

**ACI 349M-13**

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

An ACI Standard

Reported by ACI Committee 349



**American Concrete Institute®**



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## Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary

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**ACI 349M-13**

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

An ACI Standard

Reported by ACI Committee 349

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\*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 318M-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 349M-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.*

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

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**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 318M-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 349M-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 349M-13)” hereinafter called the Code. The Code is based on “Building Code Requirements for Structural Concrete (ACI 318M-08),” which is hereinafter called the Building Code. In preparing ACI 349M-13, the committee has followed the text of the Building Code wherever appropriate.

Structural plain concrete, as described in Chapter 22 of ACI 318M-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 318M-08 apply except:

- The term “building official” is replaced with the term “licensed design professional”;
- $\lambda$ , the modification factor for lightweight concrete, is not applicable for ACI 349M-13 structures. The value of  $\lambda$  for ACI 349M-13 structures is 1.0.

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## CODE

## CHAPTER 1—GENERAL REQUIREMENTS

## 1.1—Scope

**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 21 MPa, unless otherwise specified.

**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 318M-08.

**1.1.4** Intentionally left blank.

## COMMENTARY

## R1—GENERAL REQUIREMENTS

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

## R1.1—Scope

The American Concrete Institute “Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349M-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.<sup>1.1</sup> 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)”<sup>1.2</sup> 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.

**R1.1.1** In general, the Code requirements are based on test results from concrete specimens having a compressive strength of 40 MPa 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 40 MPa.

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

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

## CODE

## COMMENTARY

**1.1.5** Same as ACI 318M-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 318M-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;

**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<sup>1.3</sup> and PTI’s *Design of Post-Tensioned Slabs-on-Ground*.<sup>1.4</sup>

**R1.1.9** Refer to Section [R21.1.1](#) for details.

**R1.1.10** ACI 349M-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.<sup>1.5</sup> 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.

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- (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.

**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;

## COMMENTARY

**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<sup>1.5</sup> or ACI 359<sup>1.2</sup> 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).<sup>1.6</sup> 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.<sup>1.5</sup>

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- (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 318M-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.

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**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.<sup>1.7</sup>

#### **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.<sup>1.5</sup> Additional guidance is contained in ACI 311.4R<sup>1.6</sup> and ACI 121R.<sup>1.8</sup>

#### **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

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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 edition, 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.