ACI 349-13

Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13) and Commentary

An ACI Standard

Reported by ACI Committee 349

American Concrete Institute®

Documents
Document Sharing Hub

Full document details: ACI 349-13 (2016)

American Concrete Institute®
Advancing concrete knowledge

First Printing
Errata as of 6/23/16

Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at www.concrete.org/committees/errata.asp. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are 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. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised ACI Manual of Concrete Practice (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN: 978-0-87031-894-8

Documents
Document Sharing Hub

Full document details: ACI 349-13 (2016)

ACI 349-13

Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13) and Commentary

An ACI Standard

Reported by ACI Committee 349

Herman L. Graves III, Chair
Adeola K. Adediran, Vice Chair

Partha S. Ghosal, Vice Chair
Lisa M. Anderson, Secretary

Omesh B. Abhat
Taha D. Al-Shawaf
Ranjit L. Bandyopadhyay*
Harry A. Chambers
Ronald A. Cook
Rolf Eligehausen
Farhad Farzam
Werner A. F. Fuchs
Stewart C. Gallocher
Branko Galunic
Orhan Gurbuz
James A. Hammell
Joseph Kendall Harrold
Gunnar A. Harstead
Christopher Heinz
Charles J. Hookham
Ronald J. Janowiak
Scott A. Jensen
Richard E. Klingner
Nam-Ho Lee
Javeed Munshi
Dan J. Naus
Dragos A. Nuta
Richard S. Orr
Anton D. Pirtz
John F. Silva
Bozidar Stojadinovic
Barendra K. Talukdar
Donald T. Ward
Andrew S. Whittaker
Albert Y. C. Wong
Charles A. Zalesiak

Consulting Members
Hansraj G. Ashar
Peter J. Carrato
Mukti L. Das

The committee recognizes the following non-voting members for their contributions to the development of the code revision: Monzer M. Allam, Jorg NMI Asmus, Matthew Dominick D'Ambrosia, Chiara F. Ferraris, Ola Jovall, Angela McAlpin, Michael C. Mota, Nebojsa Orbovic, Debi Ramos, Madhumita Sircar, and J. Bret Turley.

*Ranjit L. Bandyopadhyay was a long-time member of ACI Committee 349 and the Committee Chair of ACI 349 at the time of his death in 2010. The committee expresses its appreciation for his friendship and leadership.

This standard covers the proper design and construction of concrete structures that form part of a nuclear power plant and that have nuclear safety-related functions, but does not cover concrete reactor vessels and concrete containment structures (as defined by Joint ACI-ASME Committee 359).

The structures covered by the Code include concrete structures inside and outside the containment system.

This Code may be referenced and applied subject to agreement between the owner and the Regulatory Authority.

All notation sections have been removed from the beginning of each chapter and consolidated into one list in Chapter 2.

The format of this Code is based on the "Building Code Requirements for Structural Concrete (ACI 318-08)" and incorporates recent revisions of that standard.

The commentary, which is presented after the Code, discusses some of the considerations of ACI Committee 349 in developing "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13)." This information is provided in the commentary because the Code is written as a legal document and therefore cannot present background details or suggestions for carrying out its requirements.

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.

Keywords: anchorage; authority having jurisdiction (AHJ); beam-column frame; beams; building codes; columns; composite construction; concrete cover; cracking (fracturing); creep; curing; deep beams; deflection; earthquake-resistant structures; floors; folded plates; footings; formwork; inspection; joints; joists; load tests; loads; mixture proportioning; modulus of elasticity; nuclear power plants; nuclear reactor containments; nuclear reactor safety; nuclear reactors; precast concrete; prestressed concrete; quality control; reinforced concrete; safety; serviceability; shear strength; shearwalls; shells; slabs; specifications; splicing; structural analysis; structural design; temperature; torsion; walls.

ACI 349-13 supersedes ACI 349-06, was adopted August 15, 2013, and published June 2014.

Copyright © 2014, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

Documents
Document Sharing Hub

Full document details: ACI 349-13 (2016)

CONTENTS

INTRODUCTION, p. 7

CHAPTER 1—GENERAL REQUIREMENTS, p. 9
1.1—Scope, p. 9
1.2—Drawings and specifications, p. 10
1.3—Inspection, p. 11
1.4—Approval of special systems of design or construction, p. 12
1.5—Quality assurance program, p. 12
References, Chapter 1, p. 12

CHAPTER 2—NOTATION AND DEFINITIONS, p. 14
2.1—Code notation, p. 14
2.2—Definitions, p. 22

CHAPTER 3—MATERIALS, p. 30
3.1—Tests of materials, p. 30
3.2—Cementitious materials, p. 30
3.3—Aggregates, p. 30
3.4—Water, p. 31
3.5—Steel reinforcement, p. 31
3.6—Admixtures, p. 33
3.7—Storage and identification of materials, p. 33
3.8—Referenced standards, p. 34
References, Chapter 3, p. 36

CHAPTER 4—DURABILITY REQUIREMENTS, p. 37
4.1—General, p. 37
4.2—Exposure categories and classes, p. 37
4.3—Requirements for concrete mixtures, p. 37
4.4—Additional requirements for freezing-and-thawing exposure, p. 37
4.5—Alternative cementitious materials for sulfate exposure, p. 37

CHAPTER 5—CONCRETE QUALITY, MIXING, AND PLACING, p. 38
5.1—General, p. 38
5.2—Selection of concrete proportions, p. 38
5.3—Proportioning on the basis of field experience or trial mixtures, or both, p. 39
5.4—Proportioning without field experience or trial mixtures, p. 39
5.5—Average compressive strength reduction, p. 39
5.6—Evaluation and acceptance of concrete, p. 39
5.7—Preparation of equipment and place of deposit, p. 42
5.8—Mixing, p. 42
5.9—Conveying, p. 42
5.10—Depositing, p. 42
5.11—Curing, p. 43
5.12—Cold weather requirements, p. 44
5.13—Hot weather requirements, p. 44
References, Chapter 5, p. 44

CHAPTER 6—FORMWORK, EMBEDMENTS, AND CONSTRUCTION JOINTS, p. 45
6.1—Design of formwork, p. 45
6.2—Removal of forms, shores, and reshoring, p. 45
6.3—Embedments in concrete, p. 45
6.4—Construction joints, p. 47
Referenced standards Chapter 6, p. 47

CHAPTER 7—DETAILS OF REINFORCEMENT, p. 48
7.1—Standard hooks, p. 48
7.2—Minimum bend diameters, p. 48
7.3—Bending, p. 48
7.4—Surface conditions of reinforcement, p. 48
7.5—Placing reinforcement, p. 48
7.6—Spacing limits for reinforcement, p. 48
7.7—Concrete protection for reinforcement, p. 49
7.8—Special reinforcement details for columns, p. 49
7.9—Connections, p. 49
7.10—Lateral reinforcement for compression members, p. 49
7.11—Lateral reinforcement for flexural members, p. 49
7.12—Minimum reinforcement, p. 49
7.13—Requirements for structural integrity, p. 50
References, Chapter 7, p. 50

CHAPTER 8—ANALYSIS AND DESIGN—GENERAL CONSIDERATIONS, p. 51
8.1—Design methods, p. 51
8.2—Loading, p. 51
8.3—Methods of analysis, p. 51
8.4—Redistribution of moments in continuous flexural members, p. 51
8.5—Modulus of elasticity, p. 51
8.6—Not used, p. 51
8.7—Stiffness, p. 51
8.8—Effective stiffness to determine lateral deflections, p. 52
8.9—Span length, p. 52
8.10—Columns, p. 52
8.11—Arrangement of live load, p. 52
8.12—T-beam construction, p. 52
8.13—Joist construction, p. 52
8.14—Separate floor finish, p. 52
R8.14—Separate floor finish, p. 52

CHAPTER 9—STRENGTH AND SERVICEABILITY REQUIREMENTS, p. 53
9.1—General, p. 53
9.2—Required strength, p. 56
9.3—Design strength, p. 59
9.4—Design strength for reinforcement, p. 60
9.5—Control of deflections, p. 60
References, Chapter 9, p. 65

CHAPTER 10—FLEXURE AND AXIAL LOADS, p. 67
10.1—Scope, p. 67
10.2—Design assumptions, p. 67
10.3—General principles and requirements, p. 67

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

10.4—Distance between lateral supports of flexural members, p. 67
10.5—Minimum reinforcement of flexural members, p. 67
10.6—Distribution of flexural reinforcement in beams and one-way slabs, p. 67
10.7—Deep beams, p. 67
10.8—Design dimensions for compression members, p. 67
10.9—Limits for reinforcement of compression members, p. 68
10.10—Slenderness effects in compression members, p. 68
10.11—Axially loaded members supporting slab system, p. 68
10.12—Transmission of column loads through floor system, p. 68
10.13—Composite compression members, p. 68
10.14—Bearing strength, p. 68

CHAPTER 11—SHEAR AND TORSION, p. 69
11.1—Shear strength, p. 69
11.2—Shear strength provided by concrete for nonprestressed members, p. 69
11.3—Shear strength provided by concrete for prestressed members, p. 69
11.4—Shear strength provided by shear reinforcement, p. 69
11.5—Design for torsion, p. 69
11.6—Shear-friction, p. 69
11.7—Deep beams, p. 69
11.8—Provisions for brackets and corbels, p. 69
11.9—Provisions for walls, p. 69
11.10—Transfer of moments to columns, p. 70
11.11—Provisions for slabs and footings, p. 70
References, Chapter 11, p. 71

CHAPTER 12—DEVELOPMENT AND SPLICES OF REINFORCEMENT, p. 72
12.1—Development of reinforcement—General, p. 72
12.2—Development of deformed bars and deformed wire in tension, p. 72
12.3—Development of deformed bars and deformed wire in compression, p. 72
12.4—Development of bundled bars, p. 72
12.5—Development of standard hooks in tension, p. 72
12.6—Development of headed and mechanically anchored deformed bars in tension, p. 73
12.7—Development of welded deformed wire reinforcement in tension, p. 73
12.8—Development of welded plain wire reinforcement in tension, p. 73
12.9—Development of prestressing strand, p. 73
12.10—Development of flexural reinforcement—General, p. 73
12.11—Development of positive moment reinforcement, p. 73
12.12—Development of negative moment reinforcement, p. 73
12.13—Development of web reinforcement, p. 73
12.14—Splices of reinforcement—General, p. 73
12.15—Splices of deformed bars and deformed wire in tension, p. 74
12.16—Splices of deformed bars in compression, p. 75
12.17—Special splice requirements for columns, p. 75
12.18—Splices of welded deformed wire reinforcement in tension, p. 75
12.19—Splices of welded plain wire reinforcement in tension, p. 75

CHAPTER 13—TWO-WAY SLAB SYSTEMS, p. 76
13.1—Scope, p. 76
13.2—General, p. 76
13.3—Slab reinforcement, p. 76
13.4—Openings in slab systems, p. 76
13.5—Design procedures, p. 76
13.6—Direct design method, p. 76
13.7—Equivalent frame method, p. 76

CHAPTER 14—WALLS, p. 77
14.1—Scope, p. 77
14.2—General, p. 77
14.3—Minimum reinforcement, p. 77
14.4—Walls designed as compression members, p. 77
14.5—Empirical design method, p. 77
14.6—Nonbearing walls, p. 78
14.7—Walls as grade beams, p. 78
14.8—Alternative design of slender walls, p. 78

CHAPTER 15—FOOTINGS, p. 79
15.1—Scope, p. 79
15.2—Loads and reactions, p. 79
15.3—Footings supporting circular or regular polygon-shaped columns or pedestals, p. 79
15.4—Moment in footings, p. 79
15.5—Shear in footings, p. 79
15.6—Development of reinforcement in footings, p. 79
15.7—Minimum footing depth, p. 79
15.8—Transfer of force at base of column, wall, or reinforced pedestal, p. 79
15.9—Sloped or stepped footings, p. 79
15.10—Combined footings and mats, p. 79

CHAPTER 16—PRECAST CONCRETE, p. 80
16.1—Scope, p. 80
16.2—General, p. 80
16.3—Distribution of forces among members, p. 80
16.4—Member design, p. 80
16.5—Structural integrity, p. 80
16.6—Connection and bearing design, p. 80
16.7—Items embedded after concrete placement, p. 80
16.8—Marking and identification, p. 80
16.9—Handling, p. 80
16.10—Strength evaluation of precast construction, p. 80

CHAPTER 17—COMPOSITE CONCRETE FLEXURAL MEMBERS, p. 81
17.1—Scope, p. 81

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

17.2—General, p. 81
17.3—Shoring, p. 81
17.4——Vertical shear strength, p. 81
17.5—Horizontal shear strength, p. 81
17.6—Ties for horizontal shear, p. 81

CHAPTER 18——PRESTRESSED CONCRETE, p. 82
18.1—Scope, p. 82
18.2—General, p. 82
18.3—Design assumptions, p. 82
18.4—Serviceability requirements—Flexural members, p. 82
18.5—Permissible stresses in prestressing steel, p. 82
18.6—Loss of prestress, p. 82
18.7—Flexural strength, p. 82
18.8—Limits for reinforcement of flexural members, p. 82
18.9—Minimum bonded reinforcement, p. 82
18.10—Statically indeterminate structures, p. 82
18.11—Compression members—Combined flexure and axial loads, p. 82
18.12—Slab systems, p. 83
18.13—Post-tensioned tendon anchorage zones, p. 83
18.14—Intentionally left blank, p. 83
18.15—Intentionally left blank, p. 83
18.16—Corrosion protection for unbonded tendons, p. 83
18.17—Post-tensioning ducts, p. 83
18.18—Grout for bonded tendons, p. 83
18.19—Protection for prestressing steel, p. 83
18.20—Application and measurement of prestressing force, p. 83
18.21—Post-tensioning anchorages and couplers, p. 84
18.22—External post-tensioning, p. 84

CHAPTER 19—SHELLS, p. 85
19.1—Scope and definitions, p. 85
19.2—General, p. 85
19.3—Design strength of materials, p. 86
19.4—Section design and reinforcement requirements, p. 87
19.5—Construction, p. 87

