2012, 24 pp. (This 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, tenth edition, 2008, 777 pp. (This provides tabulated designs for structural elements and slab systems. Design examples are provided to show the basis 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, Schaumburg, IL, fifth edition, 2008, 100 pp. (This 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 Detailing Manual,” Wire Reinforcement Institute, Hartford, CT, 1994, 252 pp. (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.)

“PCI Design Handbook—Precast and Prestressed Concrete,” Precast/Prestressed Concrete Institute, Chicago, IL, seventh edition, 2010, 804 pp. (This 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, second edition, 1988, 270 pp. (This updates available information on design of connections for both structural and architectural products, and presents a full spectrum of typical details. This provides design aids and examples.)

“Post-Tensioning Manual,” Post-Tensioning Institute, Farmington Hills, MI, sixth edition, 2006, 354 pp. (This provides comprehensive coverage of post-tensioning systems, specifications, design aids, and construction concepts.)
# TABLE OF CONTENTS

## CHAPTER 1
### GENERAL
1.1—Scope of ACI 318, p. 9
1.2—General, p. 9
1.3—Purpose, p. 10
1.4—Applicability, p. 10
1.5—Interpretation, p. 11
1.6—Building official, p. 12
1.7—Licensed design professional, p. 13
1.8—Construction documents and design records, p. 13
1.9—Testing and inspection, p. 13
1.10—Approval of special systems of design, construction, or alternative construction materials, p. 13

## CHAPTER 2
### NOTATION AND TERMINOLOGY
2.1—Scope, p. 15
2.2—Notation, p. 15
2.3—Terminology, p. 30

## CHAPTER 3
### REFERENCED STANDARDS
3.1—Scope, p. 45
3.2—Referenced standards, p. 45

## CHAPTER 4
### STRUCTURAL SYSTEM REQUIREMENTS
4.1—Scope, p. 49
4.2—Materials, p. 49
4.3—Design loads, p. 49
4.4—Structural system and load paths, p. 49
4.5—Structural analysis, p. 52
4.6—Strength, p. 52
4.7—Serviceability, p. 53
4.8—Durability, p. 53
4.9—Sustainability, p. 53
4.10—Structural integrity, p. 54
4.11—Fire resistance, p. 54
4.12—Requirements for specific types of construction, p. 54
4.13—Construction and inspection, p. 56
4.14—Strength evaluation of existing structures, p. 56

## CHAPTER 5
### LOADS
5.1—Scope, p. 57
5.2—General, p. 57
5.3—Load factors and combinations, p. 58

## CHAPTER 6
### STRUCTURAL ANALYSIS
6.1—Scope, p. 63
6.2—General, p. 63
6.3—Modeling assumptions, p. 68
6.4—Arrangement of live load, p. 69
6.5—Simplified method of analysis for nonprestressed continuous beams and one-way slabs, p. 70
6.6—First-order analysis, p. 71
6.7—Elastic second-order analysis, p. 79
6.8—Inelastic second-order analysis, p. 81
6.9—Acceptability of finite element analysis, p. 81

## CHAPTER 7
### ONE-WAY SLABS
7.1—Scope, p. 83
7.2—General, p. 83
7.3—Design limits, p. 83
7.4—Required strength, p. 85
7.5—Design strength, p. 85
7.6—Reinforcement limits, p. 86
7.7—Reinforcement detailing, p. 88

## CHAPTER 8
### TWO-WAY SLABS
8.1—Scope, p. 93
8.2—General, p. 93
8.3—Design limits, p. 94
8.4—Required strength, p. 97
8.5—Design strength, p. 102
8.6—Reinforcement limits, p. 103
8.7—Reinforcement detailing, p. 106
8.8—Nonprestressed two-way joist systems, p. 117
8.9—Lift-slab construction, p. 118
8.10—Direct design method, p. 118
8.11—Equivalent frame method, p. 124

