

ACI 350.5M-12

(metric)

Specifications for Environmental Concrete Structures

An ACI Standard

Reported by ACI Committee 350



American Concrete Institute®

Specifications for Environmental Concrete Structures

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ISBN-13: 978-0-87031-815-3
ISBN: 0-87031-815-2

Specifications for Environmental Concrete Structures

An ACI Standard

Reported by ACI Committee 350

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Note: Special acknowledgement to Vijai Prakash Gupta, Larry Kaiser, William Moore, and Paul St. John for their contributions to this document.

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 designing 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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ACI 350.5M-12 became effective October 5, 2012, and was published April 2013.

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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 2160 and 2560 kg/m³.

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

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

350M-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/C173M-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/C881M-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 Flow of Grout 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 350.5M-12—Specification for Environmental Concrete Structures (ACI 350.5M-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

American Petroleum Institute
1220 L St., NW
Washington, DC 20005-4070
www.api.org

American Welding Society (AWS)
550 Northwest Le Jeune Rd.
Miami, FL 33126
www.aws.org

ASTM International
100 Barr Harbor Dr.
West Conshohocken, PA 19428-2959
www.astm.org

NSF International
P.O. Box 130140 / 789 N. Dixboro Rd.
Ann Arbor, MI 48113-0140
www.nsf.org

U.S. Army Corps of Engineers [COE]
Geotechnical and Structures Laboratory
Engineer Research & Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180
www.usace.army.mil



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 $f_{cr}' \pm 7$ MPa.

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 76 m³, 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 38 m³, 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 one specimen at 28 days for acceptance, unless otherwise specified.

The compressive strength test results for acceptance shall be the average of the compressive strengths from the two specimens tested at 28 days. If one specimen in a test shows evidence of improper sampling, molding, or testing, discard the specimen and consider the strength of the remaining cylinder to be the test result. If both specimens in a test show any defects, discard the entire test.

When accelerated testing of concrete is specified or permitted as an alternative to standard testing, mold and cure two specimens from each composite sample in accordance with ASTM C684, following the procedure specified by Architect/Engineer. Make at least one accelerated strength test from each composite sample in 1.6.4.2.4 and one standard 28-day compressive-strength test for at least every other accelerated strength test in accordance with ASTM C31/C31M. Use the following test results to maintain and update the correlation between accelerated and standard 28-day compressive strength tests.

1.6.4.2.6 Determine slump of each composite sample taken in accordance with 1.6.4.2.4 and whenever consistency of concrete appears to vary, using ASTM C143/C143M.

1.6.4.2.7 Determine the temperature of each composite sample taken in accordance with 1.6.4.2.4 using ASTM C1064/C1064M.

1.6.4.2.8 Determine the air content of normalweight concrete using ASTM C231 or C173/C173M for each composite sample taken in accordance with 1.6.4.2.4 or as directed by Architect/Engineer. Additional tests will be performed as necessary.

1.6.4.2.9 Where concrete will be exposed to deicing salts as indicated in Contract Documents, air content tests will be made on samples from the first three batches in the placement and until three consecutive batches have air contents within the range specified in 5.2.2.4, at which time every fifth batch will be tested. This test frequency will be maintained until a batch is not within the range specified in 5.2.2.4, at which time testing of each batch will be resumed until three consecutive batches have air contents within the range specified in 5.2.2.4. Additional tests may be performed as necessary for control. These air content tests may be taken on composite samples in 1.6.4.2.4 or on samples from the batch at any time after discharge of 0.2 m³ of concrete.

1.6.4.2.10 Determine the fresh concrete density of each composite sample taken in accordance with 1.6.4.2.4 using ASTM C138/C138M.

1.6.4.3 Owner's Testing Agency will perform the following testing services when required by Architect/Engineer, at no cost to Contractor:

- a) Inspect concrete batching, mixing, and delivery operations.
- b) Inspect forms; foundation preparation; reinforcement; embedded items; reinforcement placing; and concrete placing, finishing, and curing operations.
- c) Sample concrete at point of placement and other locations as directed by Architect/Engineer and perform required tests.
- d) Review the manufacturer's report for each shipment of cement, reinforcement, and prestressing tendons, and

conduct laboratory tests or spot checks of the materials received for compliance with specifications.

e) Other testing or inspection services as required by Architect/Engineer.

1.6.4.4 Contractor shall pay for the following testing services performed, when necessary, by Owner's Testing Agency:

a) Additional testing and inspection required because of changes in materials or mixture proportions requested by Contractor

b) Additional testing of materials or concrete occasioned by failure to meet specification requirements

1.6.5 Tests on hardened concrete in place

1.6.5.1 General—Tests on hardened concrete will be performed by Owner's Testing Agency when such tests are needed. Testing shall be at Contractor's expense when tests are specified in Contract Documents and when performed to verify the strength of the structure as required by this specification. Owner will pay costs if tests are at Owner's request and not required by this Specification.

1.6.5.2 Nondestructive tests—Use of the rebound hammer in accordance with ASTM C805, pulse-velocity method in accordance with ASTM C597, or other nondestructive tests may be permitted by the Architect/Engineer in evaluating the uniformity and relative concrete strength in place, or for selecting areas to be cored.

1.6.5.3 Core tests

1.6.5.3.1 Where required by Architect/Engineer, obtain cores in accordance with ASTM C42/C42M. Wipe cores surface-dry immediately after coring and allow to dry in air for a period not exceeding 1 hour after drilling. Seal cores in plastic bags or nonabsorbent containers until testing.