CHAPTER 20—STRENGTH EVALUATION OF EXISTING STRUCTURES, p. 88
20.1—Strength evaluation—General, p. 88
20.2—Determination of required dimensions and material properties, p. 88
20.3—Load test procedure, p. 90
20.4—Loading criteria, p. 90
20.5—Acceptance criteria, p. 90
20.6—Provision for lower load rating, p. 91
20.7—Safety, p. 91
References, Chapter 20, p. 92

CHAPTER 21—PROVISIONS FOR EARTHQUAKE-RESISTANT DESIGN, p. 93
21.1—General requirements, p. 93
21.2—Intentionally left blank, p. 96
21.3—Intentionally left blank, p. 96
21.4—Intentionally left blank, p. 96
21.5—Flexural members of moment frames, p. 96
21.6—Moment frame members subjected to bending and axial load, p. 102
21.7—Joints of moment frames, p. 106
21.8—Special moment frames constructed using precast concrete, p. 109
21.9—Special structural walls and coupling beams, p. 109
21.10—Special structural walls constructed using precast concrete, p. 117
21.11—Structural diaphragms, p. 118
21.12—Foundations, p. 122
References, Chapter 21, p. 124

CHAPTER 22—STRUCTURAL PLAIN CONCRETE, p. 128

APPENDIX A—STRUT-AND-TIE MODELS, p. 129
A.1—Definitions, p. 129
A.2——Strut-and-tie model design procedure, p. 129
A.3—Strength of struts, p. 129
A.4—Strength of ties, p. 129
A.5—Strength of nodal zones, p. 129

APPENDIX B—ALTERNATIVE PROVISIONS FOR REINFORCED AND PRESTRESSED CONCRETE FLEXURAL AND COMPRESSION MEMBERS, p. 130

APPENDIX C—ALTERNATIVE LOAD AND STRENGTH-REDUCTION FACTORS, p. 131
C.9.1—Scope, p. 131
C.9.2—Required strength, p. 131
C.9.3—Design strength, p. 133

APPENDIX D—ANCHORING TO CONCRETE, p. 134
D.1—Definitions, p. 134
D.2—Scope, p. 136
D.3—General requirements, p. 138
D.4—General requirements for strength of anchors , p. 141
D.5—Design requirements for tensile loading, p. 146
D.6—Design requirements for shear loading, p. 155
D.7—Interaction of tensile and shear forces, p. 164
D.8—Required edge distances, spacings, and thicknesses to preclude splitting failure, p. 164
D.9—Installation of anchors, p. 165
D.10—Structural plates, shapes, and specialty inserts, p. 166
D.11—Shear strength of embedded plates and shear lugs, p. 166
D.12—Grouted embedments, p. 168
References, Appendix D, p. 169

APPENDIX E—THERMAL CONSIDERATION, p. 171
E.1—Scope, p. 171
E.2—Definitions (moved to Chapter 2), p. 173
E.3—General design requirements, p. 173
E.4—Concrete temperatures, p. 175
References, Appendix E, p. 176

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

APPENDIX F—SPECIAL PROVISIONS FOR IMPULSIVE AND IMPACTIVE EFFECTS, p. 177
F.1—Scope, p. 177
F.2—Dynamic strength increase, p. 177
F.3—Deformation, p. 178
F.4—Requirements to assure ductility, p. 183
F.5—Shear strength, p. 184
F.6—Impulsive effects, p. 185
F.7—Impactive effects, p. 187
F.8—Impactive and impulsive loads, p. 188
References, Appendix F, p. 190

SUMMARY OF CHANGES FOR ACI 349-06 CODE, p. 192

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

Page left intentionally blank.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

INTRODUCTION

This Code covers the design and construction of concrete structures that form part of a nuclear facility and that have nuclear safety-related functions, but does not cover: i) Concrete reactor vessels and concrete containment structures, as defined by Joint ACI-ASME Committee 359; or ii) Steel-plate composite walls and steel-plate composite slabs, as defined by AISC-N690 Technical Committee 12.

The structures covered by this Code include concrete structures inside and outside the containment system.

This Code may be referenced and applied subject to agreement between the owner and the Regulatory Authority.

All notation sections have been removed from the beginning of each chapter and consolidated into one list in Chapter 2.

The format of this Code is such that it depends on the "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary" and any applicable errata issued up to September 2011, and should be used in conjunction with that Code and applicable issued errata.

The Commentary, which is presented after the Code, discusses considerations of ACI Committee 349 in developing, "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13)." This information is provided in the Commentary because this Code is written as a legal document and, therefore, cannot present background details or suggestions for carrying out its requirements. For design of nuclear structures, in cases of conflict between this Code with other documents, except wherever this Code is in conflict with the specific requirements of the authority having jurisdiction (AHJ), ACI 349 shall govern.

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

COMMENTARY

INTRODUCTION

This Commentary discusses some of the considerations of Committee 349 in developing the provisions contained in "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13)" hereinafter called the Code. The Code is based on "Building Code Requirements for Structural Concrete (ACI 318-08)," which is hereinafter called the Building Code. In preparing ACI 349-13, the committee has followed the text of the Building Code wherever appropriate.

Structural plain concrete, as described in Chapter 22 of ACI 318-08, is not endorsed for use in nuclear safety-related structures.

In the following commentary, all references to the Building Code and its commentary are to the 2008 revision unless specifically noted otherwise. Provisions of the commentary of ACI 318-08 apply except:

- The term "building official" is replaced with the term "licensed design professional";
- λ, the modification factor for lightweight concrete, is not applicable for ACI 349-13 structures. The value of λ for ACI 349-13 structures is 1.0.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

Page left intentionally blank.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

CHAPTER 1—GENERAL REQUIREMENTS

R1—GENERAL REQUIREMENTS

The commentary on ACI 318-08 is applicable to this chapter except as described as follows.

1.1—Scope

R1.1—Scope

The American Concrete Institute "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13)," called the Code, provides minimum requirements for reinforced concrete design or construction in applications where protection against potential radioactive releases is a concern. The scope of the Code provides requirements for the analysis, design, construction, testing, and evaluation of new and existing concrete nuclear structures. While the requirements of this Code pertain primarily to new concrete structures, corresponding recommendations for the evaluation of existing concrete nuclear structures are provided in ACI 349.3R.[1.1] Some special structures involve unique problems that are not covered by the Code, such as structures that function as leakage barriers to contain the effects of the loss of coolant accident. The owner is to identify nuclear safety-related structures and establish which of them are covered by "Code for Concrete Containments (ACI 359)"[1.2] and its latest revisions instead of this Code. The Code is applicable to radioactive waste repository structures; however, considerations of thermal loads, load combinations, and long-term durability should be considered.

1.1.1 This Code provides minimum requirements for design and construction of nuclear safety-related concrete structures and structural members for nuclear facilities. Safety-related structures and structural members subject to this Code are those concrete structures that support, house, or protect nuclear safety class systems or component parts of nuclear safety class systems.

Specifically excluded from this Code are those structures covered by "Code for Concrete Containments," ASME Boiler and Pressure Vessel Code Section III, Division 2, and pertinent General Requirements (ACI 359).

This Code includes design and loading conditions that are unique to nuclear facilities, including shear design under biaxial tension conditions, consideration of thermal and seismic effects, and impact and impulsive loads.

For structural concrete, f_c' shall not be less than 3000 psi, unless otherwise specified.

R1.1.1 In general, the Code requirements are based on test results from concrete specimens having a compressive strength of 6000 psi or less. Although no maximum concrete compressive strength is specified, the applicability of various requirements and formulations should be verified when concrete compressive strengths are higher than 6000 psi.

Minimum compressive concrete strength has been established as 3000 psi to be consistent with the seismic provisions of Chapter 21 of ACI 349-13 and ACI 318.

1.1.2 This Code shall govern in all matters pertaining to design and construction of reinforced concrete structures, as defined in 1.1.1, except wherever this Code is in conflict with the specific provisions of the authority having jurisdiction (AHJ).

1.1.3 Same as ACI 318-08.

1.1.4 Intentionally left blank.

R1.1.4 Intentionally left blank, as this Code does not deal with residential structures.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

1.1.5 Same as ACI 318-08, except the last sentence "See also Section 22.1.3."

1.1.6 Intentionally left blank.

1.1.7 Intentionally left blank.

1.1.8 *Concrete on steel deck*

1.1.8.1 Same as ACI 318-08.

1.1.8.2 This Code does not govern the design of structural concrete slabs cast on stay-in-place, composite steel form deck. Concrete used in the construction of such slabs shall be governed by Chapters 1 through 6 of this Code, where applicable. Portions of such slabs designed as reinforced concrete are governed by this Code.

1.1.9 *Special provisions for earthquake resistance*—Provisions of Chapter 21 shall be satisfied (see Section 21.1.1).

1.1.10 This Code, along with relevant sections of ACI 350, governs design and construction of tanks and reservoirs (non-lined) associated with safety-related nuclear structures.

1.2—Drawings and specifications

1.2.1 Copies of design drawings, typical details, and specifications for all structural concrete construction shall bear the seal of a licensed design professional. These drawings (including supplementary drawings to generate the as-built condition), typical details, and specifications shall be retained by the owner, or the owner's designee, as a permanent record for the life of the structure. As a minimum, these drawings, details, and specifications together shall show:

(a) Name and date of issue of Code and supplement to which design conforms;
(b) Live load and other loads used in design;
(c) Specified compressive strength of concrete at stated ages or stages of construction for which each part of structure is designed;
(d) Specified strength or grade of reinforcement;
(e) Size and location of all structural members, reinforcement, and anchors;

COMMENTARY

R1.1.6 This Code addresses piles, piers, and caissons in Section 21.12.4.

R1.1.7 The provisions of this Code apply to slabs-on-ground. In addition to the requirements of this Code, the licensed design professional should consider other issues, as outlined in ACI 360R[1.3] and PTI's *Design of Post-Tensioned Slabs-on-Ground*.[1.4]

R1.1.9 Refer to Section R21.1.1 for details.

R1.1.10 ACI 349-13 provision is applied to the spent fuel pool pit and refueling canal as well as other safety-related tanks. In addition, detailed recommendations given in "Code Requirements for Environmental Engineering Concrete Structures and Commentary" reported by ACI Committee 350 should be followed for nonlined tanks and reservoirs associated with safety-related nuclear structures. In case of a conflict, the more restrictive provision of ACI 349 or ACI 350 should be followed.

R1.2—Drawings and specifications

The design of plain concrete is not included in this Code. Details of all contraction joints and isolation joints in reinforced concrete structures, however, are considered important to the as-built condition of the structure.

Guidelines for the preparation and retention of design documents are covered by ANSI/ASME NQA-1.[1.5] Any documentation that uniquely reflects the as-built condition of the concrete nuclear structure should be considered for retention as a permanent record for the life of the structure.

Drawings and specifications should be prepared under the direction of a licensed design professional competent in the field of design of concrete structures, who is required to sign these documents signifying owner's approval. This Code requires that the owner be responsible for drawings and calculations, but does not preclude the owner from assigning the function of detailed implementation to others.

AVA Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

(f) Provision for dimensional changes resulting from creep, shrinkage, and temperature;
(g) Magnitude and location of prestressing forces;
(h) Anchorage length of reinforcement and location and length of lap splices;
(i) Type and location of mechanical and welded splices of reinforcement;
(j) Details and location of all contraction or isolation joints;
(k) Minimum concrete compressive strength at time of post-tensioning;
(l) Stressing sequence for post-tensioning tendons;
(m) Statement if slab-on-ground is designed as a structural diaphragm (see Section 21.12.3.4).

1.2.2 Calculations pertinent to design and the basis of design (including the results of model analysis, if any) shall be retained by the owner or his designee as a permanent record for the life of the structure. Accompanying these calculations shall be a statement of the applicable design and analysis methods. When computer programs are used, design assumptions and identified input and output data shall be retained instead of calculations. Model analysis shall be permitted to supplement calculations.

COMMENTARY

1.3—Inspection

1.3.1 The owner is responsible for the inspection of concrete construction throughout all work stages. The owner shall require compliance with design drawings and specifications. The owner shall also keep records required for quality assurance and traceability of construction, fabrication, material procurement, manufacture, or installation.

1.3.2 The owner shall be responsible for designating the records to be maintained and the duration of retention. Records pertinent to plant modifications or revisions, in-service inspections, and durability and performance of structures shall be maintained for the life of the plant. The owner shall be responsible for continued maintenance of the records. The records shall be maintained at the nuclear facility or at other locations as determined by the owner. As a minimum, the following installation/construction records shall be considered for lifetime retention:
(a) Check-off sheets for tendon, steel reinforcement, and anchor installation;
(b) Concrete cylinder test reports and charts;
(c) Concrete design mixture reports;
(d) Concrete placement records;
(e) Sequence of erection and connection of precast members;
(f) Reports for construction and removal of forms and reshoring;
(g) Material property reports on steel reinforcement;
(h) Material property reports on mechanical splice material for steel reinforcement;

R1.3—Inspection

This Code requires that the owner be responsible for inspection but does not explicitly preclude the owner from assigning the function of detailed implementation to others. Inspection personnel should be ACI certified as applicable, and qualified by the owner. ANSI/ASME NQA-1[1.5] or ACI 359[1.2] Appendix VII may be used to qualify inspectors. The inspectors should be thoroughly familiar with the applicable ACI and ASTM standards (for example, ACI 311.4R).[1.6] The inspection agency should be accredited to ASTM E329. The concrete and aggregate testing laboratory should be accredited to ASTM C1077. If the owner(s) directly employ inspection personnel, the owner is permitted to follow ASTM E329 as a quality enhancement.

Requirements for the retention of inspection records should follow ANSI/ASME NQA-1.[1.5]

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

(i) Material property reports on steel embedments in concrete;
(j) Material property reports on tendon and anchorage fabrication material and corrosion inhibitors;
(k) Reports for periodic tendon inspection;
(l) Tensioning of tendons;
(m) Quality and proportions of concrete materials;
(n) Any significant construction loadings on completed floors, members, or walls.

1.3.3 Same as ACI 318-08.

1.3.4 Intentionally left blank.

1.3.5 Intentionally left blank.

1.4—Approval of special systems of design or construction

Sponsors of any system of design or construction 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 AHJ for review and approval. The AHJ may investigate the data so submitted, and may require tests and formulate rules governing design and construction of such systems to meet the intent of this Code.

