

An ACI Standard

Specifications for Concrete Construction (ACI 301-20)

Reported by ACI Committee 301

ACI 301-20



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Specifications for Concrete Construction

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An ACI Standard

Reported by ACI Committee 301

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This is a Reference Specification that the Architect/Engineer can apply to projects involving concrete construction by citing it in the Project Specification. A mandatory requirements checklist and an optional requirements checklist are provided to assist the Architect/Engineer in supplementing the provisions of this Specification as required or needed by designating or specifying individual project requirements.

The first five sections of this Specification cover general requirements for concrete construction. These sections cover materials and proportioning of concrete; reinforcement and prestressing steel; production, placing, finishing, and curing of concrete; formwork performance criteria and construction; treatment of joints; embedded items; repair of surface defects; and finishing of formed and unformed surfaces. Provisions governing testing, evaluation, and acceptance of concrete as well as acceptance of the structures are included. The remaining sections are devoted to architectural concrete, lightweight concrete, mass concrete, post-tensioned concrete, shrinkage-compensating concrete for interior slabs, industrial floor slabs, tilt-up construction, precast structural concrete, and precast architectural concrete.

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

Keywords: architectural concrete; cold weather; compressive strength; consolidation; curing; durability; finish; formwork; grouting; hot weather; industrial floors; inspection; joints; lightweight concrete; mass concrete; mixture proportions; placing; post-tensioned concrete; precast concrete; prestressing steel; repair; reshoring; shoring; shrinkage-compensating concrete; slabs-on-ground; steel reinforcement; testing; tilt-up; tolerance; welded wire reinforcement.

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SECTION 1—GENERAL REQUIREMENTS

1.1—Scope

1.1.1 This Specification covers construction of cast-in-place concrete, architectural concrete, lightweight concrete, mass concrete, post-tensioned concrete, shrinkage-compensating concrete for interior slabs, industrial floor slabs cast on ground, tilt-up construction, precast structural concrete, and precast architectural concrete.

1.1.2 Unless otherwise specified, Sections 1 through 5 apply to Work where this Specification is referenced. Work covered by Sections 6 through 14 apply only if that Work is designated in Contract Documents.

1.1.3 This Specification is incorporated by Contract Documents and provides requirements for Contractor.

1.1.4 This Specification governs for construction within its scope. If there are differences between requirements of this Specification and project-specific Contract Documents, project-specific Contract Documents govern.

1.1.5 Use shotcrete as designated in Contract Documents.

1.1.6 *Work not specified*—The following Work is not in the scope of this Specification:

- (a) Manufactured concrete products specified by ASTM standards
- (b) Environmental concrete structures
- (c) Heavyweight shielding concrete
- (d) Paving concrete
- (e) Terrazzo
- (f) Insulating concrete
- (g) Refractory concrete
- (h) Nuclear containment structures
- (i) Concrete piles; drilled piers; and caissons assigned to Seismic Design Categories A, B, and C
- (j) Fire safety
- (k) Slipformed concrete walls
- (l) Residential post-tensioned slabs-on-ground

1.1.7 This Specification governs if there is a conflict with referenced materials and testing standards.

1.1.8 Contractor is permitted to submit written alternatives to any provision in this Specification for consideration.

1.1.9 Ignore provisions of this Specification that are not applicable to Work.

1.1.10 *Units*—Values in this Specification are stated in SI units. A companion specification in inch-pound units is available.

1.1.11 Unless otherwise stated, the SI system of units is applicable to ASTM combined standards referenced in this Specification.

1.1.12 The Notes to Specifier are not part of this Specification.

1.2—Interpretation

1.2.1 Unless otherwise explicitly stated, this Specification shall be interpreted using the following principles:

1.2.1.1 Interpret this Specification consistent with the plain meaning of the words and terms used.

1.2.1.2 Definitions provided in this Specification govern over the definitions of the same or similar words or terms found elsewhere.