## CHAPTER 9
### BEAMS
9.1—Scope, p. 129
9.2—General, p. 129
9.3—Design limits, p. 130
9.4—Required strength, p. 132
9.5—Design strength, p. 134
9.6—Reinforcement limits, p. 136
9.7—Reinforcement detailing, p. 140
9.8—Nonprestressed one-way joist systems, p. 149
9.9—Deep beams, p. 151
CHAPTER 10

COLUMNS
10.1—Scope, p. 153
10.2—General, p. 153
10.3—Design limits, p. 153
10.4—Required strength, p. 154
10.5—Design strength, p. 155
10.6—Reinforcement limits, p. 156
10.7—Reinforcement detailing, p. 157

CHAPTER 11

WALLS
11.1—Scope, p. 163
11.2—General, p. 163
11.3—Design limits, p. 164
11.4—Required strength, p. 164
11.5—Design strength, p. 165
11.6—Reinforcement limits, p. 168
11.7—Reinforcement detailing, p. 169
11.8—Alternative method for out-of-plane slender wall analysis, p. 171

CHAPTER 12

DIAPHRAGMS
12.1—Scope, p. 173
12.2—General, p. 173
12.3—Design limits, p. 175
12.4—Required strength, p. 175
12.5—Design strength, p. 178
12.6—Reinforcement limits, p. 185
12.7—Reinforcement detailing, p. 185

CHAPTER 13

FOUNDATIONS
13.1—Scope, p. 187
13.2—General, p. 189
13.3—Shallow foundations, p. 192
13.4—Deep foundations, p. 193

CHAPTER 14

PLAIN CONCRETE
14.1—Scope, p. 195
14.2—General, p. 196
14.3—Design limits, p. 196
14.4—Required strength, p. 198
14.5—Design strength, p. 199
14.6—Reinforcement detailing, p. 202

CHAPTER 15

BEAM-COLUMN AND SLAB-COLUMN JOINTS
15.1—Scope, p. 203
15.2—General, p. 203
15.3—Transfer of column axial force through the floor system, p. 203
15.4—Detailing of joints, p. 204

CHAPTER 16

CONNECTIONS BETWEEN MEMBERS
16.1—Scope, p. 205
16.2—Connections of precast members, p. 205
16.3—Connections to foundations, p. 209
16.4—Horizontal shear transfer in composite concrete flexural members, p. 212
16.5—Brackets and corbels, p. 214

CHAPTER 17

ANCHORING TO CONCRETE
17.1—Scope, p. 221
17.2—General, p. 222
17.3—General requirements for strength of anchors, p. 228
17.4—Design requirements for tensile loading, p. 234
17.5—Design requirements for shear loading, p. 247
17.6—Interaction of tensile and shear forces, p. 258
17.7—Required edge distances, spacings, and thicknesses to preclude splitting failure, p. 258
17.8—Installation and inspection of anchors, p. 260

CHAPTER 18

EARTHQUAKE-RESISTANT STRUCTURES
18.1—Scope, p. 263
18.2—General, p. 263
18.3—Ordinary moment frames, p. 269
18.4—Intermediate moment frames, p. 269
18.5—Intermediate precast structural walls, p. 274
18.6—Beams of special moment frames, p. 275
18.7—Columns of special moment frames, p. 280
18.8—Joints of special moment frames, p. 285
18.9—Special moment frames constructed using precast concrete, p. 289
18.10—Special structural walls, p. 292
18.11—Special structural walls constructed using precast concrete, p. 304
18.12—Diaphragms and trusses, p. 304
18.13—Foundations, p. 310
18.14—Members not designated as part of the seismic-force-resisting system, p. 312

CHAPTER 19

CONCRETE: DESIGN AND DURABILITY REQUIREMENTS
19.1—Scope, p. 315
19.2—Concrete design properties, p. 315
19.3—Concrete durability requirements, p. 316
19.4—Grout durability requirements, p. 324
CHAPTER 20
STEEL REINFORCEMENT PROPERTIES,
DURABILITY, AND EMBEDMENTS
20.1—Scope, p. 325
20.2—Nonprestressed bars and wires, p. 325
20.3—Prestressing strands, wires, and bars, p. 330
20.4—Structural steel, pipe, and tubing for composite
columns, p. 333
20.5—Headed shear stud reinforcement, p. 334
20.6—Provisions for durability of steel reinforcement,
p. 334
20.7—Embedments, p. 339