1.5—Quality assurance program

A quality assurance program covering nuclear safety-related structures shall be developed by the owner before starting any work. The general requirements and guidelines for establishing and executing the quality assurance program during the design and construction phases of nuclear power generating stations are established by Title 10 of the Code of Federal Regulations, Part 50 (10CFR50), Appendix B, and Title 10 of the Code of Federal Regulations, Part 830, Subpart A.

COMMENTARY

R1.3.4 Intentionally left blank because for nuclear safety-related structures records are to be maintained for life of the nuclear safety-related structure.

R1.3.5 Intentionally left blank because continuous inspection of the placement of the reinforcement and concrete by a licensed design professional is a requirement for all nuclear safety-related structures.

R1.4—Approval of special systems of design or construction

New methods of design, new materials, and new uses of materials should undergo a period of development before being specifically covered in a code. Potentially suitable systems or components might be excluded from use by implication if means were not available to obtain acceptance. This section permits proponents to submit data substantiating the adequacy of their system or component to the Regulatory Authority.

Some special concrete structures also need to be evaluated for their effectiveness as radiation shields. Specific guidance for this purpose may be obtained from ANSI/ANS-6.4-2006.[1.7]

R1.5—Quality assurance program

Title 10 of the Code of Federal Regulation, Part 50, Appendix B, and Title 10 of the Code of Federal Regulations, Part 830, Subpart A, require that the owner have a quality assurance program approved by the Regulatory Authority and state that the owner is responsible for the establishment and execution of programs developed by his licensed design professionals, construction contractors, and suppliers. More detailed requirements for development and implementation of a quality assurance program are contained in ANSI/ASME NQA-1.[1.5] Additional guidance is contained in ACI 311.4R[1.6] and ACI 121R.[1.8]

References, Chapter 1

1.1. ACI Committee 349, "Evaluation of Existing Nuclear Safety-Related Concrete Structures (ACI 349.3R-02)," American Concrete Institute, Farmington Hills, MI, 2002, 18 pp.

1.2. ACI/ASME Technical Committee on Concrete Pressure Components for Nuclear Service, "Code for

Documents Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

Concrete Containments (ACI 359-07)," *2007 ASME Boiler and Vessel Pressure Code*, Section III, Division 2, ASME, New York, 2007.

1.3. ACI Committee 360, "Guide to Design of Slabs-on-Ground (ACI 360R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 72 pp.

1.4. Post-Tensioning Institute (PTI), *Design of Post-Tensioned Slabs-on-Ground*, third editiion, Post-Tensioning Institute, Farmington Hills, MI, 2004, 106 pp.

1.5. American National Standards Institute (ANSI) and American Society of Mechanical Engineers (ASME), "Quality Assurance Requirements for Nuclear Facilities," NQA-1, 2000.

1.6. ACI Committee 311, "Guide for Concrete Inspection (ACI 311.4R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 13 pp.

1.7. American National Standards Institute (ANSI) and American Nuclear Society (ANS), "Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants," ANSI/ANS-6.4, 2006.

1.8. ACI Committee 121, "Guide for Concrete Construction Quality System in Conformance with ISO 9001 (ACI 121R-08)," American Concrete Institute, Farmington Hills, MI, 2008, 35 pp.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

CHAPTER 2—NOTATION AND DEFINITIONS

All notation and definitions in ACI 318-08 are the same as used in this Code except, those noted as follows for all dependent chapters. All notation and definitions in Chapter 21, and Appendixes D, E, and F are repeated in full in this chapter. All definitions in the appendixes appear in both Chapter 2 and in each appendix.

2.1—Code notation

The notations that differ from, or are not listed in, ACI 318-08 or part of the independent chapters are:

A = effective tensile area of concrete surrounding the reinforcing bars and having the same centroid as that reinforcement, divided by the number of bars, in.^{2} When the reinforcement consists of several bar sizes, the number of bars shall be calculated as the total steel area divided by the area of the largest bar used, Chapter 7

A_1 = loaded area, in.^{2}, Chapter 10

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 for its upper base the loaded area, and having side slopes of 1 vertical to 2 horizontal, in.^{2}, Chapter 10

A_{brg} = net bearing area of the head of stud, headed deformed bar, or anchor bolt, in.^{2}, Chapter 12, Appendix D

A_c = area of concrete section resisting shear transfer, in.^{2}, Chapter 11

A_{ch} = cross-sectional area of a structural member measured out-to-out of transverse reinforcement, in.^{2}, Chapters 10, 21

A_{cv} = gross area of concrete section bounded by web thickness and length of section in the direction of shear force considered, in.^{2}, Chapter 21

A_{cw} = area of concrete section of an individual pier, horizontal wall segment, or coupling beam resisting shear, in.^{2}, Chapter 21

A_g = gross area of concrete section, in.^{2} For a hollow section, A_g is the area of the concrete only and does not include the area of the void(s), see 11.5.1, Chapters 9-11, 14-16, 21, Appendix F

A_j = effective cross-sectional area within a joint in a plane parallel to plane of reinforcement generating shear in the joint, in.^{2}, see 21.5.3.1, Chapter 21

A_{Nc} = projected concrete failure area of a single anchor or group of anchors, for calculation of strength in tension, in.^{2}, see D.5.2.1, Appendix D

A_{Nco} = projected concrete failure area of a single anchor, for calculation of strength in tension if not limited by edge distance or spacing, in.^{2}, see D.5.2.1, Appendix D

A_{ps} = area of prestressing steel in flexural tension zone, in.^{2}, Chapter 18

A_s = area of nonprestressed longitudinal tension reinforcement, in.^{2}, Chapters 10-12, 14, 15, 18

COMMENTARY

R2—NOTATION AND DEFINITIONS

R2.1—Commentary notation

The terms used in this list are used in the commentary, but not in the Code.

Units of measurement are given in the Notation section to assist the user. They are not intended to preclude the use of other correctly applied units for the same symbol, such as feet or kips.

Notations that differ from ACI 318-08, or are not listed in ACI 318-08 or part of its independent chapters, are:

A_p = area over which the punching shear P_v is applied, in.^{2}, Appendix F

c'_{a1} = limiting value of c_{a1} when anchors are located less than $1.5h_{ef}$ from three or more edges (see Fig. RD.6.2.4), Appendix D

c_v = effective side dimension of the loaded zone, Appendix F

D_h = effective side dimension of the plastic hinge zone, Appendix F

e_b = eccentricity corresponding to the balanced strain conditions specified in Section 10.3.2, in., Appendix F

e_N = actual eccentricity of a normal force on an attachment, in., (see Fig. RD.5.2.4), Appendix D

F_1, F_2 = impulsive loads, lb, Appendix F

F_v = allowable shear strength of steel plate, ksi, Appendix D

F_y = specified minimum yield strength of steel plate, ksi, Appendix D

f'_t = see also ACI 318-08, Section R8.6.1, where f'_t in 349 is defined as f_{ct} in 318-08.

f_{ut} = ultimate tensile strength of headed anchor, Appendix D

h = height of shear lugs, in, Appendix D

h'_{ef} = limiting value of h_{ef} when anchors are located less than $1.5h_{ef}$ from three or more edges (see Fig. RD.5.2.3), Appendix D

K = value of resultant force F_t to cause unit deflection at point of application of resultant force, Appendix F

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

K_C = confinement factor (RD.11), Appendix D

K_e = elastic stiffness, Appendix F

L_v = distance between local loads, Appendix F

M = moment acting on anchor or anchor group, Appendix D

M_e = equivalent mass, Appendix F

m = mass per unit area, Appendix F

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

$A_{se,N}$ = effective cross-sectional area of anchor in tension, in.^{2}, Appendix D

$A_{se,V}$ = effective cross-sectional area of anchor in shear, in.^{2}, Appendix D

A_{sh} = total cross-sectional area of transverse reinforcement (including crossties) within spacing s and perpendicular to dimension b_c, in.^{2}, Chapter 21

$A_{s,min}'$ = minimum reinforcement for concrete section having a thickness of 48 in. or more, see 7.12.2.2, Chapter 7

A_{st} = total area of nonprestressed longitudinal reinforcement, (bars or steel shapes), in.^{2}, Chapters 10, 21

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, in.^{2}, see D.6.2.1, Appendix D

A_{vd} = total area of reinforcement in each group of diagonal bars in a diagonally reinforced coupling beam, in.^{2}, Chapter 21

A_{vf} = area of shear-friction reinforcement, in.^{2}, Chapter 11

b = width of compression face of member, in., Chapter 10

b_1' = total length of that portion of perimeter b_o for which V_{c1} is calculated, in., Chapter 11

b_2' = total length of that portion of perimeter b_o for which V_{c2} is calculated, in., Chapter 11

b_c = cross-sectional dimension of member core measured to the outside edges of the transverse reinforcement composing area A_{sh}, in., Chapter 21

b_o = perimeter of critical section for shear in slabs and footings, in., see 11.11.1.2, Chapter 11

b_s = width of strut, in., Appendix A

b_t = width of that part of cross section containing the closed stirrups resisting torsion, in., Chapter 11

b_v = width of cross section at contact surface being investigated for horizontal shear, in., Chapter 17

b_w = web width, or diameter of circular section, in., Chapters 10-12, 21

c = distance from extreme compression fiber to neutral axis, in., Chapters 9, 10, 14, 21, Appendix F

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, in., Chapters 11, 13, 21

c_{ac} = critical edge distance required to develop the basic concrete breakout strength of a post-installed anchor in uncracked concrete without supplementary reinforcement to control splitting, in., see D.8.6, Appendix D

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

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

c_{a1} = distance from the center of an anchor shaft to the edge of concrete in one direction, in. If shear is

COMMENTARY

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

N_y = yield strength of tension anchors equal to $nA_{se}f_y$, Appendix D

P_a = factored external axial load on the anchorage. (P_a is positive for tension and negative for compression), Appendix D

P_v = punching shear strength, Appendix F

p = pressure, lb/in^2, Appendix F

q = steel reinforcement index = $\rho(f_y/f_c')$, Appendix F

q' = steel reinforcement index = $\rho'(f_y/f_c')$, Appendix F

q_b = tensile reinforcement index for balanced, ultimate strength conditions, Appendix F

R_s = static force to be combined with impulsive or interactive loads, Appendix F

r_u = rotational capacity of a yield hinge, Appendix F

V = shear force acting on anchor or anchor group, Appendix D

X_s = displacement due to static loads, in., Appendix F

$\bar{x}$ = sample mean of the number of tests n, Appendix D

z = distance from the point of maximum moment to zero moment, in., Appendix F

ε_u = ultimate compressive strain of concrete, Appendix F

μ' = effective ductility ratio, Appendix F

$\phi(x,y)$ = fundamental mode shape, Appendix F

ψ_u = ultimate curvature, Appendix F

ζ = exponent used in shear-tension interaction equation where ζ varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\zeta = 5/3$, Appendix D

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

applied to anchor, c_{a1} is taken in the direction of the applied shear. If the tension is applied to the anchor, c_{a1} is the minimum edge distance, Appendix D

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

c_t = distance from the interior face of the column to the slab edge measured parallel to c_1, but not exceeding c_1, in., Chapter 21

D = dead loads, or related internal moments and forces, Chapters 8, 9, 20, 21, Appendix C

d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, in., Chapters 7, 9-12, 14, 17, 18, 21, Appendix F

d_a = outside diameter of anchor or shaft diameter of headed stud, headed bolt, or hooked bolt, in., see D.8.4, Appendix D

d_a' = value substituted for d_a when an oversized anchor is used, in., see D.8.4, Appendix D

d_b = nominal diameter of bar, wire, or prestressing strand, in., Chapters 7, 12, 21

d_o = outside diameter of anchor or shaft diameter of headed stud or headed bolt, in., see D.8.4, Appendix D

d_p = distance from extreme compression fiber to centroid of prestressing steel, in., Chapters 11, 18

E = load effects of earthquake, or related internal moments and forces, Chapters 9, 21, Appendix C

E_o = load effects of operating basis earthquake (see 2.2) or related internal moments and forces, including operating basis earthquake (OBE)-induced piping and equipment reactions, Chapter 9, Appendix C

E_{ss} = load effects of safe shutdown earthquake (see 2.2) or related internal moments and forces, including safe shutdown earthquake (SSE)-induced piping and equipment reactions, Chapter 9, Appendix C

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, in.; e_N' is always positive, Appendix D

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, in., e_v' is always positive, Appendix D

f_c' = specified compressive strength of concrete, psi, Chapters 1, 4, 5, 8-12, 14, 18, 19, 21, Appendixes A, D, F

$\sqrt{f_c'}$ = square root of specified compressive strength of concrete, psi, Chapters 8, 9, 11, 12, 18, 19, 21, 22, Appendix D

f_{m1} = concrete membrane stress acting along length b_1', to be taken as positive for compression and negative for tension, psi, Chapter 11

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

f_{m2} = concrete membrane stress acting along length b_2', to be taken as positive for compression and negative for tension, psi, Chapter 11

f_r = modulus of rupture of concrete, psi, see 9.5.2.3, Chapters 9, 14, 18

f_s'' = stress in steel reinforcement, psi, Chapter 7

f_t' = specified tensile strength of concrete, psi, Chapter 7

f_{uta} = specified tensile strength of anchor steel, psi, Appendix D

f_y = specified yield strength of reinforcement, psi, Chapters 3, 7, 9-12, 14, 17, 18, 19, 21, Appendixes A, C, F

f_{ya} = specified yield strength of anchor steel, psi, Appendix D

f_{yt} = specified yield strength f_y of transverse reinforcement, psi, Chapters 9, 10, 11, 12, 19, 21

h = overall thickness or height of member, in., Chapters 9-14, 17, 18, 20, 21, Appendixes A, F

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

h_{ef} = effective embedment depth of anchor, in., see D.8.5, Appendix D

h_w = height of entire wall from base to top or height of the segment of wall considered, in., Chapters 11, 21

h_x = maximum center-to-center horizontal spacing of crossties or hoop legs on all faces of the column, in., Chapter 21

I_{cr} = moment of inertia of cracked section transformed to concrete, in.^{4}, Chapters 9, 14, Appendix F

I_e = effective moment of inertia for calculation of deflection, in.^{4}, see 9.5.2.3, Chapters 9, 14

I_g = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement, in.^{4}, Chapters 9, 10, 14, Appendix F

k_c = coefficient for basic concrete breakout strength in tension, Appendix D

k_{cp} = coefficient for pryout strength, Appendix D

L_r = roof live load, or related internal moments and forces, Chapter 9, Appendix C