1.6.5.3.2 At least three representative cores shall be taken from each member or area of concrete in place that is considered potentially deficient. The location of cores as determined by Architect/Engineer shall impair the strength of the structure as little as possible. If, before testing, cores show evidence of having been damaged subsequent to or during removal from the structure, replacement cores shall be taken.

1.6.5.3.3 Fill core holes with low-slump concrete or mortar of a strength equal to or greater than the original concrete.

1.6.6 Evaluation of concrete strength tests

1.6.6.1 Standard molded and cured strength specimens—Test results from standard molded and cured test cylinders shall be evaluated separately for each specified concrete mixture. Evaluation will be valid only if tests have been conducted in accordance with procedures specified. For evaluation, each specified mixture shall be represented by at least five tests.

1.6.6.2 Nondestructive tests—Test results will be evaluated by Architect/Engineer and will be valid only if tests have been conducted using properly calibrated equipment in accordance with recognized standard procedures and an acceptable correlation between test results and concrete compressive strength has been established and is submitted.

1.6.6.3 Core tests—Core test results will be evaluated by Architect/Engineer and will be valid only if tests have been conducted in accordance with specified procedures.

1.6.7 Acceptance of concrete strength

1.6.7.1 Standard molded and cured strength specimens—

The strength of concrete will be considered satisfactory when the averages of all sets of three consecutive compressive strength test results equal to or exceed the specified compressive strength f'_c , and no individual strength test result falls below f'_c by more than 3.5 MPa when f'_c is 35 MPa or less or by more than $0.10f'_c$ when f'_c is more than 35 MPa. These criteria apply also when accelerated strength testing is specified unless another basis for acceptance is specified in Contract Documents.

1.6.7.2 Nondestructive tests—Nondestructive tests shall not be used as the sole basis for accepting or rejecting concrete, but may be used when permitted to evaluate concrete where standard molded and cured cylinders have yielded results not meeting the criteria in 1.6.7.1.

1.6.7.3 Core tests—Strength of concrete in the area represented by core tests will be considered adequate when the average compressive strength of the cores are equal to at least 85 percent of f'_c , and if no single core is less than 75 percent of f'_c .

1.6.8 Field acceptance of concrete

1.6.8.1 Air content—Concrete not within the limits of air entrainment indicated in 5.2.2.4 and tested in accordance with 1.6.4.2.8 shall not be used in the Work.

1.6.8.2 Slump—Concrete not within the slump limits of 5.2.2.2 shall not be used in the Work.

1.6.8.3 Temperature—Concrete not within temperature limits of 5.2.2.8 shall not be used in the Work.

1.7—Acceptance of structure

1.7.1 General—Completed concrete Work shall conform to following applicable requirements of this reference specification and Contract Documents.

1.7.1.1 Concrete Work that fails to meet one or more requirements in Contract Documents but subsequently is repaired to bring the concrete into compliance may be accepted.

1.7.1.2 Concrete Work that fails to meet one or more requirements in Contract Documents and cannot be brought into compliance may be rejected.

1.7.1.3 Repair rejected concrete Work by removing and replacing or other acceptable repair methods as required by Architect/Engineer. To bring rejected Work into compliance, use repair methods that meet applicable requirements for strength, function, durability, dimensional tolerances, and appearance as determined by Architect/Engineer.

1.7.1.4 Submit for acceptance the proposed repair methods, materials, and modifications needed to assure that concrete Work will meet requirements in Contract Documents.

1.7.1.5 Contractor shall be responsible to bring concrete Work into compliance with requirements of Contract Documents.

1.7.2 Dimensional tolerances

1.7.2.1 Formed surfaces resulting in concrete dimensions smaller than permitted by the tolerances of ACI 117M may be considered deficient in strength and subject to the provisions of 1.7.4.

1.7.2.2 Formed surfaces resulting in concrete dimensions larger than permitted by ACI 117M may be rejected. Remove excess materials when required by Architect/Engineer.

1.7.2.3 Inaccurately formed concrete surfaces that exceed ACI 117M tolerances may be rejected.

1.7.2.4 Tolerances on finished slabs exceeding the tolerances in 6.3.4.3 may be corrected provided they are brought into compliance with 1.7.3, 1.7.4, and 1.7.5.

1.7.3 Appearance—Concrete not meeting the requirements of 6.3.3 or 6.3.4 shall be brought into compliance in accordance with 1.7.1.

1.7.4 Strength of structure

1.7.4.1 Criteria for determining potential strength deficiency—Strength will be considered deficient and concrete Work will be rejected when the Work fails to comply with requirements that control the strength of the structure including, but not limited to, the following conditions:

- a) Concrete strength failing to comply with requirements of 1.6.7
- b) Reinforcement size, quantity, strength, position, or arrangement at variance with the requirements of Section 3 or Contract Documents
- c) Concrete elements that differ from the required dimensions or location
- d) Curing not in accordance with Contract Documents
- e) Mechanical injury, construction fires, accidents, or premature removal of formwork resulting in deficient strength
- f) Insufficient protection of concrete from detrimental environmental conditions as required by 6.3.5.5

1.7.4.2 Action required when strength is potentially deficient—When strength of the structure is considered potentially deficient, the following actions may be required by Architect/Engineer:

- a) Structural analysis, additional testing, or both
- b) Core tests (If testing is inconclusive or impractical or if structural analysis does not confirm the safety of the structure, load tests may be required and their results evaluated in accordance with ACI 350M)
- c) Concrete Work rejected by structural analysis or by results of a load test shall be strengthened with additional construction when required by Architect/Engineer, or replaced
- d) Document all repair Work proposed to bring strength-deficient concrete Work into compliance with Contract Documents, and submit the documentation to Architect/Engineer for acceptance

