

**ACI 350.5-12**

**Specifications for Environmental  
Concrete Structures**

An ACI Standard

Reported by ACI Committee 350



**American Concrete Institute®**



**American Concrete Institute®**  
*Advancing concrete knowledge*

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## **Specifications for Environmental Concrete Structures**

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# Specifications for Environmental Concrete Structures

An ACI Standard

Reported by ACI Committee 350

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*This specification is a Reference Specification that the Architect/Engineer can make applicable to a construction project by citing it in the Project Specifications. The Architect/Engineer supplements the provisions of this Reference Specification as needed by designating or specifying individual project requirements.*

*The document covers materials and proportioning of concrete; reinforcement and prestressing reinforcement; production, placing, finishing, and curing of concrete; formwork design and construction; and shotcrete. Methods of treatment of joints and embedded items, repair of surface defects, and finishing of formed and unformed surfaces are specified. Separate sections are devoted to architectural concrete, mass concrete, and internal and external post-tensioned prestressed concrete. Provisions governing testing, evaluation, and acceptance of concrete as well as acceptance of the structure are included.*

**Keywords:** admixtures; aggregates; air entrainment; architectural concrete; compressive strength; consolidation; curing; density; durability; evaluation; environmental concrete; finishes; floors; formwork (construction); grouting; inspection; joints; mass concrete; mixture proportioning; post-tensioned prestressed concrete; prestressing reinforcement; reinforcing steels; reshoring; shoring; subgrades; tolerances.

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(Mandatory portion follows)

### SECTION 1—GENERAL REQUIREMENTS

#### 1.1—Scope

**1.1.1 Work specified**—This specification covers cast-in-place environmental concrete and shotcrete. Provisions of this specification shall govern except where other provisions are specified in Contract Documents.

**1.1.2 Work not specified**—The following subjects are not in the scope of this specification:

- a) Precast concrete products
- b) Heavyweight shielding concrete
- c) Slipformed paving concrete
- d) Lightweight concrete
- e) Shrinkage-compensating concrete
- f) Terrazzo
- g) Insulating concrete
- h) Refractory concrete
- i) Self-consolidating concrete
- j) Slipformed concrete walls

- k) Tilt-up concrete construction

#### 1.2—Definitions

**accepted**—determined to be satisfactory by Architect/Engineer.

**ACI Concrete Field Testing Technician Grade I**—a person who has demonstrated knowledge and ability to perform and record the results of ASTM standard tests on freshly mixed concrete and to make and cure test specimens. Such knowledge and ability shall be demonstrated by passing prescribed written and performance examinations and having credentials that are current with ACI.

**ACI Reference Specification**—a standardized mandatory-language document prescribing materials, dimensions, and workmanship incorporated by reference in contract documents with information in the Mandatory Requirements Checklist required to be provided in the Project Specification.

**Architect/Engineer**—Architect, Engineer, architectural firm, engineering firm, or architectural and engineering firm issuing Contract Documents, administering the Work under Contract Documents, or both.

**architectural concrete**—concrete designated by Architect/Engineer as requiring a specified appearance.

**backshores**—shores placed snugly under a concrete slab or structural member after the original formwork and shores have been removed from a small area at a time, without allowing the slab or member to deflect, or support its own weight or existing construction loads.

**Contract Documents**—a set of documents supplied by Owner to Contractor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.

**Contractor**—person, firm, or entity under contract for construction of the Work.

**core wall**—portion of the externally prestressed circular concrete tank wall placed in circumferential compression by prestressing.

**cover coat**—the layer or layers of shotcrete applied over the wire coat of an externally prestressed circular concrete tank wall.

**diaphragm**—thin metal sheet formed with vertical ribs embedded within the core wall of circular externally prestressed concrete tanks.

**duct**—a conduit (plain or corrugated) to accommodate prestressing steel for post-tensioned installation.

**exposed to view**—portion of structure that can be observed by the user during normal use.

**finish coat**—final layer of shotcrete placed on the cover coat of an externally prestressed circular concrete tank wall.

**high-early-strength concrete**—concrete that, through the use of ASTM C150 Type III cement or admixtures, is capable of attaining specified strength at an earlier age than normal concrete.

**environmental engineering concrete structures**—concrete structures intended for conveying, storing, or treating water, wastewater, or other nonhazardous liquids, and for secondary containment of hazardous materials.

**Licensed Design Engineer**—an individual engaged by the Contractor who is licensed to practice engineering as defined by the statutory requirements of the licensing laws of the state or jurisdiction in which the project is to be constructed.

**mass concrete**—a volume of concrete with dimensions large enough to require that measures be taken to prevent damage from the generation of heat and temperature gradients from hydration of the cementitious materials and attendant volume change.