ℓ_c = length of compression member in a frame, measured center-to-center of the joints in the frame, in., Chapters 10, 14

ℓ_d = development length in tension of deformed bar, deformed wire, plain and deformed welded wire reinforcement, or pretensioned strand, in., Chapters 7, 12, 19, 21

ℓ_{dh} = development length in tension of deformed bar or deformed wire with a standard hook, measured from critical section to outside end of hook (straight embedment length between critical section and start of hook [point of tangency] plus inside radius of bend and one bar diameter), in., see 12.5 and 21.7.5, Chapters 12, 21

ℓ_e = load-bearing length of anchor for shear, in., see D.6.2.2, Appendix D

COMMENTARY

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

ℓ_h = maximum unsupported length of rectangular hoop measured between perpendicular legs of the hoop or supplementary crossties, in., Appendix F

ℓ_n = length of clear span measured face-to-face of supports, in., Chapters 8-10, 13, 16, 18, 21

ℓ_o = length, measured from joint face along axis of structural member, over which special transverse reinforcement must be provided, in., Chapter 21

ℓ_w = length of entire wall or length of segment of wall considered in direction of shear force, in., Chapters 11, 14, 21

M = maximum unfactored moment due to service loads, including P-Δ effects, in.-lb, Chapter 14

M_n = nominal flexural strength at section, in.-lb, Chapters 11, 12, 14, 18, 21, 22

M_{nb} = nominal flexural strength of beam including slab where in tension, framing into joint, in.-lb, see 21.6.2.2, Chapter 21

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, in.-lb, see 21.6.2.2, Chapter 21

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at the joint faces assuming a tensile stress in the longitudinal bars of at least $1.25f_y$ and a strength-reduction factor ϕ of 1.0, in.-lb, Chapter 21

M_{sa} = maximum unfactored applied moment due to service loads, not including P-Δ effects, in.-lb, Chapter 14

M_{slab}= portion of slab factored moment balanced by support moment, in.-lb, Chapter 21

M_u = factored moment at section, in.-lb, Chapters 10, 11, 13, 14, 15, 21, 22

N_b = basic concrete breakout strength in tension of a single anchor in cracked concrete, lb, see D.5.2.2, Appendix D

N_{cb} = nominal concrete breakout strength in tension of a single anchor, lb, see D.5.2.1, Appendix D

N_{cbg} = nominal concrete breakout strength in tension of a group of anchors, lb, see D.5.2.1, Appendix D

N_n = nominal strength in tension, lb, Appendix D

N_p = pullout strength in tension of a single anchor in cracked concrete, lb, see D.5.3.3 and D.5.3.4, Appendix D

N_{pn} = nominal pullout strength in tension of a single anchor, lb, see D.5.3.1, Appendix D

N_{sa} = nominal strength of a single anchor or group of anchors in tension as governed by the steel strength, lb, see D.5.1.1 and D.5.1.2, Appendix D

N_{sb} = side-face blowout strength of a single anchor, lb, Appendix D

N_{sbg} = side-face blowout strength of a group of anchors, lb, Appendix D

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

N_{ua} = factored tensile force applied to anchor or group of anchors, lb, Appendix D

n = number of items, such as strength tests, bars, wires, monostrand anchorage devices, anchors, or shearhead arms, Chapters 5, 11, 12, 18, Appendix D

P_a = differential pressure load, or related internal moments and forces, generated by a postulated pipe break accident, Chapter 9, Appendix C

P_b = nominal axial strength at balanced strain conditions, lb, see 10.3.2, Chapters 9, 10, Appendix C

P_n = nominal axial strength of cross section, lb, Chapters 9, 10, 14, Appendix C

P_u = factored axial force; to be taken as positive for compression and negative for tension, lb, Chapters 10, 14, 21

R = rain load, or related internal moments and forces, Chapter 9, Appendix C

R_R = resistance, Appendix F

R_a = piping and equipment reactions, or related internal moments and forces, under thermal conditions generated by a postulated pipe break and including R_o, Chapter 9, Appendix C

R_m = maximum resistance, Appendix F

R_o = piping and equipment reactions, or related internal moments and forces, that occur under normal operating and shutdown conditions, excluding dead load and earthquake reactions, Chapter 9, Appendix C

$r\theta$ = rotational capacity, radians, Appendix F

S = snow load, or related internal moments and forces, Chapter 9, 21, Appendix C

S_n = nominal flexural, shear, or axial strength of connection, Chapter 21

S_y = yield strength of connection, based on f_y, for moment, shear, or axial force, Chapter 21

s = center-to-center spacing of items, such as longitudinal reinforcement, transverse reinforcement, prestressing tendons, wires, or anchors, in., Chapters 10-12, 17-21, Appendix D

s_h = center-to-center spacing of hoops, in., Appendix F

s_o = center-to-center spacing of transverse reinforcement within the length ℓ_o, in., Chapter 21

s_s = sample standard deviation, psi, Chapter 5, Appendix D

T_a = internal moments and forces caused by temperature distributions within the concrete structure occurring as a result of accident conditions generated by a postulated pipe break and including T_o, Chapter 9, Appendix C

T_o = internal moments and forces caused by temperature distributions within the concrete structure and other temperature-induced loads occurring as a result of normal operating or shutdown conditions, Chapter 9, Appendix C

V_b = basic concrete breakout strength in shear of a single anchor in cracked concrete, lb, see D.6.2.2 and D.6.2.3, Appendix D

COMMENTARY

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

V_c = nominal shear strength provided by concrete, lb, Chapters 8, 11, 13, 21

V_{c1} = punching shear strength provided by a concrete plane of length b_1', lb, Chapter 11

V_{c2} = punching shear strength provided by a concrete plane of length b_2', lb, Chapter 11

V_{cb} = nominal concrete breakout strength in shear of a single anchor, lb, see D.6.2.1, Appendix D

V_{cbg} = nominal concrete breakout strength in shear of a group of anchors, lb, see D.6.2.1, Appendix D

V_{cp} = nominal concrete pryout strength of a single anchor, lb, see D.6.3.1, Appendix D

V_{cpg} = nominal concrete pryout strength of a group of anchors, lb, see D.6.3.1, Appendix D

V_e = design shear force corresponding to the development of the probable moment strength of the member, lb, see 21.5.4.1 and 21.6.5.1, Chapter 21

V_n = nominal shear strength, lb, Chapters 8, 10, 11, 21, Appendix D

V_{sa} = nominal strength in shear of a single anchor or group of anchors as governed by the steel strength, lb, see D.6.1.1 and D.6.1.2, Appendix D

V_u = factored shear force at section, lb, Chapters 11-13, 17, 21

V_{ua} = factored shear force applied to a single anchor or group of anchors, lb, Appendix D

v_n = nominal shear stress, psi, Chapters 11, 21

W = operating basis wind load (OBW), or related internal moments and forces, Chapter 9, Appendix C

W_t = loads generated by the design basis tornado (DBT) or related internal moments and forces. These include loads due to tornado wind pressure, tornado-created differential pressures, and tornado-generated missiles, Chapter 9, Appendix C

w_c = density (unit weight) of normalweight concrete, lb/ft^3, Chapters 8, 9

X_m = maximum acceptable displacement, Appendix F

X_y = displacement at effective yield point, Appendix F

Y_j = jet impingement load, or related internal moments and forces, on the structure generated by a postulated pipe break, Chapter 9, Appendix C

Y_m = missile impact load, or related internal moments and forces, on the structure generated by a postulated pipe break, such as pipe whip, Chapter 9, Appendix C

Y_r = loads, or related internal moments and forces, on the structure generated by the reaction of the broken pipe during a postulated break, Chapter 9, Appendix C

α = angle defining the orientation of reinforcement, Chapters 11, 21, Appendix A

α_c = coefficient defining the relative contribution of concrete strength to nominal wall shear strength, see 21.9.4.1, Chapter 21

β = ratio of long to short dimensions: clear spans for two-way slabs, see 9.5.3.1; sides of column,

COMMENTARY

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

concentrated load or reaction area, see 11.11.2.1; or sides of a footing, see 15.4.4.2, Chapters 9, 11, 15

β_1 = factor relating depth of equivalent rectangular compressive stress block to neutral axis depth, see 10.2.7.3, Chapters 10, 18

β_c = ratio of long side to short side of concentrated load or reaction area, see 11.11.2.3.1 and 11.11.2.3.2

β_d = ratio used to compute magnified moments in columns due to sustained loads, see 10.11.1, 10.13.6, Chapter 10

β_e = ratio of length of continuous edges to total perimeter of a slab panel, Chapter 9

γ = ratio of the bending moments of factored loads to unfactored loads, see 9.5.1.3, Chapter 9

γ_f = factor used to determine the unbalanced moment transferred by flexure at slab-column connections, see 13.5.3.2, Chapters 11, 13, 21

δ_{ns} = moment magnification factor for frames braced against sidesway, to reflect effects of member curvature between ends of compression member, Chapter 10

δ_u = design displacement, in., Chapter 21

λ = modification factor reflecting the reduced mechanical properties of lightweight concrete, all relative to normalweight concrete of the same compressive strength. Lightweight concrete is not permitted for nuclear safety-related structures, therefore $\lambda = 1.0$ (for normalweight concrete). See 9.5.2.3, 12.2.4(d), 12.5.2, Chapters 11, 12, 17, 21, and Appendixes A, D

μ = coefficient of friction, see 11.6.4.3, Chapters 11, 19, 21

μ_d = ductility ratio (dimensionless), Appendix F

ρ = ratio of A_s to bd, Chapters 11, 13, 21, Appendix F

ρ' = ratio of A_s' to bd, Chapter 9, Appendix F

ρ_b = ratio of A_s to bd producing balanced strain conditions, see 10.3.2, Chapters 10, 14

ρ_ℓ = ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement, Chapters 11, 14, 21

ρ_s = ratio of volume of spiral reinforcement to total volume of core confined by the spiral (measured out-to-out of spirals), Chapters 10, 21, Appendix F

ρ_t = ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement, Chapters 11, 14, 21

ρ_1' = reinforcement ratio in direction "1" based on section thickness h. See 11.11.2.3.1, Chapter 11

ρ_2' = reinforcement ratio in direction "2" based on section thickness h. See 11.11.2.3.2, Chapter 11

ϕ = strength-reduction factor, see 9.3, Chapters 8-11, 13, 14, 17-21, 22, Appendixes A, C, D

$\psi_{c,N}$ = factor used to modify tensile strength of anchors based on presence or absence of cracks in concrete, see D.5.2.6, Appendix D

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

$\psi_{c,P}$ = factor used to modify pullout strength of anchors based on presence or absence of cracks in concrete, see D.5.3.6, Appendix D

$\psi_{c,V}$ = factor used to modify shear strength of anchors based on presence or absence of cracks in concrete and presence or absence of supplementary reinforcement, see D.6.2.7 for anchors in shear, Appendix D

$\psi_{cp,N}$ = factor used to modify tensile strength of post-installed anchors intended for use in uncracked concrete without supplementary reinforcement, see D.5.2.4, Appendix D

$\psi_{ec,N}$ = factor used to modify tensile strength of anchors based on eccentricity of applied loads, see D.5.2.7, Appendix D

$\psi_{ec,V}$ = factor used to modify shear strength of anchors based on eccentricity of applied loads, see D.6.2.5, Appendix D

$\psi_{ed,N}$ = factor used to modify tensile strength of anchors based on proximity to edges of concrete member, see D.6.2.5, Appendix D

$\psi_{ed,V}$ = factor used to modify shear strength of anchors based on proximity to edges of concrete member, see D.6.2.6, Appendix D

$\psi_{h,V}$ = factor used to modify shear strength of anchors located in concrete members with $h_a < 1.5c_{a1}$, see D.6.2.8, Appendix D

ω = tension reinforcement index, see 18.7.2, Chapter 18

ω' = compression reinforcement index, see 18.7.2, Chapter 18

ω_p = prestressing steel index, see B.18.8.1

ω_{pw} = prestressing steel index for flanged sections, see B.18.8.1

ω_w = tension reinforcement index for flanged sections, see B.18.8.1

ω_w' = compression reinforcement index for flanged sections, see B.18.8.1

COMMENTARY

2.2—Definitions

The following terms are defined for general use in this Code. Specialized definitions appear in individual chapters.

accident or abnormal temperatures—these are normally short-duration or transient temperatures, which usually produce nonlinear temperature distributions across structural sections. See RE.1.1.

ambient temperatures—these are outdoor atmospheric temperatures that depend on the location of the nuclear safety-related structure and vary with meteorological changes. See RE.1.1.

anchor—a steel element either cast into concrete or post-installed into a hardened concrete member and used to transmit applied loads, including headed bolts, headed studs, expansion anchors, undercut anchors, or specialty inserts. See Appendix D.

anchor group—a number of anchors of approximately equal effective embedment depth with each anchor spaced

R2.2—Definitions

Definitions that differ from ACI 318-08, or are not listed in ACI 318-08 or from its independent chapters, are:

accident or abnormal temperatures;
ambient temperatures;
anchor;
anchor group;
anchor pullout strength;
anchor reinforcement;
attachment;
authority having jurisdiction (AHJ);
auxiliary members;
base temperature;
brittle steel element;
cast-in anchor;
concrete breakout strength;
concrete pryout strength;
creep;

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

at less than three times its embedment depth from one or more adjacent anchors when subjected to tension, or $3c_{a1}$ from one or more adjacent anchors when subjected to shear. Only those anchors susceptible to the particular failure mode under investigation shall be included in the group. See Appendix D.

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. See Appendix D.

anchor reinforcement—reinforcement used to transfer the full design load from the anchors into the structural member. See D.5.2.10 or D.6.2.9. See Appendix D.

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

authority having jurisdiction (AHJ)—a federal government agency (or agencies), such as the U.S. Nuclear Regulatory Commission, the Department of Energy, that is empowered to enforce regulations affecting the design, construction, and operation of nuclear facilities.

auxiliary members—ribs or edge beams that serve to strengthen, stiffen, or support the shell; usually, auxiliary members act jointly with the shell. See 19.1.6.

base of structure—level at which the horizontal earthquake ground motions are assumed to be imparted to a structure. This level does not necessarily coincide with the ground level. See Chapter 21.

base temperature—the temperature at which a concrete member is cured.

boundary element—portions along structural wall and structural diaphragm edge strengthened by longitudinal and transverse reinforcement. Boundary elements do not necessarily require an increase in the thickness of the wall or diaphragm. See Chapter 21.

brittle steel element—an element with a tensile test elongation of less than 14 percent, or reduction in area of less than 30 percent, or both. See Appendix D.

cast-in anchor—a headed bolt or headed stud, installed before placing concrete. See Appendix D.