1.7.5 Durability

1.7.5.1 Criteria for determining potential durability deficiency—Durability of concrete Work will be considered deficient and the concrete Work will be rejected when it fails to comply with the requirements that control durability of the structure including, but not limited to, the following conditions:

- a) Strength failing to comply with 1.6.7
- b) Materials for concrete not conforming to the requirements in 5.2.1.1 through 5.2.1.4

c) Concrete not conforming to the air-entrainment requirements in Contract Documents or the air content limits of Table 5.2.2.4

d) Curing not in accordance with Contract Documents

e) Inadequate protection of concrete from temperature and other environmental conditions during early stages of hardening and strength development

f) Concrete not conforming to the maximum allowable chloride-ion content requirements in Table 5.2.2.6

g) Concrete not in compliance with concrete mixture requirements in Section 5

1.7.5.2 Action required when durability is potentially deficient—When durability of the structure is considered to be deficient, the following actions may be required by Architect/Engineer:

a) Obtain and test samples of the ingredient materials used in the concrete

b) Obtain samples of concrete from the structure by coring, sawing, or other acceptable means

c) Laboratory evaluation of concrete and concrete materials to assess the ability of concrete to resist weathering action, chemical attack, abrasion, reinforcement corrosion, or other deterioration

d) Repair or replace concrete rejected for lack of durability as directed by Architect/Engineer

e) Document repair Work to bring concrete Work into compliance with Contract Documents and submit the documentation to Architect/Engineer for acceptance

1.8—Protection of in-place concrete

1.8.1 Loading and support of concrete—Do not allow construction loads to exceed the superimposed load that the structural member, with necessary supplemental support, is capable of carrying safely and without damage.

1.8.2 Protection from mechanical injury—During the curing period, protect concrete from damaging mechanical disturbances including load stresses, shock, and harmful vibration. Protect concrete surfaces from damage by construction traffic, equipment, materials, rain or running water, and other adverse weather conditions.

SECTION 2—FORMWORK AND FORMWORK ACCESSORIES

2.1—General

2.1.1 Description—This section covers design, construction, and treatment of formwork to confine and shape concrete to the required dimensions.

2.1.2 Submittals

2.1.2.1 Submit the data required in (a) through (c) unless otherwise specified:

a) Data on form-facing materials proposed for smooth-form finish if different from that specified in 2.2.1.1

b) Data on formwork release agent or form liner proposed for use with each formed surface

c) Manufacturer's data for form ties

d) When reshoring or backshoring is required or permitted, submit reshoring or backshoring procedures and drawings,

before use, signed and sealed by a Licensed Design Engineer. Include formwork removal procedure and magnitude of construction loads permitted during reshoring or backshoring on shop drawings

2.1.2.2 Submit the data required in (a) through (e) when required in Contract Documents:

a) Shop drawings for formwork sealed by a Licensed Design Engineer

b) Calculations for formwork, shoring, reshoring, and backshoring, sealed by a Licensed Design Engineer

c) Samples of form ties

d) Unless otherwise specified or permitted, leave formwork and shoring in place to support construction loads and weight of concrete in beams, slabs, and other structural members until in-place strength of concrete determined in accordance with 2.3.4 is at least f'_c

e) Detail plans for formwork removal operations when removal of forms at concrete strengths lower than that specified in 2.3.2.5 is proposed

2.2—Products

2.2.1 Materials

2.2.1.1 Form-facing materials—Materials for form faces in contact with concrete shall meet 6.3.3.5 and the following requirements unless otherwise specified in Contract Documents:

a) For Environmental Surface Finish 2.0 (ESF-2.0): No form-facing material is specified.

b) For Environmental Surface Finish 3.0 (ESF-3.0): Use plywood, tempered concrete-form-grade hardboard, steel, plastic, paper, or other acceptable materials capable of producing the desired finish for form-facing materials. Form-facing materials shall produce a smooth, uniform texture on the concrete. Do not use form-facing materials with raised grain, torn surfaces, worn edges, patches, dents, or other defects that will impair the texture of concrete surfaces.

2.2.1.2 Formwork accessories—Use commercially manufactured accessories for formwork accessories that are partially or wholly embedded in concrete, including ties and hangers. Do not use nonfabricated wire form ties. Moldings for chamfers and rustications and the recesses for joint sealants shall be smooth and of nonabsorbent material.

2.2.1.3 Form ties for environmental engineering concrete structures—Form ties shall have no metal or other material within 40 mm of the concrete surface. The form tie assembly shall be provided with cone-shaped depressions at the concrete surface at least 25 mm in diameter and 40 mm deep to allow for filling and patching. Portions of form ties that are to remain in place shall have an integral water barrier at or near the midpoint of the tie. When permitted, form ties that are to be entirely removed from the structure shall be tapered for easy removal and suitable size for filling of the void after removal.

2.2.1.4 Formwork release agents—Use commercially manufactured formwork release agents that prevent formwork absorption of moisture, prevent bond with concrete, and do not stain the concrete surfaces. When curing surfaces are in contact with potable water, use formwork release

agents shall be acceptable for potable water in accordance with federal, state, and local regulations.

2.2.1.5 Other embedded items—Use sleeves, inserts, anchors, and other embedded items of the material and design indicated in Contract Documents.

2.2.2 Performance and design requirements

2.2.2.1 Design and engineering of formwork shall be the responsibility of Contractor. When required in Contract Documents, design calculations for formwork and formwork drawings shall be signed and sealed by Licensed Design Engineer in the state where the Work will be done.

2.2.2.2 Design formwork, shores, reshores, and backshores to carry all loads transmitted to them and to comply with the requirements of the applicable building code. Design formwork to withstand the pressure resulting from placement and vibration of concrete and to maintain specified tolerances.