**normalweight concrete**—concrete containing aggregate that conforms to ASTM C33 and that typically has a density between 135 and 160 lb/ft<sup>3</sup>.

**Owner**—corporation, association, partnership, individual, public body, or authority for whom the Work is constructed.

**permitted**—accepted or acceptable to Architect/Engineer usually pertaining to a request by Contractor or when specified in Contract Documents.

**plain mass concrete**—mass concrete containing no reinforcement or less reinforcement than necessary to be considered reinforced mass concrete.

**post-tensioning**—a method of prestressing reinforced concrete in which tendons are tensioned after the concrete has attained a specified minimum in-place strength or a specified minimum age.

**prestressing sheathing**—a material encasing prestressing steel to prevent bonding of the prestressing steel with the surrounding concrete, to provide corrosion protection, and to contain the corrosion-inhibiting coating.

**prestressed concrete**—structural concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads.

**Project Drawings**—graphic presentation of project requirements.

**Project Specifications**—written documents that details requirements for the Work in accordance with service parameters and other specific criteria.

**reference standards**—standardized mandatory-language documents of a technical society, organization, or association, including codes of local or federal authorities, that are incorporated by reference in Contract Documents.

**reinforced mass concrete**—mass concrete containing adequate reinforcement, prestressed or nonprestressed, designed to act together with the concrete in resisting forces including those induced by temperature and shrinkage.

**required**—mandatory as prescribed in project specification or Contract Documents.

**reshores**—shores placed snugly under a stripped concrete slab or other structural member after the original forms and shores have been removed from a large area, thus requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied before installation of the reshores.

**shore**—a temporary support designed to carry the weight of formwork, fresh concrete, and construction loads from above for recently built structures that have not developed full design strength.

**strength test**—the average of the compressive strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of specified compressive strength  $f'_c$ .

**submittal**—document or material provided to Architect/Engineer for review and acceptance.

**wire coat**—layer of shotcrete in direct contact with the prestressed reinforcement of an externally prestressed circular concrete tank wall.

**wood formwork sheathing**—the materials forming the contact face of forms; also called lagging or sheeting.

**Work**—the entire construction or separately identifiable parts thereof required to be furnished under Contract Documents.

**wrapped prestressing system**—prestressing system that applies a high tensile strand or wire, wound under tension by machines, around a circular concrete tank wall.

### 1.3—Reference standards

#### *American Concrete Institute*

117-90—Standard Specifications for Tolerances for Concrete Construction and Materials

350-06—Code Requirements for Environmental Engineering Concrete Structures

423.6-01—Specification for Unbonded Single-Strand Tendons and Commentary (withdrawn)

506.2-95—Specifications for Shotcrete

#### *American Petroleum Institute*

RP 13B-1-09—Recommended Practice for Field Testing Water-Based Drilling Fluids

#### *American Welding Society*

AWS D1.4-98—Structural Welding Code—Reinforcing Steel

#### *ASTM International*

A82/A82M-97a—Standard Specification for Steel Wire, Plain, for Concrete Reinforcement

A184/A184M-01—Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement

A185/A185M-97—Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete Reinforcement

A416/A416M-02—Standard Specification for Steel Strand, Uncoated Seven Wire for Prestressed Concrete

A421/A421M-02—Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete

A475-98—Standard Specification for Zinc-Coated Steel Wire Strand

A496/A496M-97a—Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement

A497-99—Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete Reinforcement

A615/A615M-03—Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

A641/A641M-98—Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire

A648-95—Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Pipe

A653/A653M-03—Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A675/A675M-03—Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

A706/A706M-03—Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

A722/A722M-98—Standard Specification for Uncoated High Strength Steel Bars for Prestressing Concrete

A767/A767M-00b—Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

A775/A775M-01—Standard Specification for Epoxy-Coated Reinforcing Steel Bars

A779/A779M-00—Standard Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, Stress-Relieved for Prestressed Concrete

A780-01—Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

A821/A821M-99—Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Tanks

A882/A882M-02a—Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand

A884/A884M-02—Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement for Reinforcement

A934/A934M-03—Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

A955/A955M-04a—Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement

A970/A970M-04a—Standard Specification for Headed Steel Bars for Concrete Reinforcement

A996/A996M-03—Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

A1008/A1008M-06—Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

C31/C31M-03a Standard Practice for Making and Curing Concrete Test Specimens in the Field

C33-03 Standard Specification for Concrete Aggregates

C39/C39M-03a—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

C42/C42M-03—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C94/C94M-03—Standard Specification for Ready Mixed Concrete

C138/C138M-01a—Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M-03—Standard Test Method for Slump of Hydraulic-Cement Concrete