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

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

connection—a region that joins two or more members.

creep—time-dependent deformation due to sustained load.

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

COMMENTARY

design basis earthquake (DBE) and beyond design basis earthquake (BDBE);
design basis tornado (DBT);
distance sleeve;
ductile embedment;
ductile steel embedment;
edge distance;
effective embedment depth;
elastic analysis;
elevated or differential temperature;
embedment;
evaluation;
expansion anchor;
expansion sleeve;
experimental analysis;
five percent fractile;
folded plates;
gradient temperature distribution;
gross failure;
headed stud;
inelastic analysis;
load, dead;
load, live;
load, sustained;
loads, abnormal;
loads, extreme environmental;
loads, normal;
loads, several environmental;
local area;
long term;
massive concrete;
mean temperature distribution;
moment frame;
operating basis earthquake (OBE);
operating basis wind (OBW);
operating temperatures;
owner;
position dependent;
post-installed anchor;
projected area;
ribbed shells;
safe shutdown earthquake (SSE);
shear wall structures;
short term;
shrinkage;
side-face blowout strength;
specialty insert;
stress relaxation;
structural walls;
supplementary reinforcement;
temperature distribution;
thermal strain;
thermal stress;
thin shells;
time dependent;
toughness of a structural system; and

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

same longitudinal bars shall be alternated end for end. See Chapters 7, 21.

design basis earthquake (DBE) and beyond design basis earthquake (BDBE)—design basis earthquake is an earthquake excitation consistent with the design hazard approved by the AHJ. BDBE is a rare, but possible, earthquake excitation exceeding the design hazard approved by the AHJ.

design basis tornado (DBT)—the combinations of translational speed, rotational speed, and prescribed pressure drop related to the effects of tornadoes on structures. Design basis tornado shall be as defined by the AHJ at the site.

distance sleeve—a 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.

ductile embedment—an embedment designed for a ductile steel failure in accordance with D.3.6.1. See Appendix D.

ductile steel element—an element with a tensile test elongation of at least 14 percent and reduction in area of at least 30 percent. A steel element meeting the requirements of ASTM A307 shall be considered ductile. See Appendix D.

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

effective embedment depth—the overall depth through which the anchor transfers force to or from the surrounding concrete. The 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. See Appendix D.

elastic analysis—an analysis of deformations and internal forces based on equilibrium, compatibility of strains, and assumed elastic behavior, and representing to a suitable approximation the three-dimensional action of the shell together with its auxiliary members. See 19.1.7.

elevated or differential temperature—elevated or differential temperature refers to the temperatures that are different than the construction temperatures, which are assumed to be stress free.

embedment—a steel component embedded in the concrete to transmit applied loads to the concrete structure. The embedment can be fabricated of plates, shapes, fasteners, reinforcing bars, shear connectors, inserts, or any combination thereof.

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

evaluation—an engineering review of an existing safety-related concrete structure with the purpose of determining physical condition and functionality. This review may include analysis, condition surveys, maintenance, testing, and repair.

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

COMMENTARY

undercut anchor.

The user of SEI/ASCE 7-02 for ACI 349-13 applications should be warned of the differences, such as the need to recreate Table 6-2 in SEI/ASCE 7-02 and modify equations listed in 6.5.12 and 6.5.13 for 100-year recurrence using Table C6-3 in SEI/ASCE 7-05 and its commentary.

anchorage device—Most anchorage devices for post-tensioning are standard manufactured devices available from commercial sources. In some cases, "special" details or assemblages are developed that combine various wedges and wedge plates for anchoring prestressing steel. These informal designations as standard anchorage devices or special anchorage devices have no direct relation to the Code and "AASHTO LRFD Bridge Design Specifications" classification of anchorage devices as Basic Anchorage Devices or Special Anchorage Devices.

base temperature—The temperature at which it is assumed the material is free of thermal stresses. Seventy degrees Fahrenheit can be used as a base temperature for most calculations.

basic anchorage devices—Devices so proportioned 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.

concrete, structural lightweight—Lightweight concrete is not permitted for nuclear safety-related structures.

cover, specified concrete—Tolerances on specified concrete cover (7.5.2.1).

headed deformed bars—The bearing area of a headed deformed bar is, for the most part, perpendicular to the bar axis, as shown in Fig. R3.5.9. In contrast, the bearing area of the head of headed stud reinforcement is a non-planar spatial surface of revolution, as shown in Fig. R3.5.5. 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.

special anchorage devices—Special anchorage devices are any devices (monostrand or multistrand) that do not meet the relevant Post-Tensioning Institute (PTI) or American Association of State Highway and Transportation Officials (AASHTO) limit on bearing stress and, where applicable, stiffness requirements. Most commercially marketed multibearing surface anchorage devices are special anchorage devices. As provided in 18.15.1, such devices can be used only when 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.

temperature distribution—The temperature distribution across a section can vary with time as well as vary along

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

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 the length of travel of the sleeve or plug. See Appendix D.

expansion sleeve—the 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 Appendix D.

experimental analysis—an analysis procedure based on the measurement of deformations or strains, or both, of the structure or its model; experimental analysis is based on either elastic or inelastic behavior. See 19.1.9.

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

folded plates—a class of shell structure formed by joining flat, thin slabs along their edges to create a three-dimensional spatial structure. See 19.1.4.

gradient temperature distribution—the temperature distribution minus the mean temperature distribution across a section at a point in time.

gross failure—failure of a structure or component to the degree that it no longer meets the intended design function.

headed deformed bars—deformed reinforcing bars with heads attached at one or both ends. Heads are attached to the bar end by means such as welding or forging onto the bar, internal threads on the head mating to threads on the bar end, or a separate threaded nut to secure the head to the bar. The net bearing area of a headed deformed bar equals the gross area of the head minus the larger of the area of the bar and the area of any obstruction.

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 common base rail consisting of a steel plate or shape.

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.

hoop—a closed tie or continuously wound tie. A closed tie can be made up of several reinforcement elements each having seismic hooks at both ends. A continuously wound tie shall have a seismic hook at both ends. See Chapter 21.

inelastic analysis—an analysis of deformations and internal forces based on equilibrium, nonlinear stress-strain relations for concrete and reinforcement, consideration of cracking and time-dependent effects, and compatibility of strains. The analysis shall represent to a suitable approximation three-dimensional action of the shell together with its auxiliary members. See 19.1.8.

joint—portion of structure common to intersecting members. The effective cross-sectional area of a joint of a special moment frame, A_j, for shear strength calculations is defined in 21.7.4.1. See Chapter 21.

COMMENTARY

the length of the member. For such variations, the licensed design professional should evaluate the effects of temperature distribution at a number of sections and for a number of time durations.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

load, dead—dead weight supported by a member, as defined by general building code of which this Code forms a part (without load factors).

load, live—live load specified by the licensed design professional (without load factors).

load, service—loads without load factors used where specified in this Code to proportion or investigate members for adequate serviceability conditions, as in Section 9.5, Control of Deflections or cracking in Chapters 10 and 18.

load, sustained—a subset of service loads that has a high probability of being on the structure for a sufficient period of time to cause time-dependent effects. These loads are typically used to investigate members for long-term deflections as in 9.5.1 or for soil response or foundation design.

loads, abnormal—those loads generated by a postulated high-energy pipe break accident, including P_a, T_a, R_a, Y_r, Y_j, and Y_m.

loads, extreme environmental—those loads that are credible but are highly improbable, including E_{ss} and W_t.

loads, normal—those loads that are encountered during normal facility operation and shutdown, including C_{cr}, D, L, F, H, L_r, S, R, T_o, and R_o. See 9.1.

loads, severe environmental—those loads that could infrequently be encountered during the life of the nuclear safety-related structure, including E_o and W. See 9.1.

local area—region of structure exposed to elevated temperature that may affect concrete performance and stress distribution in the immediate area, without changing the overall component or member behavior. For example, areas around hot piping that are penetrating transversely through the component.

long term—the time period following stabilization of the temperature distribution across the concrete section.

massive concrete—mass of concrete of sufficient dimensions to produce excessive temperatures due to heat of hydration unless special precautions are taken regarding concrete placement temperatures, placing rate, or heat removal. Portions of the structure to be treated as massive concrete shall be so identified on the design drawings or specifications.

mean temperature distribution—average temperature distribution across a section at a point in time.

moment frame—frame in which members and joints resist forces through flexure, shear, and axial force.

operating basis earthquake (OBE)—the operating basis earthquake for a reactor site is that which produces the vibratory ground motion for which those features of the nuclear facility necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional. The OBE is only associated with facility shutdown and inspection unless selected by the owner as a design input. See Appendix S of 10CFR50 of the Federal Regulation.

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

operating basis wind (OBW)—wind velocities and forces required for the design of a structure in accordance with SEI/ASCE 7-05 for a 100-year recurrence interval.

operating temperatures—the temperatures as obtained in various locations inside the nuclear power facility under normal operating conditions. Under steady state normal operating conditions, these temperatures usually produce linear temperature distributions across structural sections. See RE.1.1.

owner—the organization responsible for the operation, maintenance, safety, and power generation of the nuclear power facility.

plastic hinge region— length of frame element over which flexural yielding may occur due to earthquake design displacements, extending not less than a distance h from the critical section where flexural yielding initiates. See Chapter 21.

position dependent—variations through the thickness and along the geometric center of the member. See RE.1.1.

post-installed anchor—an anchor installed in hardened concrete. Expansion anchors and undercut anchors are examples of post-installed anchors. See Appendix D.

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

Regulatory Authority—a governmental agency that regulates businesses in the public interest (such as U.S. Nuclear Regulatory Commission—an independent federal agency created in 1974 to license and regulate nuclear power facilities).

reinforced concrete—structural concrete reinforced with no less than the minimum amounts of prestressing steel or nonprestressed reinforcement specified in Chapters 1 through 21 and Appendixes A and C.

ribbed shells—spatial structures with material placed primarily along certain preferred rib lines, with the area between the ribs filled with thin slabs or left open. See 19.1.5.

safe shutdown earthquake (SSE)—the safe shutdown earthquake ground motion is the vibratory ground motion for which certain structures, systems, and components (SSCs) in nuclear power facilities must be designed to remain functional. For the definition of these SSCs and for more information, see Appendix S of 10CFR50 of the Federal Regulation. In the Department of Energy (DOE) nuclear facilities and older nuclear plants, the term "design basis earthquake (DBE)" is used, conveying the same meaning as SSE for design purposes.

seismic hook—a 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 a $6d_b$ (but not less than 3 in.) extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop. See 7.1.4 and Chapter 21.

shear wall structures—reinforced concrete structures that generally consist of shear walls and diaphragms, although they may also incorporate columns and beams as part of the seismic-force-resisting system.

COMMENTARY

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

short term—the time period before stabilization of the temperature distribution across the concrete section. Short term for the purposes of E.4.2 is considered up to 30 days.

shrinkage—time-temperature-humidity-dependent volume reduction of concrete as a result of hydration, moisture migration, and drying process.

side-face blowout strength—the strength of anchors with deeper embedment but thinner side cover corresponding to concrete spalling on the side face around the embedded head whereas no major breakout occurs at the top concrete surface. See Appendix D, Figure RD.4.1.

special boundary element—boundary element required by 21.9.6.2 or 21.9.6.3.

specialty insert—predesigned and prefabricated cast-in anchors specifically designed for attachment of bolted or slotted connections. Specialty inserts are often used for handling, transportation, and erection, but are also used for anchoring structural members. See Appendix D.

specification, construction—an explicit set of requirements, typically specified by the owner and/or licensed design professional, for the procurement of materials and for the erection of the nuclear safety-related structures.

specification, design—an explicit set of requirements, typically created by the owner, for the design of a safety-related structure.

specification, technical—the design and performance criteria and operating limits and principles of an operating license to be observed during the initial fuel loading, critical testing, start-up, power operations, refueling, and maintenance operations.

stress relaxation—the time-dependent decrease in stress in a material held at a constant strain.

structural diaphragm—structural member, such as a floor or roof slab, that transmits forces acting in the plane of the member to the vertical elements of the lateral-force-resisting system. See Chapter 21 for requirements in earthquake-resistant structures.

structural wall—wall proportioned to resist combinations of shears, moments, and axial forces. A shear wall is a structural wall.

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

temperature distribution—the variation of the temperature across a section at a point in time.

technical safety requirements—the limits, controls, and related actions that establish the specific parameters and requisite actions for the safe operation of a nuclear facility.

thermal strain—strain produced by thermal expansion or contraction due to thermal loads, including the effects of thermal restraint.

thermal stress—stress produced by restraint of thermal strain.

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

thin shells—three-dimensional spatial structures made up of one or more curved slabs or folded plates whose thicknesses are small compared with their other dimensions. Thin shells are characterized by their three-dimensional load-resisting behavior, which is determined by the geometry of their forms, by the manner in which they are supported, and by the nature of the applied load. See 19.1.3.

time dependent—transient temperature distribution and the final steady state condition. See RE.1.1.

toughness of a structural system—the ability of a structure to resist the earthquake forces through the combination of strength and ductility.

undercut anchor—a 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. The undercutting is achieved with a special drill before installing the anchor or alternatively by the anchor itself during its installation. See Appendix D.

COMMENTARY

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

CHAPTER 3—MATERIALS

R3—MATERIALS

The commentary of ACI 318-08 is applicable to this chapter except as described as follows. Replace the term "building official" with "licensed design professional" whenever it occurs.

3.1—Tests of materials

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

3.1.2 Same as ACI 318-08.

3.1.3 A complete record of tests of materials and of concrete shall be available for inspection as required by 1.3.2.

R3.1—Tests of materials

R3.1.3 The owner shall designate the period of retention for all records of tests of materials and of concrete used in concrete nuclear structures. Typically, any documentation that uniquely describes tests of materials and of concrete used in concrete nuclear structures should be retained by the owner for the life of the nuclear safety-related structure.