2.2.2.3 Do not use earth cuts as forms for vertical or sloping surfaces unless required or permitted in Contract Documents.

2.2.2.4 Maximum deflection of facing materials reflected on concrete surfaces exposed to view shall be 1/240 of the span between structural members of the formwork, unless otherwise specified. For architectural concrete, refer to 7.2.2.1.1.

2.2.2.5 For an Environmental Surface Finish 3.0 (ESF-3.0), set the facing materials in an orderly and symmetrical arrangement, and keep the number of seams to a practical minimum. Facing materials shall be supported with studs or other backing capable of maintaining deflections within the tolerances specified in 2.2.2.4. Fit adjacent panels with tight joints.

2.2.2.6 Forms for circular structures shall conform to the circular shape of the structure. When permitted, straight panels may be substituted for circular panels if the straight panels do not exceed 600 mm in width and do not have a deflection angle greater than 3-1/2 degrees per joint.

2.2.2.7 Forms for prestressed concrete shall be designed and constructed to permit any necessary movement due to application of prestressing force.

2.2.3 Fabrication and manufacture

2.2.3.1 Formwork shall be essentially watertight and shall prevent loss of mortar from concrete. Seal all joints or gaps with an acceptable material.

2.2.3.2 Use 20 mm minimum chamfer strips in the corners of formwork.

2.2.3.3 Design temporary openings, where needed, at the base of vertical formwork to facilitate cleaning and inspection at construction joints and along form.

2.2.3.4 Repair tie holes in accordance with 6.3.6.2.

2.3—Execution

2.3.1 Construction and erection of formwork

2.3.1.1 At construction joints, lap contact surface of the form sheathing for flush surfaces exposed to view over the hardened concrete in the previous placement. Ensure formwork is placed against hardened concrete so that offsets at construction joints attain specified tolerances and minimize

loss of mortar. Form installation shall not cause damage to previously-placed concrete.

2.3.1.2 Unless otherwise specified in Contract Documents, construct formwork so that concrete surfaces conform to the tolerance limits of ACI 117M. The class of surface for offset between adjacent pieces of formwork facing material, as defined in ACI 117M, shall be Class B for surfaces permanently exposed to view and Class D for surfaces that will be permanently concealed, unless otherwise specified.

2.3.1.3 Provide positive means of adjustment (such as wedges or jacks) of shores and struts. Do not make adjustments in the formwork after concrete has reached its time of initial setting. Brace formwork securely against lateral deflection and lateral instability.

2.3.1.4 To maintain specified tolerances, camber formwork to compensate for anticipated deflections in formwork during concrete placement. Set formwork and intermediate screed strips for slabs accurately to produce designated elevations and contours of the finished surface before removal of formwork. Ensure that edge forms and screed strips are sufficiently strong to support vibrating screeds or roller pipe screeds when the specified finish requires the use of such equipment.

2.3.1.5 When formwork is cambered, set screeds to a like camber to maintain required concrete thickness.

2.3.1.6 Fasten form wedges in place after final adjustment of forms and before concrete placement.

2.3.1.7 Anchor formwork to shores, supporting surfaces, or members to prevent upward or lateral movement of the formwork system before and during concrete placement.

2.3.1.8 Construct formwork for wall openings to facilitate removal and to counteract swelling of wood formwork.

2.3.1.9 Provide runways for moving equipment and support runways directly on the formwork or structural member without resting on the reinforcement.

2.3.1.10 Place sleeves, inserts, anchors, and embedded items required for adjoining Work or for support of adjoining Work before concrete placement. Using acceptable procedures, secure all embedments against displacement, fill voids in inserts to prevent entry of concrete, and isolate or coat surfaces of aluminum embedments to prevent reaction with the concrete.

2.3.1.11 Place 20 mm minimum chamfer strips in the corners of formwork to produce beveled edges on permanently exposed surfaces unless otherwise specified. Do not bevel reentrant corners or edges of formed joints of concrete unless specified in Contract Documents.

2.3.1.12 Seal tie holes in formwork to prevent leakage where ties penetrate the formwork. When permitted, taper form ties shall be placed with the larger end on the side of the structure that will be in contact with liquid.

2.3.1.13 Clean surfaces of formwork and embedded materials of mortar, grout, and foreign materials before concrete is placed.

2.3.1.14 Cover surfaces of formwork with an acceptable material that will prevent bond with the concrete. A field-applied formwork release agent or a field-applied oil may be used. If a formwork release agent is used, apply to

the surfaces of the formwork in accordance with the manufacturer's recommendations before placing reinforcement. Do not allow formwork release agent to puddle in the forms. Do not allow formwork release agent to contact reinforcement or hardened concrete against which fresh concrete is to be placed.

2.3.1.15 Inspect formwork and remove deleterious material immediately before concrete is placed.

2.3.2 Removal of formwork

2.3.2.1 When formed surfaces require finishing, remove forms as soon as removal operations will not damage concrete.

2.3.2.2 Remove top forms on sloping surfaces of concrete as soon as removal will not allow concrete to sag. Perform needed repairs or treatment required at once and follow immediately with specified curing.

2.3.2.3 Loosen wood formwork for wall openings as soon as loosening operations will not damage concrete.

2.3.2.4 Do not damage concrete during removal of formwork for columns, walls, sides of beams, and other parts not supporting the weight of the concrete. Perform needed repair and treatment required on vertical surfaces at once and follow immediately with specified curing.