1.2.1.3 Headings are part of this Specification and are intended to identify the scope of the provisions or sections that follow. If there is a difference in meaning or implication between the text of a provision and a heading, the meaning of the text governs.

1.2.1.4 Notes to a table are part of this Specification. The meaning of the provision text governs in the event of a difference in meaning or implication between the provision text and a note to a table.

1.2.1.5 If a provision of this Specification involves two or more items, conditions, requirements, or events connected by the conjunctions “and” or “or,” interpret the conjunction as follows:

- (a) “and” indicates that all the connected items, conditions, requirements, or events apply.
- (b) “or” indicates that the connected items, conditions, requirements, or events apply singularly.

1.2.1.6 The use of the verbs “may” or “will” indicates that the specification provision is for information to Contractor.

1.2.1.7 The phrases “as indicated in Contract Documents” and “as designated in Contract Documents” mean the specifier included provision requirements in Contract Documents.

1.2.1.8 The phrase “unless otherwise specified” means the specifier may have included an alternative to the default requirement in Contract Documents.

1.2.1.9 The phrase “if specified” means the specifier may have included a requirement in Contract Documents for which there is no default requirement in this Specification.

1.3—Definitions

acceptable or accepted—determined to be satisfactory by Architect/Engineer based on requirements of Contract Documents.

acceptance—acknowledgment by Architect/Engineer that submittal or completed Work is acceptable.

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; knowledge and ability shall be demonstrated by passing prescribed written and performance examinations and having credentials that are current with the American Concrete Institute.

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

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.

cast-in-place concrete—concrete that is deposited and allowed to harden in the place where it is required to be in the completed structure.

check test—test performed to verify result of previous test result of freshly-mixed concrete.

Contract Documents—a set of documents that form the basis of an agreement between Owner and Contractor; these documents can contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.

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

defective work—construction or material that does not comply with Contract Documents.

design reference sample—sample of architectural concrete for color, finish, and texture that is submitted for initial verification of design intent.

drawings—graphic presentation that details requirements for Work.

duct—a conduit in a concrete member to accommodate the prestressing steel of a post-tensioning tendon and provide an annular space for protective coating.

encapsulated tendon—a tendon that is enclosed completely in a watertight covering from end to end, including anchorages, sheathing with coating, and caps over the strand tails.

equivalent diameter of bundle—the diameter of a circle having an area equal to the sum of the bar areas in a bundle of reinforcing bars.

expansive cement—a cement that, when mixed with water, produces a paste that, after setting, increases in volume and is used to compensate for volume decrease due to shrinkage or to induce tensile stress in reinforcement.

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

high-early-strength concrete—concrete that, through the use of additional cement, high-early-strength cement, admixtures, or other acceptable methods, has accelerated early-age strength development.

jack clearance—minimum space required to safely install, operate, and remove a hydraulic jack through its full range of movement in stressing of a tendon.

licensed design engineer—an individual retained by the Contractor who is licensed to practice engineering as defined by the statutory requirements of the professional licensing laws of the state or jurisdiction in which the project is to be constructed.

movement joint—an interface between adjacent portions of Work that allows movement in one or more direction.

nonencapsulated tendon—a tendon that has bare metallic anchorages and sheathing that is continuous between anchorages but not connected to the anchorages.

normalweight concrete—concrete containing aggregate that conforms to [ASTM C33/C33M](#) and that typically has a density between 2160 and 2560 kg/m³.

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

placing drawing—drawing that gives size, location, and spacing of reinforcement, and other information required for site-cast concrete construction.

point of delivery—location where concrete is discharged from the vehicle used to transport concrete to the project site.

point of placement—location where concrete is placed in structure.

prestressing steel—high-strength steel element; for example, strand, bars, or wire, used to impart prestress forces to concrete.

quality assurance—actions taken by Owner or Owner's Representative to provide confidence that Work done and materials provided are in accordance with Contract Documents.

quality control—actions taken by Contractor to ensure that Work meets the requirements in Contract Documents.

reference specification—a standardized mandatory-language document prescribing materials, dimensions, and workmanship, incorporated by reference in Contract Documents.