C144-03—Standard Specification for Aggregate for Masonry Mortar

C150-02a—Standard Specification for Portland Cement

C171-03—Standard Specification for Sheet Materials for Curing Concrete

C172-99—Standard Practice for Sampling Freshly Mixed Concrete

C173-01—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C192/C192M-02—Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

C227-10—Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C231-04—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C260-01—Standard Specification for Air-Entraining Admixtures for Concrete

C309-03—Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C387-04—Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete

C404-03—Standard Specification for Aggregates for Masonry Grout

C494/C494M-99a—Standard Specification for Chemical Admixtures for Concrete

C595-03—Standard Specification for Blended Hydraulic Cements

C597-02—Standard Test Method for Pulse Velocity Through Concrete

C618-03—Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C684-99(2003)—Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens

C685/C685M-01—Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

C803/C803M-03—Standard Test Method for Penetration Resistance of Hardened Concrete

C805-02—Standard Test Method for Rebound Number of Hardened Concrete

C845-96—Standard Specification for Elastomeric Joint Sealants

C873-04—Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

C881-02—Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete

C900-01—Standard Test Method for Pullout Strength of Hardened Concrete

C920-02—Standard Specification for Elastomeric Joint Sealants

C928-00—Standard Specification for Packaged, Dry, Rapid Hardening Cementitious Materials for Concrete Repairs

C939-97—Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

C940-98a(03)—Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory

C942-99(04)—Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory

C953-06—Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory

C989-99—Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars  
 C1017/C1017M-98—Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete  
 C1059-99—Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete  
 C1064/C1064M-03—Standard Test Methods for Temperature of Freshly Mixed Hydraulic-Cement Concrete  
 C1074-04—Standard Practice for Estimating Concrete Strength by the Maturity Method  
 C1077-03—Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation  
 C1107-02—Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink)  
 C1138-97—Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)  
 C1218/C1218M-99—Standard Test Method for Water-Soluble Chloride in Mortar and Concrete  
 C1240-03a—Standard Specification for Silica Fume for Use in Hydraulic-Cement Concrete, Mortar, and Grout  
 C1260-07—Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)  
 C1293-08—Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction  
 C1315-03—Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete  
 C1567-11—Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)  
 C1602/C1602M-04—Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete  
 D994-98(2003)—Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)  
 D1056-00—Specification for Flexible Cellular Materials – Sponge or Expanded Rubber  
 D1751-99—Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)  
 D1752-84—Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction  
 E329-03—Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction  
 E1155-96(2001)—Standard Test Method for Determining  $F_F$  Floor Flatness and  $F_L$  Levelness Using the F-Number System

*U.S. Army Corps of Engineers*

CRD-C 513-74—Specification for Rubber Waterstops  
 CRD-C 572-99—Specification for Polyvinylchloride Waterstops

*National Science Foundation*

NSF 61-11—Drinking Water System Components—Health Effects

*Field references—Keep in Contractor's field office a copy of the following references:*

ACI SP-15—Field Reference Manual: Specifications for Structural Concrete (ACI 301-10) with Selected ACI & ASTM References

ACI 350.5-12—Specification for Environmental Concrete Structures (ACI 350.5-12) and Commentary

ASTM C231-04—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C 1064/1064M-03: Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

Also when conducting any shotcrete work:

ACI 506.2-95—Specification for Shotcrete

Also when conducting any unbonded post-tensioning work:

ACI 423.6-01—Specification for Unbonded Single-Strand Tendons

#### **1.4—Standards-producing organizations**

Abbreviations for and complete names and addresses of organizations issuing documents referred to in this Reference Specification are listed:

American Concrete Institute (ACI)  
 38800 Country Club Dr.  
 Farmington Hills, MI 48331  
[www.concrete.org](http://www.concrete.org)

American Petroleum Institute  
 1220 L St., NW  
 Washington, DC 20005-4070  
[www.api.org](http://www.api.org)

American Welding Society (AWS)  
 550 Northwest Le Jeune Rd.  
 Miami, FL 33126  
[www.aws.org](http://www.aws.org)

ASTM International  
 100 Barr Harbor Dr.  
 West Conshohocken, PA 19428-2959  
[www.astm.org](http://www.astm.org)

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## 1.5—Submittals

**1.5.1 General**—Unless otherwise specified, submittals required in this Reference Specification shall be submitted for review and acceptance.

**1.5.2 Testing agency reports**—Testing agencies shall report results of concrete and concrete materials tests and inspections performed during the course of the Work to Owner, Architect/Engineer, Contractor, and the Concrete Supplier. Strength test reports shall include location in the Work where the batch represented by test was deposited and the batch ticket number. Reports of strength tests shall include detailed information of storage and curing of specimens before testing. Final reports shall be provided within 7 days of test completion.