2.3.2.5 Unless otherwise specified or permitted, leave formwork and shoring in place to support construction loads and weight of concrete in beams, slabs, and other structural members until in-place strength of concrete determined in accordance with 2.3.4 is at least f'_c . Unless otherwise specified, when shores and other supports are arranged to allow form-facing material to be removed without allowing structural slabs or members to deflect, form-facing material and horizontal supporting members may be removed at an earlier age.

2.3.2.6 Construct formwork to permit easy removal.

2.3.3 Reshoring and backshoring

2.3.3.1 Submittals for reshoring and backshoring operations shall comply with 2.1.2.2.

2.3.3.2 During reshoring and backshoring, do not allow concrete in beams, slabs, columns, or any structural member to be loaded with combined dead and construction loads in excess of the loads permitted by Architect/Engineer for the concrete compressive strength at the time of reshoring and backshoring.

2.3.3.3 Place reshores and backshores in sequence with stripping operations.

2.3.3.4 Tighten reshores and backshores to carry the required loads without overstressing the concrete members. Leave them in place until tests required by 2.3.4 indicate that the concrete compressive strength has attained the minimum value specified in 2.3.2.5.

2.3.3.5 For floors supporting shores under newly placed concrete, either leave the original supporting shores in place, or install reshores or backshores. The shoring system and the supporting slabs shall resist the anticipated loads. Locate reshores and backshores directly under a shore position or as indicated on formwork shop drawings.

2.3.3.6 In multistory structures, extend reshoring or backshoring over a sufficient number of stories to distribute the

weight of newly placed concrete, forms, and construction live loads such that the design loads of the floors supporting the shores, reshores, or backshores are not exceeded.

2.3.4 Strength of concrete required for removal of formwork

2.3.4.1 When removal of formwork or reshoring is based on concrete reaching a specified compressive strength, concrete shall be presumed to have reached this strength when test cylinders, field cured the same as the concrete they represent, have reached the compressive strength specified for removal of formwork or reshoring. Mold and cure cylinders in accordance with ASTM C31/C31M. Test cylinders in accordance with ASTM C39/C39M.

2.3.4.2 Alternatively, when specified or permitted, use methods in (a) through (d) to evaluate concrete strength for formwork removal. Before using methods in (b) through (d), submit data using project materials to demonstrate correlation of measurements on the structure with the compressive strength of laboratory-cured molded cylinders or drilled cores. Submit correlation data on the proposed alternative method for determining strength to Architect/Engineer.

a) Tests of cast-in-place cylinders in accordance with ASTM C873. This is limited to slabs with concrete depths from 125 to 300 mm.

b) Penetration resistance in accordance with ASTM C803/C803M.

c) Pullout strength in accordance with ASTM C900.

d) Maturity method in accordance with ASTM C1074.

2.3.5 Field quality control

2.3.5.1 Establish and maintain controls and benchmarks in an undisturbed condition until final completion and acceptance of the project.

2.3.5.2 Variations from plumb and designated building lines shall not exceed the tolerances specified in ACI 117M.

SECTION 3—REINFORCEMENT AND REINFORCEMENT SUPPORTS

3.1—General

This section covers materials, fabrication, placement, and tolerances of reinforcement and reinforcement accessories.

3.1.1 Submittals, data, and drawings—Unless otherwise required in Contract Documents, submit the following data and drawings for review and acceptance before fabrication and execution.

3.1.1.1 Submit the following data unless otherwise specified.

3.1.1.1.1 Placing drawings—Submit placing drawings showing fabrication dimensions and locations for placement of reinforcement and reinforcement supports. Placing drawings shall indicate the length and location of all lap splices.

3.1.1.1.2 Splices—Submit a list and request to use splices not indicated in Contract Documents.

3.1.1.1.3 Mechanical splices—Submit request for the use of mechanical splices not indicated on the Project Drawings.

3.1.1.1.4 Column dowels—Submit requests for placement of column dowels without the use of templates.

3.1.1.1.5 Field bending—Submit requests and procedure to field bend or straighten reinforcement partially embedded in concrete.

3.1.1.1.6 Reinforcement—Submit manufacturer's certified test report.

3.1.1.2 Submit the following data when required.

3.1.1.2.1 Welding—Submit description of reinforcement weld locations, chemical analysis of reinforcement, welding procedures, and welder qualifications when welding is permitted in accordance with 3.2.2.2.

3.1.1.2.2 Supports—If coated reinforcement is required, submit description of reinforcement supports not described in 3.3.2.4 and materials for fastening coated reinforcement.

3.1.1.3 Submit the following data when alternatives are proposed.

3.1.1.3.1 Submit a request to relocate any reinforcement that exceeds placement tolerances.

3.1.1.3.2 Submit inspection and quality-control program of plants applying epoxy coating if proposed plant is not certified in accordance with the Concrete Reinforcing Steel Institute (CRSI) Plant Certification Program.

3.1.2 Materials delivery, storage, and handling

3.1.2.1 Prevent permanent bending and protect bar surfaces from contact with soil, oil, or other materials that may decrease bond to concrete.

3.1.2.2 For handling coated reinforcement, use equipment having contact areas padded to avoid damaging the coating. Lift bundles of coated reinforcement at multiple pickup points to prevent bar-to-bar abrasion from sags in the bundles. Do not drop or drag coated reinforcement. Store coated reinforcement on cribbing that will not damage the coating.

3.2—Products

3.2.1 Materials

3.2.1.1 Reinforcing bars—Use deformed bars as reinforcement except spirals and welded wire reinforcement, which may be plain. Reinforcement grades, types, and sizes shall be as specified in Contract Documents and shall conform to ASTM A615/A615M, ASTM A706/A706M, ASTM A970/A970M, or ASTM A996/A996M (rail-steel bars shall be Type R).