3.2—Cementitious materials

3.2.1 Same as ACI 318-08.

3.2.2 Same as ACI 318-08.

3.2.3 Every shipment of cement shall be accompanied by a certified mill test report stating the results of tests representing the cement in shipment and the ASTM specification limits for each item of required chemical, physical, and optional characteristics. No cement shall be used in any structural concrete before receipt of 7-day ASTM C109 strength test results.

R3.2—Cementitious materials

R3.2.1 Adequate performance of expansive cements should be demonstrated for the particular application before selecting such materials, such as in areas of high temperature and irradiation. Additionally, the user should address potential adverse reactions with dissimilar metals that can exist in certain expansive hydraulic cements.

R3.2.2 Concrete mixture proportions shall be subject to the limitations of Chapter 4.

R3.2.3 The requirement for receipt of certified 7-day mill test materials reports in advance of use is imposed to inform the materials licensed design professional of changes in cement strength to provide guidance in altering concrete mixtures when significant changes in strength occur. Such alterations can both achieve increased assurance against low strengths and reduce the standard deviation of strengths, providing a means of optimizing the cement contents and reducing the heat of hydration effects in these relatively massive structures.

3.3—Aggregates

3.3.1 Concrete aggregates shall conform to one of the following specifications:

(a) Normalweight: ASTM C33;

(b) Radiation-Shielding: (ASTM C637).

Exception: Aggregates failing to meet ASTM C33 or C637, but that have been shown by special test or actual service to produce concrete of adequate strength and durability, shall be permitted to be used for normalweight concrete where authorized by the licensed design professional.

3.3.2 Same as in ACI 318-08.

R3.3—Aggregates

R3.3.1 The reference to lightweight aggregates has been deleted. The minimum thickness of most concrete members in nuclear plant construction is based on shielding requirements that are dependent on the density of the concrete. Lightweight aggregates would require larger minimum thicknesses because the sizing of columns and spacing of walls is usually controlled by live load, seismic, or shielding requirements and not floor dead loads. There appears to be no advantage in using lightweight aggregates in nuclear structures.

R3.3.2 Same as ACI 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

3.3.3 *Testing requirements*

3.3.3.1 Tests for potential reactivity shall be performed before usage in construction unless such tests are specifically exempted by the design specifications as not being applicable.

3.3.3.2 A daily inspection control program shall be carried out during concrete production to determine and control consistency in potentially variable characteristics such as aggregate water content, gradation, fineness modulus and material finer than No. 200 sieve.

3.3.3.3 Tests for conformance with ASTM C131, ASTM C289, and ASTM C88 shall be repeated periodically and whenever there is reason to suspect a change in the basic geology or mineralogy of the aggregates.

3.4—Water

3.4.1 Same as ACI 318-08.

3.4.2 Same as ACI 318-08.

3.5—Steel reinforcement

3.5.1 Same as ACI 318-08.

3.5.2 Welding of reinforcing bars shall conform to ANSI/AWS D1.4, and be performed by a certified welder. Type and location of welded splices and other required welding of reinforcing bars shall be indicated in the contract documents. ASTM reinforcing bar specifications, except for ASTM A706, shall be supplemented to require a report of material properties necessary to conform to the requirements in ANSI/AWS D1.4.

3.5.3 *Deformed reinforcement*

3.5.3.1 Same as ACI 318-08 except delete (d).

COMMENTARY

R3.3.3 Minimum testing requirements are specified to assure aggregate quality.

R3.3.3.3 Whenever there is a basic change in aggregate source, the aggregate should be tested to determine suitability for use. Retests for soundness (ASTM C88), abrasion resistance (ASTM C131), and potential reactivity (ASTM C289) are required because they are not included in the routine testing of aggregates.

R3.4—Water

R3.4.1 Same as ACI 318-08.

R3.5—Steel reinforcement

R3.5.1 Same as ACI 318-08.

R3.5.2 Same as ACI 318-08.

R3.5.3 *Deformed reinforcement*—Zinc used in the galvanizing process may negatively react with alkaline materials commonly found in concrete. In addition, potential galvanic corrosion with other embedded metals, as well as hydrogen generation and potential for hydrogen embrittlement, suggest that such coatings may be detrimental. Research conducted by Sergi[3.1] concluded that zinc coatings provide little value in providing long-term protection of steel reinforcement, and cautionary statements in ACI 201.2R-01[3.2] support this position. These industry concerns have prompted ACI Committee 349 to prohibit use of zinc coatings on steel reinforcement in nuclear safety-related structures until adequate data justifying its use can be reviewed.

R3.5.3.1 Use of rail and axle steel reinforcing bars is excluded because of inadequate traceability.

AVA Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

3.5.3.1.1 A minimum of one tensile test shall be required for each 50 tons of each bar size produced from each heat of steel (ASTM A370).

3.5.3.2 Same as ACI 318-08.

3.5.3.3 Same as ACI 318-08.

3.5.3.4 Same as ACI 318-08.

3.5.3.5 Same as ACI 318-08.

3.5.3.6 Same as ACI 318-08.

3.5.3.7 Same as ACI 318-08.

3.5.3.8 Epoxy-coated reinforcing bars shall conform to ASTM A775 or ASTM A934. Bars to be epoxy-coated shall conform to one of the specifications listed in 3.5.3.1.

The licensed design professional shall evaluate the suitability of coated steel reinforcement and epoxy-coated steel wire and welded wire reinforcement for the expected service environment in each application.

3.5.3.9 Same as ACI 318-08.

3.5.3.10 Same as ACI 318-08.

3.5.4 *Plain reinforcement*

3.5.4.1 Plain bars for spiral reinforcement shall conform to the specification listed in 3.5.3.1(a) or (b) including additional requirements of 3.5.3.1.1.

3.5.4.2 Same as ACI 318-08.

3.5.5 Same as ACI 318-08.

3.5.5.1 Same as ACI 318-08.

3.5.6 Same as ACI 318-08.

3.5.6.1 Same as ACI 318-08.

3.5.6.2 Same as in ACI 318-08.

3.5.7 *Structural steel, steel pipe, or tubing*

3.5.7.1 Structural steel used with reinforcing bars in composite compression members meeting requirements of

COMMENTARY

R3.5.3.2 Same as in ACI 318-08 except ASTM A615 includes provisions for Grade 75 and Grade 80 bars in sizes No. 3 through 18 and ASTM A706 includes provisions for Grade 80 bars in sizes No. 3 through 18.

R3.5.3.5 Same as ACI 318-08.

R3.5.3.6 Same as ACI 318-08.

R3.5.3.7 Same as ACI 318-08.

R3.5.3.8 Current industry studies have not quantified the long-term durability of epoxy coatings in areas of elevated temperature and irradiation. Degradation of the epoxy coating, under certain environmental conditions, may adversely affect steel reinforcement performance and anchorage, resulting in splitting effects. Adequate performance of the epoxy-coated reinforcement and concrete should be demonstrated for the particular environmental application before selecting epoxy-coated reinforcement.

R3.5.3.10 Same as ACI 318-08.

R3.5.4 *Plain reinforcement*

R3.5.4.1 Use of rail and axle steel reinforcing bars is excluded because of inadequate traceability.

R3.5.5 Same as ACI 318-08.

R3.5.6 Same as ACI 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

10.13.7 or 10.13.8 shall conform to one of the following specifications:

(a) Same as ACI 318-08;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08;
(d) Same as ACI 318-08;
(e) Same as ACI 318-08.

3.5.7.2 Steel pipe or tubing for composite compression members composed of a steel encased concrete core meeting requirements of 10.13.6 shall conform to one of the following specifications:

(a) Same as ACI 318-08;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08.

3.5.8 Intentionally left blank.

3.5.9 Same as ACI 318-08.

3.6—Admixtures

3.6.1 Same as ACI 318-08.

3.6.2 Same as ACI 318-08.

3.6.3 Admixtures to be used in concrete that do not conform to 3.6.1 and 3.6.2 shall be subject to prior approval by the licensed design professional.

3.6.4 Same as ACI 318-08. See 4.3.1 and 6.3.2.

3.6.5 Same as ACI 318-08.

3.6.6 *Testing*

3.6.6.1 Tests for compliance with the specification for each admixture shall be required before initial shipment and acceptance on site for usage in construction and periodically thereafter.

3.6.6.2 An infrared spectrum trace of the conformance test sample of air-entraining and water-reducing admixture shall be furnished with the conformance test results (ASTM E204).

3.7—Storage and identification of materials

3.7.1 Measures shall be established to provide for storage of all materials so as to prevent damage or deterioration. When necessary for particular products, special protective environments such as inert gas atmosphere, specific moisture content levels, and control temperatures shall be provided.

All stored materials shall be properly tagged or labeled to permit identification.

COMMENTARY

R3.5.8 Intentionally left blank.

R3.5.9 Same as ACI 318-08.

R3.6—Admixtures

R3.6.1 Adequate performance of ground-granulated blast-furnace slag should be demonstrated for the particular application before selecting such materials, such as areas of high temperature and irradiation.

R3.6.4 Same as ACI 318-08.

R3.6.5 Same as ACI 318-08.

R3.6.6 For quality assurance, all admixtures should be fully tested and verified to be in compliance with the referenced ASTM test methods before use.

R3.7—Storage and Identification of materials

R3.7.1 Expanded emphasis on the protection and traceability of materials in storage is given to assure that the proper materials are used and to minimize deterioration of these materials during storage. Certified Material Test Reports (CMTRs) provided for concrete material, reinforcing system material, prestressing system material, and welding and brazing material, should include the following:

Documents Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

(a) Certified reports of the actual results of all required chemical analyses, physical tests, mechanical tests, examinations (including radiographic film), repairs, and heat treatments (including times and temperatures) performed on the material.
(b) A statement listing any chemical analyses, tests, examinations, and heat treatment required by the material specification, which were not performed.
(c) A statement giving the manner in which the material is identified, including a specific marking.

3.7.2 Cementitious materials and aggregates shall be stored in such manner as to prevent deterioration or intrusion of foreign matter. Any material that has deteriorated or has been contaminated shall not be used for concrete.

R3.7.2 Concrete materials should be handled and stored in accordance with Chapter 2 of ACI 304R.[3.3]

3.7.3 Steel reinforcement shall be stored in such a manner as to permit inventory control and to preclude damage or degradation of properties to less than ASTM specification requirements.

Steel reinforcement, by groups of bars or shipments, shall be identifiable by documentation, tags, or other means of control, to a specific heat number or heat code until review of the Certified Material Test Report has been performed.

3.7.4 Prestressing system materials shall be stored in such a manner as to ensure traceability to the Certified Material Test Report during production and while in transit and storage.

R3.7.4 To prevent detrimental corrosion, prestressing systems should normally be stored in a completely enclosed building.

3.8—Referenced standards

3.8.1 Standards of the ASTM referred to in this Code are listed as follows with their serial designations, including year of adoption or revision, and are declared to be part of this Code as if fully set forth herein. Standards listed in ACI 318-08 are applicable unless otherwise mentioned in the Commentary. Standards common to ACI 318-08 (including the year) are not listed here.

A36/A36M-08—Standard Specification for Carbon Structural Steel

A307-07b—Standard Specification for Carbon-Steel Bolts and Studs, 60,000 PSI Tensile Strength

A615/A615M-09b—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

A706/A706M-09b—Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

A775/A775M-07b—Standard Specification for Epoxy-Coated Steel Reinforcing Bars

A970/A970M-07—Standard Specification for Headed Steel Bars for Concrete Reinforcement

A992/A992M-06a—Standard Specification for Structural Steel Shapes

C29/C29M-07—Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate

R3.8—Referenced standards

Use of zinc-coated (galvanized) steel reinforcing bars (ASTM A767/A787M) is excluded for use in nuclear structures.

Use of rail- and axle-steel reinforcing bars (ASTM A996/A996M) is excluded because of inadequate traceability.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

C31/C31M-08a—Standard Practice for Making and Curing Concrete Test Specimens in the Field

C33-07—Historical Standard: Standard Specification for Concrete Aggregates

C39/C39M-05$^{\varepsilon 2}$—Historical Standard: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

C42/C42M-04—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C88-05—Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C94/C94M-07—Standard Specification for Ready-Mixed Concrete

C109/C109M-07$^{\varepsilon 1}$—Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C131-06—Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C150-07—Standard Specification for Portland Cement

C172-08—Standard Practice for Sampling Freshly Mixed Concrete

C192/C192M-07—Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

C231-08b—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C289-07—Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

C494/C494M-08a—Standard Specification for Chemical Admixtures for Concrete

C595-08—Standard Specification for Blended Hydraulic Cements

C618-08—Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C685/C685M-07—Historical Standard: Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

C1017/C1017M-07—Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

C1077-07a—Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

C1157-08—Standard Performance Specification for Hydraulic Cement

E204-98(2007)— Standard Practices for Identification of Material by Infrared Absorption Spectroscopy, Using the ASTM Coded Band and Chemical Classification Index

3.8.2 Same as ACI 318-08.

3.8.3 Same as ACI 318-08.

COMMENTARY

R3.8.2 Same as ACI 318-08.

R3.8.3 Same as ACI 318-08.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

3.8.4 Same as ACI 318-08.

3.8.5 Requirements of the U.S. Nuclear Regulatory Commission referred to in this Code are listed as follows and are declared to be a part of this Code as if fully set forth herein.

Code of Federal Regulations (Published by Office of the Federal Register):

10 CFR50—Domestic Licensing of Production and Utilization Facilities, Appendix B to Part 50 – Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

10 CFR100—Reactor Site Criteria, Appendix A – Seismic and Geologic Siting Criteria for Nuclear Power Plants

3.8.6 "Qualification of Post-Installed Mechanical Anchors in Concrete (ACI 355.2-07)" is declared to be acceptable for fulfilling the purpose cited in Appendix D (D.2 and D.3) of this Code.

3.8.7 Same as ACI 318-08.

3.8.8 Same as ACI 318-08.

3.8.9 Intentionally left blank.

3.8.10 "Process Piping," ASME B 31.3-90 is declared to be a part of this Code as set forth herein.

COMMENTARY

R3.8.5 Same as ACI 318-08.