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

required—required in this Specification or in 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.

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

shop drawings—drawings that provide details for a particular portion of Work that are prepared by Contractor in accordance with Contract Documents and are reviewed by Architect/Engineer.

shore—vertical or inclined support members designed to support the weight of the formwork, concrete, and construction loads above.

strength test—standard test conducted for evaluation and acceptance of concrete determined as the average of the compressive strengths of at least two 150 x 300 mm cylinders or at least three 100 x 200 mm cylinders made from the same sample of concrete, taken in accordance with [ASTM C172/C172M](#) at the point of delivery, handled and standard cured in accordance with [ASTM C31/C31M](#), and tested in accordance with [ASTM C39/C39M](#) at 28 days or at test age designated for f'_c .

structural concrete—plain or reinforced concrete in a member required to transfer gravity loads, lateral loads, or both, to the ground.

submit—provide to Architect/Engineer for review.

submittal—documents or materials provided to Architect/Engineer for review and acceptance.

surface defects—imperfections in concrete surfaces defined in Contract Documents requiring repair.

tendon—in pretensioned applications, the tendon is the prestressing steel; in post-tensioned applications, the tendon is a complete assembly consisting of a sheath and

prestressing steel, and sheathing with coating for unbonded applications or ducts with grout for bonded applications.

testing agency—person, firm, or entity under contract for providing testing services that will be used to determine conformance to Contract Documents.

waste slab—temporary slab to provide a casting surface for tilt-up panels.

water-cementitious materials ratio (w/cm)—ratio of mass of water, excluding that absorbed by aggregate, to the mass of cementitious materials in a mixture, stated as a decimal.

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

1.4—Referenced standards

1.4.1 Standards cited in this Specification are listed with serial designation including year of adoption or revision.

1.4.1.1 American Concrete Institute standards

ACI 117M-10(15)—Specification for Tolerances for Concrete Construction and Materials and Commentary

ACI 216.1M-14(19)—Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies

ACI 423.7-14—Specification for Unbonded Single-Strand Tendon Materials

ACI ITG-7M-09—Specification for Tolerances for Precast Concrete

1.4.1.2 ASTM International standards

ASTM A36/A36M-19—Standard Specification for Carbon Structural Steel

ASTM A47/A47M-99(2018)—Standard Specification for Ferritic Malleable Iron Castings

ASTM A108-18—Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished

ASTM A123/A123M-17—Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

ASTM A153/A153M-16a—Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

ASTM A184/A184M-17—Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement

ASTM A193/A193M-19—Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

ASTM A276/A276M-17—Standard Specification for Stainless Steel Bars and Shapes

ASTM A307-14—Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 PSI Tensile Strength

ASTM A325-14—Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

ASTM A416/A416M-18—Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete

ASTM A421/A421M-15—Standard Specification for Stress-Relieved Steel Wire for Prestressed Concrete

ASTM A490-14a—Standard Specification for Structural Bolts, Steel, Heat Treated, 150 ksi Minimum Tensile Strength

ASTM A500/A500M-18—Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

ASTM A563-15—Standard Specification for Carbon and Alloy Steel Nuts

ASTM A572/A572M-18—Standard Specification for High Strength Low-Alloy Columbium-Vanadium Structural Steel

ASTM A615/A615M-18e1—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A666-15—Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

ASTM A675/A675M-14(2019)—Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

ASTM A706/A706M-16—Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

ASTM A722/A722M-16—Standard Specification for High-Strength Steel Bars for Prestressing Concrete

ASTM A767/A767M-16—Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

ASTM A775/A775M-17—Standard Specification for Epoxy-Coated Steel Reinforcing Bars

ASTM A779/A779M-16—Standard Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, for Prestressed Concrete