3.2.1.2 Coated reinforcing bars—Use zinc or epoxy reinforcing bar coatings where required as specified in Contract Documents.

3.2.1.2.1 Zinc-coated (galvanized) reinforcing bars shall conform to ASTM A767/A767M. Repair zinc-coating damage that occurs during shipping, handling, and placing in accordance with ASTM A780. The maximum allowed damaged areas due to shipping, handling, and placing, including previously repaired areas damaged prior to shipment, shall not exceed 2 percent of the surface area in each linear foot of each bar or the bar shall not be used. The 2 percent limit on maximum allowed damaged coating area shall include repaired areas damaged prior to shipment as required by ASTM A767/A767M.

3.2.1.2.2 Epoxy-coated reinforcing bars shall conform to ASTM A775/A775M or ASTM A934/A934M as specified in Contract Documents.

Coatings shall be applied in plants that are certified in accordance with the Concrete Reinforcing Steel Institute (CRSI) Plant Certification Program or an equivalent program acceptable to Architect/Engineer.

Repair epoxy coating damaged areas with patching material conforming to ASTM A775/A775M or ASTM A934/A934M as applicable and in accordance with the material manufacturer's written recommendations. Repair epoxy coating damage that occurs during shipping, handling, and placing. The maximum damaged areas due to shipping, handling, and placing, including previously repaired areas damaged prior to shipment, shall not exceed 2 percent of the surface area in each linear foot of each bar or the bar shall not be used. The 2 percent limit on maximum allowed damaged coating area shall include repaired areas damaged prior to shipment as required by ASTM A775/A775M or ASTM A934/A934M. Fading of the coating color shall not be cause for rejection of epoxy-coated reinforcing bars.

3.2.1.3 Stainless steel bars—Stainless steel bars shall conform to ASTM A955/A955M.

3.2.1.4 Bar mats—Use bar mats conforming to ASTM A184/A184M, when permitted. When welding the bars, conform to 3.2.2.2. When coated bar mats are required or permitted, repair coatings after welding in accordance with 3.2.2.2.2.

3.2.1.5 Wire—Use plain or deformed wire as indicated in Contract Documents. Plain wire may be used for spirals.

3.2.1.5.1 Plain wire shall conform to ASTM A82/A82M.

3.2.1.5.2 Deformed wire size D4 and larger shall conform to ASTM A496/A496M.

3.2.1.5.3 Epoxy-coated wire shall conform to ASTM A884/A884M. The maximum damaged areas due to shipping, handling, and placing including previously repaired areas damaged prior to shipment shall not exceed 2 percent of the surface area in each linear foot of each wire bar or the bar shall not be used. The 2 percent limit on maximum damaged coating area shall include repaired areas damaged prior to shipment as required by ASTM A884/A884M. Repair all damaged areas. Fading of the coating color shall not be cause for rejection of epoxy-coated reinforcing bars.

3.2.1.5.4 For wire with a specified yield strength f_y exceeding 420 MPa, f_y shall correspond to a strain of 0.35 percent.

3.2.1.6 Welded wire reinforcement—Use welded wire reinforcement specified in Contract Documents and conforming to one of the following.

3.2.1.6.1 Plain welded wire reinforcement shall conform to ASTM A185/A185M, with welded intersections spaced not farther apart than 300 mm in the direction of principal reinforcement.

3.2.1.6.2 Deformed welded wire reinforcement shall conform to ASTM A497/A497M, with welded intersections spaced not farther apart than 400 mm in the direction of principal reinforcement.

3.2.1.6.3 Epoxy-coated welded wire reinforcement shall conform to ASTM A884/A884M with the maximum total damaged areas due to shipping, handling, and placing, including previously repaired areas damaged prior to shipment, shall not exceed 2 percent of the surface area in each linear foot of each wire. The 2 percent limit on maximum damaged coating area shall include repaired areas damaged prior to shipment as required by ASTM A884/A884M. Repair all damaged areas. Fading of the coating color shall not be cause for rejection of epoxy-coated reinforcing bars.

3.2.1.6.4 For welded wire reinforcement with a specified yield strength f_y exceeding 420 MPa, f_y shall correspond to a strain of 0.35 percent.

3.2.1.7 Reinforcement supports—Provide reinforcement support types as required in Contract Documents. Unless otherwise permitted, reinforcement supports shall be of a type indicated in 3.2.1.7.1 through 3.2.1.7.5 as specified. Reinforcement supports shall secure and support the reinforcement within specified tolerances.

3.2.1.7.1 Plastic protected wire-reinforcement supports—The plastic shall have a thickness of 2.5 mm or greater at points of contact with formwork and the plastic shall extend along the wire at least 13 mm from the point of contact with the formwork.

3.2.1.7.2 Stainless steel protected wire-reinforcement supports—The non-stainless steel portion of the supports shall not extend closer than 20 mm from the form surface.

3.2.1.7.3 Epoxy-coated, vinyl-coated, or plastic-coated wire-reinforcement supports—Coating shall have a minimum thickness of 0.13 mm.

3.2.1.7.4 Precast concrete reinforcement supports—Unless otherwise specified, use precast concrete supports that have a surface area of not less than 2600 mm² and have a compressive strength equal to or greater than specified compressive strength of concrete being placed. Water absorption and porosity of precast concrete supports shall be equal to or less than water absorption and porosity of concrete being placed.

3.2.1.7.5 All-plastic reinforcement supports—All-plastic reinforcement supports shall incorporate perforations in plane areas to compensate for the difference in the coefficient of thermal expansion between the plastic and concrete.

3.2.2 Fabrication

3.2.2.1 Reinforcement—Bend reinforcement cold unless heating is permitted. Fabricate reinforcement in accordance with fabricating tolerances of ACI 117M.