## 1.6—Quality assurance

**1.6.1 General**—Concrete materials and operations may be tested and inspected by Owner as Work progresses. Failure to detect defective Work or material early will not prevent rejection. If a defect is discovered later, Architect/Engineer is not obligated to accept the defective Work.

**1.6.2 Testing agencies**—Agencies that perform testing services on concrete materials shall meet the requirements of ASTM C1077. Testing agencies that perform testing services on reinforcing steel shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by Architect/Engineer before performing any Work. Field tests of concrete required in 1.6.3 and 1.6.4 shall be made by an ACI Concrete Field Testing Technician Grade I or equivalent. Equivalent certification programs shall include acceptable requirements for written and performance examinations.

### 1.6.3 Testing responsibilities of Contractor

**1.6.3.1** Submit data on qualifications of proposed Testing Agency for acceptance. Use of testing services will not relieve Contractor of the responsibility to furnish materials and construction in full compliance with Contract Documents.

**1.6.3.2** Unless otherwise specified in Contract Documents, Contractor shall assume the following duties and responsibilities.

**1.6.3.2.1** Qualify proposed materials and establish mixture proportions.

**1.6.3.2.2** Allow access and furnish any necessary labor to assist Owner's Testing Agency in obtaining and handling samples at the project site or at the source of materials.

**1.6.3.2.3** Advise Owner's Testing Agency at least 24 hours in advance of operations to allow for completion of quality tests and for assignment of personnel.

**1.6.3.2.4** Provide and maintain for the sole use of the Testing Agency adequate facilities for safe storage and proper curing of concrete test specimens on the project site for initial curing as required by ASTM C31/C31M.

**1.6.3.2.5** Submit data and test documentation on materials and mixture proportions.

**1.6.3.2.6** Submit quality-control program of the concrete supplier and provide copies of test reports pertaining to the Work.

**1.6.3.2.7** When specified or permitted to base concrete acceptance on accelerated strength testing, submit correlation data for the standard 28-day compressive strength based on at least 15 sets of test data in accordance with 1.6.4.2.5 with concrete made with the same materials providing a range of at least the required average strength  $f_{cr}' \pm 1000$  psi.

**1.6.3.3** Unless otherwise specified in Contract Documents, Contractor shall provide, at no cost to Owner, the necessary testing services for the following.

a) Qualification of proposed materials and establishment of concrete mixtures

b) Other testing services needed or required by Contractor

### 1.6.4 Testing responsibilities of Owner's Testing Agency

**1.6.4.1** Unless otherwise specified in Contract Documents, Owner's Testing Agency shall provide the necessary services for the following.

**1.6.4.1.1** Representatives of Owner's Testing Agency will inspect, sample, and test materials and production of concrete required by Architect/Engineer. When it appears that material furnished or Work performed by Contractor fails to conform to Contract Documents, the Testing Agency will immediately report such deficiency to Architect/Engineer, Contractor, and concrete supplier.

**1.6.4.1.2** The Testing Agency and its representatives are not authorized to revoke, alter, relax, enlarge, or release any requirement in Contract Documents, nor to accept or reject any portion of the Work.

**1.6.4.1.3** The Testing Agency will report test and inspection results that pertain to the Work to Architect/Engineer, Contractor, and concrete supplier within 7 days after tests and inspections are performed.

**1.6.4.2** When required by Owner or Architect/Engineer, Owner's Testing Agency will perform the following testing services at no cost to Contractor:

**1.6.4.2.1** Review and check-test proposed materials for compliance with Contract Documents.

**1.6.4.2.2** Review and check-test proposed concrete mixture as required by Architect/Engineer.

**1.6.4.2.3** Obtain production samples of materials at plants or stockpiles during the course of the Work and test for compliance with Contract Documents.

**1.6.4.2.4** Obtain samples in accordance with ASTM C172. Select the trucks or batches of concrete to be tested on a random basis, using random numbers selected before commencement of concrete placement.

Obtain at least one composite sample for each 100 yd<sup>3</sup>, or a fraction thereof, of each concrete mixture placed in any one day. When the total quantity of a given concrete mixture is less than 50 yd<sup>3</sup>, the strength tests may be waived by Architect/Engineer.

**1.6.4.2.5** Conduct strength tests of concrete during construction in accordance with the following procedures:

a) Mold and cure three cylinders from each sample in accordance with ASTM C31/C31M. Record any deviations from the ASTM requirements in the test report.

b) Test cylinders in accordance with ASTM C39/C39M. Test one specimen at 7 days for information, and two specimens at 28 days for acceptance, unless otherwise specified.