R3.8.6 ACI Committee 355 developed a test method to define the level of performance required for post-installed anchors. This test method, ACI 355.2, contains requirements for the testing and evaluation of post-installed anchors for both cracked and uncracked concrete applications. ACI 355.2 is generally suited for small to medium anchor diameters (1/4 to 1-1/4 in.) and embedments (1-1/2 to 12 in.). Certain ACI 355.2 test methods—in particular, testing opening and closing cracks—depending on the anchorage mechanism, may not be practical for anchor diameters and embedment larger than 1-1/4 in. and 12 in., respectively. In these cases, qualification of the anchor system at the small and medium diameter/embedment range in the context of ACI 355.2 with limited testing of larger sizes may be adequate to establish design parameters and acceptable performance.

R3.8.7 Same as ACI 318-08.

R3.8.9 Precast wall is not part of ACI 349-13.

References, Chapter 3

3.1. Sergi, G.; Short, N.; and Page, C., "Corrosion of Galvanized and Galvannealed Steel in Solutions of pH 9.0 to 14.0," National Association of Corrosion Engineers, Nov. 1985.

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

3.3. ACI Committee 304, "Guide for Measuring, Mixing, Transporting, and Placing Concrete (ACI 304R-00)," American Concrete Institute, Farmington Hills, MI, 2000, 43 pp.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

CHAPTER 4—DURABILITY REQUIREMENTS

In ACI 318-08, the provisions of Chapter 4 were revised and renumbered to present durability requirements in terms of exposure categories.

Chapter 4 in ACI 349-13 is the same as in ACI 318-08, except that all references to lightweight concrete are not applicable.

4.1—General

4.1.1 Same as ACI 318-08.

4.1.2 Intentionally left blank.

4.2—Exposure categories and classes

4.2.1 Same as ACI 318-08.

4.3—Requirements for concrete mixtures

4.3.1 Same as ACI 318-08 except minimum f_c' of 2500 psi mentioned in Table 4.3.1 is read as 3000 psi.

4.4—Additional requirements for freezing-and-thawing exposure

4.4.1 Normalweight concrete subject to Exposure Classes F1, F2, or F3 shall be air-entrained with air content indicated in ACI 318-08 Table 4.4.1. Tolerance on air content as delivered shall be ±1.5 percent. For f_c' greater than 5000 psi, reduction of air content indicated in ACI 318-08 Table 4.4.1 by 1.0 percent shall be permitted.

4.4.2 Same as ACI 318-08.

4.5—Alternative cementitious materials for sulfate exposure

4.5.1 Same as ACI 318-08.

COMMENTARY

R4—DURABILITY REQUIREMENTS

The commentary on ACI 318-08 is applicable to this chapter except as described as follows.

R4.1—General

Same as ACI 318-08.

R4.1.1 Same as ACI 318-08.

R4.1.2 This Code does not address lightweight concrete because it cannot be used in safety-related nuclear structures.

R4.2—Exposure categories and classes

R4.2.1 Same as ACI 318-08.

R4.3—Requirements for concrete mixtures

R4.3.1 Same as ACI 318-08 except minimum f_c' of 2500 psi mentioned in Table 4.3.1 should be read as 3000 psi. Minimum compressive concrete strength has been established as 3000 psi for nuclear facilities.

R4.4—Additional requirements for freezing-and-thawing exposure

Same as ACI 318-08.

R4.4.1 Same as ACI 318-08.

R4.4.2 Same as ACI 318-08.

R4.5—Alternative cementitious materials for sulfate exposure

R4.5.1 Same as ACI 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

CHAPTER 5—CONCRETE QUALITY, MIXING, AND PLACING

5.1—General

5.1.1 Same as ACI 318-08 except minimum f_c' shall not be less than 3000 psi.

5.1.2 Same as ACI 318-08.

5.1.3 Same as ACI 318-08.

5.1.4 Intentionally left blank.

5.1.5 Same as ACI 318-08.

5.1.6 Intentionally left blank.

5.1.7 Design drawings shall show specified compressive strength of concrete f_c' for which each part of the structure is designed.

5.2—Selection of concrete proportions

5.2.1 Same as ACI 318-08.

5.2.2 Same as ACI 318-08.

5.2.3 Same as ACI 318-08.

COMMENTARY

R5—CONCRETE QUALITY, MIXING, AND PLACING

The commentary on ACI 318-08 is applicable to this chapter except as described as follows. Certain sections of the commentary in ACI 318-08, Chapter 5, have been repeated in this commentary chapter to maintain correspondence with footnote numbers in the reference section.

R5.1—General

Same as 318-08.

R5.1.1 Same as 318-08.

R5.1.3 Concrete members 24 in. or thicker will retain sufficient moisture throughout the first 12 months to assure continuous curing and hydration of the major portion of the cross section. These large members rarely receive full service loads for many months and, therefore, the test age designated for the determination of compliance with the specified strength may be later than the usual 28 days. The use of such later-age strength requirements may permit the use of lower cement content and, therefore, help limit or control temperature rise due to hydration and the danger of cracking that may occur as these large members cool to ambient temperature levels. The need to control early temperature rise increases in proportion to the minimum thickness of the section.

R5.1.4 In ACI 318-08, splitting tensile strength tests are associated with the determination of λ for lightweight aggregate concrete. The use of lightweight aggregate concrete for safety-related structures is not permitted in this Code.

R5.1.5 Same as 318-08.

R.5.1.6 This Code does not include provisions for the use of fiber-reinforced concrete in nuclear facilities.

R5.2—Selection of concrete proportions

Same as 318-08.

R5.2.1 Same as 318-08.

R5.2.3 Same as 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

5.3—Proportioning on the basis of field experience or trial mixtures, or both

5.3.1 *Sample standard deviation*

5.3.1.1 Same as ACI 318-08.
(a) Same as ACI 318-08;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08.

5.3.1.2 Same as ACI 318-08.

5.3.2 *Required average strength*

5.3.2.1 Same as ACI 318-08.

5.3.2.2 Same as ACI 318-08.

5.3.3 *Documentation of average compressive strength*—Same as ACI 318-08.

5.3.3.1 Same as ACI 318-08.

5.3.3.2 Same as ACI 318-08.
(a) Same as ACI 318-08;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08;
(d) Same as ACI 318-08;
(e) Same as ACI 318-08.

5.4—Proportioning without field experience or trial mixtures

5.4.1 Same as ACI 318-08.

5.4.2 Same as ACI 318-08.

5.5—Average compressive strength reduction

Same as ACI 318-08.

5.6—Evaluation and acceptance of concrete

5.6.1 Same as ACI 318-08.

5.6.2 *Frequency of testing*

COMMENTARY

R5.3—Proportioning on the basis of field experience or trial mixtures, or both

The licensed design professional should verify that test records are applicable to the proposed materials and mixture designs.

R5.3.1 Same as 318-08.

R5.3.2 Same as 318-08.

R5.3.2.1 Same as 318-08.

R5.3.3 Same as 318-08.

R5.3.3.2 Same as 318-08.

R5.4—Proportioning without field experience or trial mixtures

Same as 318-08.

R5.4.1 Same as 318-08.

R5.6—Evaluation and acceptance of concrete

R5.6.1 Same as 318-08.

R5.6.2 *Frequency of testing*—The frequency of testing has little influence on the accuracy of calculating standard deviations after 25 or more tests of one mixture have been performed on a given class of concrete. It therefore has little effect on the level of concrete production required to assure strength requirements of Section 5.3.3. When the calculated standard deviation for 30 tests indicates better than normal control, then the frequency of tests has even less effect on the predictability of the strengths. The reduced testing frequency

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

is therefore given to reward good control and lessen the requirements where lower concrete strength allowables are used to reduce hydration heat in the thick concrete members. In such areas, concrete strength generally has little effect on design strength.

5.6.2.1 Specimens for strength tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 100 yd^3 of concrete placed. When the standard deviation for 30 consecutive tests of a given class is less than 600 psi, the amount of concrete placed between tests is permitted to be increased by 50 yd^3 for each 100 psi the standard deviation is below 600 psi, except that the minimum testing rate should not be less than one test for each production shift when concrete is placed on more than one shift per day or not less than one test for each 200 yd^3 of concrete placed.

R5.6.2.1 Same as 318-08.

5.6.2.2 Same as ACI 318-08.

R5.6.2.2 Same as 318-08.

5.6.2.3 When total quantity of a given class of concrete is less than 50 yd^3, strength tests are not required when evidence of satisfactory strength is submitted to and approved by the licensed design professional.

5.6.2.4 Same as ACI 318-08.

R5.6.2.4 Same as 318-08.

5.6.3 *Standard-cured specimens*

R5.6.3 Same as 318-08.

5.6.3.1 Same as ACI 318-08.

5.6.3.2 Same as ACI 318-08.

R5.6.3.2 Same as 318-08.

5.6.3.3 Same as ACI 318-08.
(a) Same as ACI 318-08;
(b) Same as ACI 318-08.

R5.6.3.3 Same as 318-08.

5.6.3.4 Same as ACI 318-08.

R5.6.3.4 Same as 318-08.

5.6.4 *Field-cured specimens*

R5.6.4 *Field-cured specimens*

5.6.4.1 If required by the licensed design professional, results of strength tests of cylinders cured under field conditions shall be provided.

R5.6.4.1 Field-cured cylinders do not represent the in-place strength of typical concrete members used in nuclear plant construction, particularly during the first 24 hours following placement, because of the effects of hydration heat. The in-place strengths may be several times that of the field-cured cylinders, particularly during cold weather placements. Nondestructive testing properly correlated against laboratory-cured cylinders during the concrete design phase, using methods such as sonic methods or other similar techniques, may be used by the licensed design professional to better understand the in-place strength and concrete quality in the structure.

5.6.4.2 Same as ACI 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

5.6.4.3 Same as ACI 318-08.

5.6.4.4 Same as ACI 318-08.

5.6.5 *Investigation of low-strength test results*

5.6.5.1 Same as ACI 318-08.

5.6.5.2 Same as ACI 318-08.

5.6.5.3 Same as ACI 318-08.

5.6.5.4 Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of f_c' and if no single core is less than 75 percent of f_c'. Additional testing of cores extracted from locations represented by erratic core strength results shall be permitted within limits established by the licensed design professional.

5.6.5.5 If criteria of 5.6.5.4 are not met and if the structural adequacy remains in doubt, the licensed design professional shall be permitted to require load tests as outlined in Chapter 20 to further assess adequacy or to take other appropriate action.

COMMENTARY

R5.6.4.4 Same as 318-08.

R5.6.5 *Investigation of low-strength test results*—Instructions for the procedure to be followed in the case when strength tests have failed to meet the specified acceptance criteria are provided in this section. In such cases, the licensed design professional should apply judgment as to the significance of low test results and whether they indicate need for concern. If further investigation is deemed necessary, such investigation may include nondestructive tests or, in extreme cases, strength tests of cores taken from the structure.

Nondestructive tests of the concrete in place, such as probe penetration, impact hammer, ultrasonic pulse velocity (ASTM C595), or pullout may be useful in determining whether or not a portion of the structure actually contains low-strength concrete. Such tests are of value primarily for comparisons within the same project rather than as quantitative measures of strength. See ASTM for additional cautions and clarifications of these tests. For cores, if required, conservatively safe acceptance criteria are provided that should ensure structural adequacy for virtually any type of construction.[5.1-5.4] Lower strength may, of course, be tolerated under many circumstances, but this again becomes a matter of judgment on the part of the licensed design professional. When the core tests fail to provide assurance of structural adequacy, it may be practical, particularly in the case of floor or roof systems, for the licensed design professional to require a load test (Chapter 20). Short of load tests, if time and conditions permit, an effort may be made to improve the strength of the concrete in place by supplemental wet curing. Effectiveness of such a treatment should be verified by further strength evaluation using procedures previously discussed.

A core obtained through the use of a water-cooled bit results in a moisture gradient between the exterior and interior of the core being created during drilling. This adversely affects the compressive strength of the core.[5.5] The restriction on the commencement of core testing provides a minimum time for the moisture gradient to dissipate.

Core tests having an average of 85 percent of the specified strength are realistic. The concrete strength values in core tests are typically lower than those from cylinder tests because differences in the size of specimens, conditions of obtaining specimens, and procedures for curing do not permit equal values to be obtained.

The Code, as stated, concerns itself with assuring structural safety, and the instructions in 5.6 are aimed at that objective. It is not the function of the Code to assign responsibility for strength deficiencies, whether or not they are such as to require corrective measures.

In accordance with the requirements of this section, cores taken to confirm structural adequacy will usually be taken at ages later than those specified for determination of f_c'.

Documents Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

5.6.6 Intentionally left blank.

COMMENTARY

R5.6.6 See R5.1.6.

R5.6.6.1 Intentionally left blank.

R5.6.6.2 Intentionally left blank.

5.7—Preparation of equipment and place of deposit

5.7.1 Preparation before concrete placement shall include the following:

(a) Same as ACI 318-08;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08;
(d) Same as ACI 318-08;
(e) Same as ACI 318-08;
(f) Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used;
(g) All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete. The method for cleaning construction joints shall be stated in the construction specification.

R5.7—Preparation of equipment and place of deposit

Section 5.7.1(f) requires free water deeper than 1/4 in. in depressions be removed from the forms.

Section 5.7.1(g): The requirement for specifying the method for cleaning joints in the construction specification was added to ensure that only an approved method or methods of joint cleanup would be used.

5.8—Mixing

5.8.1 All concrete shall be batched using automated equipment with digital recording capability and shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.

5.8.2 Same as ACI 318-08.

5.8.3 Concrete mixed at the job site shall be mixed in accordance with (a) through (e):

(a) Mixing shall be done in a batch mixer of type approved by the licensed design professional;
(b) Same as ACI 318-08;
(c) Same as ACI 318-08;
(d) Same as ACI 318-08;
(e) Same as ACI 318-08.

R5.8—Mixing

Same as 318-08.

5.9—Conveying

5.9.1 Same as ACI 318-08.

5.9.2 Same as ACI 318-08.

5.9.3 Aluminum pipe shall not be used to convey concrete.

R5.9—Conveying

Same as 318-08.