3.2.2.2 Welding

3.2.2.2.1 When welding of reinforcement is specified or permitted, comply with the requirements of AWS D1.4. Do not weld crossing bars (tack welding) for assembly of reinforcement, supports, or embedded items.

3.2.2.2.2 After completing welds on zinc-coated (galvanized) or epoxy-coated reinforcement, repair coating damage in accordance with requirements in 3.2.1.2.1 or 3.2.1.2.2, respectively. Coat welds and steel splice members used to splice reinforcement with the same material used for repair of coating damage.

3.3—Execution

3.3.1 Preparation—At the time of concrete placement, reinforcement shall be free of materials deleterious to bond. Reinforcement with rust, mill scale, or a combination of both, shall be considered satisfactory provided the minimum nominal dimensions, nominal weight, and the minimum average height of deformations of a hand-wire-brushed test specimen are not less than the applicable ASTM specification requirements.

3.3.2 Placement

3.3.2.1 Tolerances—Place, support, and fasten reinforcement as indicated in Contract Documents. Do not exceed the placing tolerances specified in ACI 117M before concrete is placed. Placing tolerances shall not reduce cover requirements except as specified in ACI 117M.

3.3.2.2 Reinforcement relocation—When necessary to move reinforcement beyond the specified placing tolerances to avoid interference with other reinforcement, conduits, or embedded items, submit the resulting arrangement of reinforcement for acceptance.

3.3.2.3 Concrete cover—Minimum concrete cover for reinforcement, except for extremely corrosive atmosphere, future extensions, other severe exposures, or fire protection, shall be as indicated in Table 3.3.2.3.

For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle but need not be greater than 50 mm, except the minimum cover shall not be less than specified in Table 3.3.2.3. The equivalent diameter of the bundle shall be based on a single bar of a diameter derived from the equivalent total area. Tolerances on minimum concrete cover shall meet the requirements of ACI 117M.

3.3.2.4 Reinforcement supports—Unless otherwise permitted, use the following reinforcement supports:

- a) Place reinforcement supported from the ground or mud mat on precast concrete reinforcement supports.
- b) Place uncoated reinforcement supported from formwork on reinforcement supports made of concrete, metal, or plastic.
- c) Place zinc-coated (galvanized) reinforcement supported from formwork on wire reinforcement supports that are galvanized, coated with dielectric material, or made of dielectric material.
- d) Reinforcement and embedded steel items used with zinc-coated (galvanized) reinforcement shall be zinc-coated (galvanized) or coated with nonmetallic materials.
- e) Place epoxy-coated reinforcement supported from formwork on coated wire reinforcement supports or on reinforcement supports made of dielectric material. Use coatings or materials compatible with concrete.
- f) When precast reinforcement supports with embedded tie wires or dowels are used with epoxy-coated reinforcement, use wires or dowels coated with dielectric material.
- g) Reinforcement used as supports with epoxy-coated reinforcement shall be epoxy coated.
- h) In walls reinforced with epoxy-coated reinforcement, use spreader bars that are epoxy coated. Properly use reinforcement bar clips and spreaders in walls with epoxy-

Table 3.3.2.3—Minimum concrete cover for reinforcement

Cast-in-place concrete	
(a) Concrete cast against and permanently exposed to earth	75 mm
(b) Concrete exposed to earth, liquid, weather, or bearing on work mat, or slabs supporting earth cover:	
Slabs and joists	50 mm
Beams and columns	
Stirrups, spirals, and ties	50 mm
Primary reinforcement	65 mm
Walls	50 mm
Footings and base slabs	
Formed surfaces	50 mm
Top of footings and base slabs	50 mm
Shells, folded plate members	40 mm
(c) Conditions not covered in Table 3.3.2.3(a) and (b)	
Slabs and joists	
No. 36 bars and smaller	20 mm
No. 43 and No. 57 bars	40 mm
Beams and columns	
Stirrups, spirals, and ties	40 mm
Primary reinforcement	50 mm
Walls	
No. 26 bars and smaller	20 mm
No. 43 and No. 57 bars	40 mm
Shells, folded plate members	
No. 16 bars, MW200 or MD200 wire and smaller	13 mm
No. 19 bars and larger	20 mm
Precast concrete (manufactured under plant control conditions)	
The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts, and end fittings.	
(d) Concrete exposed to earth, liquid, weather, or bearing on work mat, or slabs supporting earth cover	
Slabs and joists	40 mm
Beams and columns	
Stirrups, spirals, and ties	40 mm
Primary reinforcement	50 mm
Walls	40 mm
Shells, folded plate members	25 mm
(e) Conditions not covered in (d)	
Slabs and joists	
No. 36 bars, prestressing tendons 40 mm diameter and smaller	20 mm
No. 43 and No. 57 bars, prestressing tendons larger than 40 mm diameter	40 mm
Beams and columns	
Stirrups, spirals, and ties	25 mm
Primary reinforcement	40 mm
Walls	
No. 36 bars, prestressing tendons 40 mm diameter and smaller	20 mm
No. 43 and No. 57 bars, prestressing tendons larger than 40 mm diameter	40 mm
Shells, folded plate members	
No. 16 bars, MW200 or MD200 wire and smaller	20 mm
No. 19 bars and larger	25 mm
Cast-in-place concrete (prestressed)	
The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts, and end fittings.	
(f) Concrete cast against and permanently exposed to earth	
	75 mm
(g) Concrete exposed to earth, liquid, weather, or bearing on work mat, or slabs supporting earth cover	
Slabs and joists	40 mm
Beams and columns	
Stirrups, spirals, and ties	40 mm
Primary reinforcement	50 mm
Walls	40 mm
Shells, folded plate members	25 mm
(h) Conditions not covered in (f) and (g)	
Slabs and joists	
No. 36 bars and smaller	20 mm
No. 43 and No. 57 bars	40 mm
Beams and columns	
Stirrups, spirals, and ties	25 mm
Primary reinforcement	40 mm
Walls	
No. 36 bars and smaller	25 mm
No. 43 and No. 57 bars	40 mm
Shells, folded plate members	
No. 16 bars, MW200 and MD200 wire and smaller	20 mm
No. 19 bars and larger	25 mm



coated reinforcement shall be made of corrosion-resistant material or coated with dielectric material.

i) Fasten epoxy-coated reinforcement with tie wires coated with epoxy or other polymer.