ASTM A780/A780M-09(2015)—Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

ASTM A820/A820M-16—Standard Specification for Steel Fibers for Fiber-Reinforced Concrete

ASTM A882/A882M-04a(2010)—Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand

ASTM A884/A884M-14—Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement

ASTM A886/A886M-17—Standard Specification for Steel Strand, Indented, Seven-Wire, Stress-Relieved for Prestressed Concrete

ASTM A910/A910M-18—Standard Specification for Uncoated, Weldless, 2-Wire and 3-Wire Steel Strand for Prestressed Concrete

ASTM A934/A934M-16—Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

ASTM A955/A955M-18b—Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

ASTM A970/A970M-18—Standard Specification for Headed Steel Bars for Concrete Reinforcement

ASTM A992/A992M-11(2015)—Standard Specification for Structural Steel Shapes



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ASTM A996/A996M-16—Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

ASTM A1022/A1022M-16b—Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement

ASTM A1035/A1035M-16b—Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement

ASTM A1044/A1044M-16a—Standard Specification for Steel Stud Assemblies for Shear Reinforcement of Concrete

ASTM A1055/A1055M-16—Standard Specification for Zinc and Epoxy Dual-Coated Steel Reinforcing Bars

ASTM A1060/A1060M-16b—Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM A1064/A1064M-18a—Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM C31/C31M-19—Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C33/C33M-18—Standard Specification for Concrete Aggregates

ASTM C39/C39M-18—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C42/C42M-18a—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C67-14—Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile

ASTM C94/C94M-18—Standard Specification for Ready-Mixed Concrete

ASTM C109/C109M-16—Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

ASTM C114-15—Standard Test Methods for Chemical Analysis of Hydraulic Cement

ASTM C126-15—Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units

ASTM C138/C138M-17a—Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

ASTM C143/C143M-15—Standard Test Method for Slump of Hydraulic-Cement Concrete

ASTM C144-11—Standard Specification for Aggregate for Masonry Mortar

ASTM C150/C150M-19a—Standard Specification for Portland Cement

ASTM C157/C157M-08(2014)e1—Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

ASTM C171-07—Standard Specification for Sheet Materials for Curing Concrete

ASTM C172/C172M-17—Standard Practice for Sampling Freshly Mixed Concrete

ASTM C173/C173M-16—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C192/C192M-15—Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

ASTM C216-15—Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)

ASTM C231/C231M-17a—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C260/C260M-10a(2016)—Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C309-11—Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C330/C330M-17a—Standard Specification for Lightweight Aggregates for Structural Concrete

ASTM C373-14a—Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products, Ceramic Tiles, and Glass Tiles

ASTM C387/C387M-15—Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar

ASTM C404-11—Standard Specification for Aggregates for Masonry Grout

ASTM C469/C469M-14—Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

ASTM C494/C494M-17—Standard Specification for Chemical Admixtures for Concrete

ASTM C567/C567M-14—Standard Test Method for Determining Density of Structural Lightweight Concrete

ASTM C578-15—Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation

ASTM C591-15—Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation

ASTM C595/C595M-18—Standard Specification for Blended Hydraulic Cements

ASTM C597-09—Standard Test Method for Pulse Velocity through Concrete

ASTM C618-19—Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

ASTM C642-13—Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

ASTM C650-04(2014)—Standard Test Method for Resistance of Ceramic Tile to Chemical Substances

ASTM C666/C666M-15—Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing

ASTM C685/C685M-17—Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

ASTM C803/C803M-18—Standard Test Method for Penetration Resistance of Hardened Concrete

ASTM C805/C805M-13a—Standard Test Method for Rebound Number of Hardened Concrete

ASTM C834-14—Standard Specification for Latex Sealants

ASTM C845/C845M-18—Standard Specification for Expansive Hydraulic Cement

ASTM C873/C873M-15—Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

ASTM C878/C878M-14a—Standard Test Method for Restrained Expansion of Shrinkage-Compensating Concrete