R5.9.3 Conveyance of concrete by pumping through aluminum pipe is not permitted because hydrogen gas bubbles are produced by the reaction of aluminum abraded from the pipe with the alkalis in the concrete. These gas bubbles are retained in the hardened concrete and reduce concrete strength.[5.6, 5.7]

5.10—Depositing

R5.10—Depositing

Same as 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

5.10.1 Same as ACI 318-08.

5.10.2 Same as ACI 318-08.

5.10.3 Same as ACI 318-08.

5.10.4 Retempered concrete shall not be used.

5.10.5 Same as ACI 318-08.

5.10.6 Same as ACI 318-08.

5.10.7 Same as ACI 318-08.

5.10.8 Same as ACI 318-08.

5.10.9 Where conditions make consolidation difficult, or where reinforcement is congested, batches can be reproportioned to substitute the larger of the coarse aggregate gradations with finer coarse aggregate or self-consolidating concrete may be used. Such substitutions shall be limited to only those made in limited areas of specific difficulty and subject to the approval of the licensed design professional as to location, mixture proportioning, or alterations of the mixture.

5.11—Curing

5.11.1 Same as ACI 318-08.

5.11.2 Same as ACI 318-08.

5.11.3 *Accelerated curing*

5.11.3.1 Same as ACI 318-08.

5.11.3.2 Same as ACI 318-08.

5.11.3.3 Same as ACI 318-08.

5.11.4 Same as ACI 318-08.

5.11.5 Where a liquid membrane curing compound is used, particular attention shall be given to its compatibility with any protective coatings that are to be applied following curing.

5.11.6 The method of curing shall be stated in the construction specification.

COMMENTARY

R5.10.4 The wording has been changed from ACI 318-08 to be more specific and to exclude the use of retempered concrete.

R5.10.9 This section of the Code was modified to provide the licensed design professional with flexibility in modifying the size of the coarse aggregate or using self-consolidating concrete. The use of reproportioned batches will aid in preventing honeycomb and poor bonding of the concrete with the reinforcement. The reproportioned concrete and the concrete containing larger aggregate can be used in the same concrete placement, provided that the concrete placed in the first step is still in plastic or fluid condition.

R5.11—Curing

Same as 318-08.

R5.11.3 Same as 318-08.

R5.11.4 Same as 318-08.

R5.11.5 In many areas, protective coatings are required, and no curing procedure should be used that may be incompatible with those coatings.

R5.11.6 The method or methods of curing should not be left to the discretion of the contractor or to arbitration. Acceptable methods should be clearly stated in the construction specification.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

5.12—Cold weather requirements

5.12.1 Same as ACI 318-08.

5.12.2 Same as ACI 318-08.

5.12.3 Same as ACI 318-08.

5.13—Hot weather requirements

5.13.1 Same as Section 5.13 in ACI 318-08.

5.13.2 The method of controlling concrete temperatures shall be specified in the construction specification.

COMMENTARY

R5.12—Cold weather requirements

Recommendations for cold weather concreting are given in detail in "Cold Weather Concreting" reported by ACI Committee 306.[5.8] The report presents requirements and methods for producing satisfactory concrete during cold weather.

R5.13—Hot weather requirements

The method or methods of curing should not be left to the discretion of the contractor or to arbitration. Acceptable methods should be clearly stated in the construction specification.

The designer should also consult the ACI Committee 207 report "Report on Thermal and Volume Change Effects on Cracking of Mass Concrete"[5.9] for additional information on crack control.

References, Chapter 5

5.1. Bloem, D. L., "Concrete Strength Measurement—Cores vs. Cylinders," *Proceedings*, ASTM, V. 65, 1965, pp. 668-696.

5.2. Bloem, D. L., "Concrete Strength in Structures," *ACI Journal*, V. 65, No. 3, Mar. 1968, pp. 176-187.

5.3. Malhotra, V. M., "Testing Hardened Concrete: Nondestructive Methods," *ACI Monograph* No. 9, American Concrete Institute/Iowa State University Press, Farmington Hills, MI, 1976, 188 pp.

5.4. Malhotra, V. M., "Contract Strength Requirements—Cores Versus In Situ Evaluation," *ACI Journal*, V. 74, No. 4, Apr. 1977, pp. 163-172.

5.5. Bartlett, M. F., and MacGregor, J. G., "Effect of Moisture Condition on Concrete Core Strength," *ACI Materials Journal*, V. 91, No. 3, May-June 1994, pp. 227-236.

5.6. Newlon, H. Jr., and Ozol, A., "Delayed Expansion of Concrete Delivered by Pumping Through Aluminum Pipe Line," Concrete Case Study No. 20, Virginia Highway Research Council, Oct. 1969, 39 pp.

5.7. Fowler, E. E., and Holmgren, E. F., "Expansion of Concrete Pumped Through Aluminum Pipeline," *ACI Journal*, V. 68, No. 12, Dec. 1971, pp. 950-953; and discussion, *ACI Journal*, V. 69, No. 6, June 1972, pp. 357-360.

5.8. ACI Committee 306, "Cold Weather Concreting (ACI 306R-88)," American Concrete Institute, Farmington Hills, MI, 1988, 23 pp.

5.9. ACI Committee 207, "Report on Thermal and Volume Change Effects on Cracking of Mass Concrete (ACI 207.2R-07)," American Concrete Institute, Farmington Hills, MI, 2007, 28 pp.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

COMMENTARY

CHAPTER 6—FORMWORK, EMBEDMENTS, AND CONSTRUCTION JOINTS

R6—FORMWORK, EMBEDMENTS, AND CONSTRUCTION JOINTS

The commentary on ACI 318-08 is applicable to this chapter except as described as follows. Replace the term "building official" with "licensed design professional" whenever it occurs.

6.1—Design of formwork

R6.1—Design of formwork

Same as ACI 318-08.

6.1.2 Same as ACI 318-08.

6.1.3 Same as ACI 318-08.

6.1.4 Same as ACI 318-08.

6.1.5 Same as ACI 318-08.

6.1.6 Same as ACI 318-08.

6.1.7 When using steel liners as formwork, special attention shall be given to 6.1.7.1 and 6.1.7.2.

R6.1.7 The use of steel liners as formwork requires considerations in addition to tolerances.

6.1.7.1 To liner supports to provide the required tolerances for penetrations.

6.1.7.2 To the depth of placement to limit the deformation of the liner.

6.1.8 Where coating systems are to be applied to the concrete, formwork shall be compatible with the coating system.

R6.1.8 Form release agents and surface effects of wood type used in the formwork needs to be compatible with coating systems to assure a durable coating system.

6.2—Removal of forms, shores, and reshoring

R6.2—Removal of forms, shores, and reshoring

Same as ACI 318-08.

6.2.1 Same as ACI 318-08.

6.2.2 Same as ACI 318-08.

6.2.3 Where coating systems are to be applied to the concrete, only those hardeners, additives, and form release agents that are compatible with the coating system shall be used.

R6.2.3 Form release agents and surface effects of wood type used in the formwork needs to be compatible with coating systems to assure a durable coating system.

6.3—Embedments in concrete

6.3.1 Same as ACI 318-08.

6.3.2 Same as ACI 318-08.

6.3.3 Same as ACI 318-08.

6.3.4 Same as ACI 318-08.

6.3.5 Same as ACI 318-08.

6.3.6 Same as ACI 318-08.

R6.3—Embedments in concrete

R6.3.1 Same as ACI 318-08.

R6.3.2 Same as ACI 318-08.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

6.3.7 Same as ACI 318-08.

6.3.7.1 All piping and fittings except as provided in 6.3.7.1.1 shall be tested as a unit for leaks before concrete placement. Pressure tests shall be in accordance with ASME B31.3 standard. Where pressure testing requirements are not specified in ASME B31.3,[6.1] pressure testing shall meet the following requirements: 1) the testing pressure above atmospheric pressure shall be 50 percent in excess of pressure to which piping and fittings will be subjected, but minimum testing pressure shall not be less than 150 psi above atmospheric pressure; 2) the test pressure shall be held for 4 hours with no drop in pressure allowed, except that which is caused by a drop in air temperature.

6.3.7.1.1 Drain pipes and other piping designed for pressures of not more than 1 psi above atmospheric pressure need not be tested as required in 6.3.7.1.

6.3.7.1.2 Pipes carrying liquid, gas, or vapor that is explosive or injurious to health shall again be tested as specified in 6.3.7.1 after the concrete has reached its design strength.

6.3.8 Same as ACI 318-08.

6.3.9 Same as ACI 318-08.

6.3.10 Same as ACI 318-08.

6.3.11 Same as ACI 318-08.

6.3.12 Same as ACI 318-08.

6.3.13 Piping and conduit shall be so fabricated and installed that cutting, bending, or displacement of reinforcement from its proper location will not be required.

6.3.14 All piping containing liquid, gas, or vapor pressure in excess of 200 psi above atmospheric pressure or temperature in excess of 150°F shall be designed to limit concrete and reinforcement stresses to allowable design strength and to limit concrete temperatures to the following:

(a) For normal operation or any other long-term period, the temperatures shall not exceed 150°F, except for local areas that are allowed to have increased temperatures not to exceed 200°F;

This limit is permitted to be increased to 180°F for general surface area and 230°F for local surface area if the tested concrete strength (for example, measured compressive

COMMENTARY

R6.3.7 Same as ACI 318-08.

R6.3.7.1 The testing requirements were changed to ensure that there would be no conflict in Code applications for the many different piping systems used in nuclear plant construction.

R6.3.8 If an entire piping system cannot be tested as a unit, a minimum concrete strength of 1000 psi is required for concrete encasing a previously tested length of pipe that has to be filled with liquid, gas, or vapor for testing an added length of the pipe in accordance with 6.3.7.1.

R6.3.13 Piping systems that are embedded in concrete will be inaccessible for normal maintenance. Certain mechanical connections, such as a screwed pipe connection, may not be as reliable as a sealed welded pipe connection and are, therefore, prohibited from use.

R6.3.14 The design limits specified for concrete temperatures are those in general use in nuclear structures. See, for example, Paragraph CC-3440 of ACI 359. A provision is made for the use of higher temperatures, provided the effects of higher temperatures on concrete strengths have been established by tests and these effects are incorporated into the design.

All piping containing liquid, gas, or vapor at a temperature in excess of 150°F should be sleeved, insulated, or otherwise separated from the concrete or cooled to limit concrete stresses and strains, or both.

Documents
Document Sharing Hub

American Concrete Institute Copyrighted Material—www.concrete.org

Full document details: ACI 349-13 (2016)

CODE

strength at 28 days or more) is equal to or greater than 115 percent of the specified 28-day compressive design strength.

(b) During an accident or for any other short-term interruption, the temperatures shall not exceed 350°F for the interior surface. Local areas, however, are allowed to reach 650°F from fluid jets in the event of a pipe failure;

(c) Higher temperatures than given in (a) and (b) are allowed in the concrete if tests are provided to evaluate the reduction in strength and this reduction is applied to the design strength. Evidence shall also be provided that verifies that the increased temperatures do not cause deterioration of the concrete with or in the absence of applied loads.

COMMENTARY

The effect of pressure in excess of 200 psi and expansion of embedded pipe should be considered in the design of the concrete members. The restraint of the piping by the concrete should be considered in the piping qualification.

For explanation, see Appendix E commentary, Section RE.4.

6.4—Construction joints

6.4.1 Same as ACI 318-08.

6.4.2 Same as ACI 318-08.

6.4.3 Construction joints shall be so made and located as not to impair the strength of the structure. All construction joints shall be indicated on the design drawings or shall be approved by the licensed design professional. Provision shall be made for transfer of shear and other forces through construction joints (see Section11.6.9).

6.4.4 Same as ACI 318-08.

6.4.5 Same as ACI 318-08.

6.4.6 Same as ACI 318-08.

6.4.7 Same as ACI 318-08.

R6.4—Construction joints

Same as ACI 318-08.

R6.4.2 Same as ACI 318-08.

R6.4.3 Indiscriminate location of construction joints should not be allowed in these structures. The licensed design professional is responsible for all construction joint locations.

R6.4.6 Same as ACI 318-08.

R6.4.7 Same as ACI 318-08.

Referenced standards, Chapter 6

6.1. ASME B31.3, "Process Piping," ASME, Fairfield, NJ, 2010.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)

CODE

CHAPTER 7—DETAILS OF REINFORCEMENT

7.1—Standard hooks
Same as ACI 318-08.

7.2—Minimum bend diameters
Same as ACI 318-08.

7.3—Bending
Same as ACI 318-08.

7.4—Surface conditions of reinforcement

7.4.1 At the time concrete is placed, reinforcement shall be free from mud, oil, or other nonmetallic coatings that decrease bond. Epoxy-coating of steel reinforcement in accordance with standards referenced in Section 3.5.3.8 shall be permitted if the coating is qualified for service conditions (that is, temperature and radiation) as well as fabrication conditions (that is, damaged epoxy coatings shall be repaired).

7.4.2 Same as 318-08.

7.4.3 Same as 318-08.

7.5—Placing reinforcement
7.5.1 Same as 318-08.

7.5.2 Same as 318-08.

7.5.3 Same as 318-08.

7.5.4 Same as 318-08.

7.5.5 Bars shall be permitted to be moved as necessary to avoid interference with other steel reinforcement, conduits, or embedded items subject to the approval of the licensed design professional. If bars are moved more than one bar diameter, or enough to exceed the tolerances specified in Section 7.5.2, the resulting arrangement of bars shall be subject to approval by the licensed design professional.

7.6—Spacing limits for reinforcement
Same as in ACI 318-08.

COMMENTARY

R7—DETAILS OF REINFORCEMENT

R7.1—Standard hooks
Same as ACI 318-08.

R7.2—Minimum bend diameters
Same as ACI 318-08.

R7.3—Bending
Same as ACI 318-08.

R7.4—Surface conditions of reinforcement
Same as ACI 318-08.

R7.4.1 For an explanation of the service conditions, that is, temperature and radiation, under which an epoxy coating may be qualified, see Section R3.5.3.8 of the commentary in this Code.

R7.4.3 All tendons should be protected against deleterious corrosion from the time they are manufactured to the time they are incorporated in the work, that is, during storage. In the event the tendons are to be grouted (bonded) and coatings or rust inhibitors are used to provide protection against deleterious corrosion, complete removal of the coating or rust inhibitor should be required unless it can be demonstrated that such coatings or inhibitors do not affect the required bond values.

R7.5—Placing reinforcement
Same as ACI 318-08.

R7.6—Spacing limits for reinforcement
Same as ACI 318-08.

Documents
Document Sharing Hub
American Concrete Institute Copyrighted Material—www.concrete.org
Full document details: ACI 349-13 (2016)