3.3.2.5 Welded wire reinforcement for slabs on soil—For slabs on soil, extend welded wire reinforcement to within 50 mm of the concrete edge. Lap edges and ends of welded wire reinforcement sheets a minimum of one wire spacing unless otherwise specified in Contract Documents. Unless otherwise permitted, do not extend welded wire reinforcement through contraction joints. Support welded wire reinforcement during placing of concrete to ensure required positioning in the slab. Do not place welded wire reinforcement on grade and subsequently raise into position in concrete.

3.3.2.6 Column dowels—Furnish and use templates for placement of column dowels unless otherwise permitted.

3.3.2.7 Splices—Make splices as indicated on the Project Drawings unless otherwise permitted. Mechanical splices for reinforcement not shown on the Project Drawings shall not be used unless accepted by Architect/Engineer. Remove reinforcement coating in the area of the mechanical splice if so required by the splice manufacturer. After installing mechanical splices on zinc-coated (galvanized) or epoxy-coated reinforcement, repair coating damage and areas of removed coating in accordance with 3.2.1.2.1 or 3.2.1.2.2. Coat exposed parts of mechanical splices used on coated bars with the same material used for repair of coating damage.

3.3.2.8 Field bending or straightening—When permitted, bend or straighten reinforcement partially embedded in concrete in accordance with the following procedures. Reinforcing bar sizes No. 10 through No. 16 may be bent cold the first time, provided reinforcing bar temperature is above 0°C. For other bar sizes, preheat reinforcing bars before bending.

3.3.2.8.1 Preheating—Apply heat by any method that does not harm the reinforcing bar material or cause damage to the concrete. Preheat a length of reinforcing bar equal to at least five bar diameters in each direction from the center of the bend but do not extend preheating below the surface of the concrete. Do not allow the temperature of the reinforcing bar at the concrete interface to exceed 250°C. The preheat temperature of the reinforcing bar shall be between 600 to 650°C. Maintain the preheat temperature before bending or straightening is complete. Unless otherwise permitted, measure the preheat temperature by temperature measurement crayons or contact pyrometer. Do not artificially cool heated reinforcing bars until the temperature of the bar is less than 300°C.

3.3.2.8.2 Bend diameters—Minimum inside bend diameters shall conform to the requirements of Table 3.3.2.8.2 unless otherwise permitted. In addition, the beginning of the bend shall not be closer to the concrete surface than the minimum diameter of the bend.

3.3.2.8.3 Repair of bar coatings—After field bending or straightening zinc-coated (galvanized) or epoxy-coated reinforcing bars, repair coating damage in accordance with 3.2.1.2.1 or 3.2.1.2.2.

Table 3.3.2.8.2—Minimum diameter of bend

Bar size	Minimum inside bend diameter
No. 10 through 25	Six bar diameters
No. 29 through 36	Eight bar diameters
No. 43 and 57	Ten bar diameters

3.3.2.9 Field cutting of reinforcement—Reinforcement shall not be cut in the field except when specifically permitted. Do not flame-cut epoxy-coated reinforcement.

3.3.2.9.1 When zinc-coated (galvanized) reinforcing bars are cut in the field, coat the ends of the bars with a zinc-rich formulation used in accordance with the manufacturer's recommendations, and repair any coating damage in accordance with 3.2.1.2.1.

3.3.2.9.2 When epoxy-coated reinforcing bars are cut in the field, coat the ends of the bars with the same material used for repair of coating damage, and repair any coating damage in accordance with 3.2.1.2.2.

3.3.2.10 Reinforcement through expansion joints—Do not continue reinforcement through expansion joints or bond other embedded metal items to concrete on each side of expansion joints. Dowels bonded on only one side of a joint and waterstops shall extend through the joint.

3.3.2.11 Reinforcement termination—Where reinforcement does not extend through a joint, terminate the reinforcement 50 mm from the face of the joint.

SECTION 4—JOINTS AND ACCESSORIES

4.1—General

4.1.1 Description—This section covers construction of joints in concrete, including materials and accessories.

4.1.2 Submittals

4.1.2.1 Submit the following data and drawings unless otherwise specified:

a) Location and details of construction, expansion, and contraction joints proposed, if different from those indicated in Contract Documents

b) Manufacturer's data for waterstops

c) Manufacturer's data for expansion joint materials, including premolded joint fillers, joint sealants, bond breaker tape, and other joint accessories

d) Manufacturer's data for smooth dowels, including expansion caps and bond breaker where required

4.1.2.2 Submit the following when required in Contract Documents:

a) Samples for waterstops

b) Samples for expansion joint materials

c) Manufacturer's data for bonding agents

d) Manufacturer's data for bond breakers to be used at contraction joint surfaces

4.2—Products

4.2.1 Materials

4.2.1.1 Flexible waterstops—Flexible waterstops shall conform to the following requirements.



Documents

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