CHAPTER 21
STRENGTH REDUCTION FACTORS
21.1—Scope, p. 341
21.2—Strength reduction factors for structural concrete
members and connections, p. 341

CHAPTER 22
SECTIONAL STRENGTH
22.1—Scope, p. 347
22.2—Design assumptions for moment and axial strength,
p. 347
22.3—Flexural strength, p. 349
22.4—Axial strength or combined flexural and axial
strength, p. 350
22.5—One-way shear strength, p. 351
22.6—Two-way shear strength, p. 360
22.7—Torsional strength, p. 371
22.8—Bearing, p. 378
22.9—Shear friction, p. 380

CHAPTER 23
STRUT-AND-TIE MODELS
23.1—Scope, p. 385
23.2—General, p. 386
23.3—Design strength, p. 392
23.4—Strength of struts, p. 392
23.5—Reinforcement crossing bottle-shaped struts, p. 394
23.6—Strut reinforcement detailing, p. 395
23.7—Strength of ties, p. 395
23.8—Tie reinforcement detailing, p. 396
23.9—Strength of nodal zones, p. 397

CHAPTER 24
SERVICEABILITY REQUIREMENTS
24.1—Scope, p. 399
24.2—Deflections due to service-level gravity loads, p. 399
24.3—Distribution of flexural reinforcement in one-way
slabs and beams, p. 403
24.4—Shrinkage and temperature reinforcement, p. 405
24.5—Permissible stresses in prestressed concrete flexural
members, p. 407

CHAPTER 25
REINFORCEMENT DETAILS
25.1—Scope, p. 411
25.2—Minimum spacing of reinforcement, p. 411
25.3—Standard hooks, seismic hooks, crossties, and
minimum inside bend diameters, p. 412
25.4—Development of reinforcement, p. 414
25.5—Splices, p. 428
25.6—Bundled reinforcement, p. 433
25.7—Transverse reinforcement, p. 434
25.8—Post-tensioning anchorages and couplers, p. 443
25.9—Anchorage zones for post-tensioned tendons, p. 443

CHAPTER 26
CONSTRUCTION DOCUMENTS AND
INSPECTION
26.1—Scope, p. 453
26.2—Design criteria, p. 455
26.3—Member information, p. 455
26.4—Concrete materials and mixture requirements, p. 455
26.5—Concrete production and construction, p. 462
26.6—Reinforcement materials and construction
requirements, p. 468
26.7—Anchoring to concrete, p. 472
26.8—Embedments, p. 473
26.9—Additional requirements for precast concrete, p. 473
26.10—Additional requirements for prestressed concrete,
p. 474
26.11—Formwork, p. 476
26.12—Concrete evaluation and acceptance, p. 478
26.13—Inspection, p. 483

CHAPTER 27
STRENGTH EVALUATION OF EXISTING
STRUCTURES
27.1—Scope, p. 487
27.2—General, p. 487
27.3—Analytical strength evaluation, p. 488
27.4—Strength evaluation by load test, p. 489
27.5—Reduced load rating, p. 492

COMMENTARY REFERENCES

APPENDIX A
STEEL REINFORCEMENT INFORMATION

APPENDIX B
EQUIVALENCE BETWEEN SI-METRIC,
MKS-METRIC, AND U.S. CUSTOMARY UNITS OF
NONHOMOGENOUS EQUATIONS IN THE CODE

INDEX
CODE

CHAPTER 1—GENERAL

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.

COMMENTARY

R1—GENERAL

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; composite columns with structural steel shapes, pipes, or tubing; and anchoring to concrete.

This Code is substantially reorganized from the previous version, ACI 318-11. 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.