ASTM C881/C881M-15—Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete

ASTM C900-15—Standard Test Method for Pullout Strength of Hardened Concrete

ASTM C920-14a—Standard Specification for Elastomeric Joint Sealants

ASTM C979/C979M-16—Standard Specification for Pigments for Integrally Colored Concrete

ASTM C989/C989M-18a—Standard Specification for Slag Cement for Use in Concrete and Mortars

ASTM C1012/C1012M-18b—Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

ASTM C1017/C1017M-13e1—Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C1064/C1064M-12—Standard Test Methods for Temperature of Freshly Mixed Hydraulic-Cement Concrete

ASTM C1074-17—Standard Practice for Estimating Concrete Strength by the Maturity Method

ASTM C1077-17—Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

ASTM C1107/C1107M-14a—Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

ASTM C1116/C1116M-10a(2015)—Standard Specification for Fiber-Reinforced Concrete

ASTM C1152/C1152M-04(2012)e1—Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete

ASTM C1157/C1157M-11—Standard Performance Specification for Hydraulic Cement

ASTM C1218/C1218M-17—Standard Test Method for Water-Soluble Chloride in Mortar and Concrete

ASTM C1240-15—Standard Specification for Silica Fume Used in Cementitious Mixtures

ASTM C1260-14—Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar Bar Method)

ASTM C1289-16—Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board

ASTM C1293-08b(2015)—Standard Test Method for Determination Length of Change of Concrete Due to Alkali-Silica Reaction

ASTM C1315-11—Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete

ASTM C1567-13—Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

ASTM C1602/C1602M-18—Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

ASTM C1609/C1609M-12—Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)

ASTM C1610/C1610M-17—Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique

ASTM C1611/C1611M-14—Standard Test Method for Slump Flow of Self-Consolidating Concrete

ASTM C1621/C1621M-14—Standard Test Method for Passing Ability of Self-Consolidating Concrete Using Column Technique

ASTM C1761/C1761M-15—Standard Specification for Lightweight Aggregate for Internal Curing of Concrete

ASTM C1778-16—Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete

ASTM C1797-17—Standard Specification for Ground Calcium Carbonate and Aggregate Mineral Fillers for use in Hydraulic Cement Concrete

ASTM D98-15—Standard Specification for Calcium Chloride

ASTM D412-15a—Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

ASTM D638-14—Standard Test Method for Tensile Properties of Plastics

ASTM D698-12e2—Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort [12 400 ft-lbf/ft³ (600 kN-m/m³)]

ASTM D994/D994M-11—Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)

ASTM D1621-10—Standard Test Methods for Compressive Properties of Rigid Cellular Plastics

ASTM D1751-04(2013)e1—Standard Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)

ASTM D1752-04a(2013)—Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction

ASTM D2240-15—Standard Test Method for Rubber Property—Durometer Hardness

ASTM D2940/D2940M-15—Standard Specification for Graded Aggregate Material for Bases or Subbases for Highways or Airports

ASTM D3575-14—Standard Test Methods for Flexible Cellular Materials Made from Olefin Polymers

ASTM D4397-10—Standard Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications

ASTM E165/E165M-12—Standard Practice for Liquid Penetrant Examination for General Industry

ASTM E329-14a—Standard Specification for Agencies Engaged in Construction Inspection, Testing, and Monitoring Inspection

ASTM E488/E488M-15—Standard Test Methods for Strength of Anchors in Concrete Elements

ASTM E1155-14—Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers

ASTM E1444/E1444M-12—Standard Practice for Magnetic Particle Testing

ASTM E1643-11—Standard Practice for Selection, Design, Installation, and Inspection of Water Vapor Retarders Used in Contact with Earth or Granular Fill under Concrete Slabs

ASTM E1745-11—Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

ASTM F436-11—Standard Specification for Hardened Steel Washers

ASTM F593-13a—Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs

ASTM F594-09(2015)—Standard Specification for Stainless Steel Nuts

ASTM F844-07a(2013)—Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

ASTM F1554-18—Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

1.4.1.3 Other referenced standards—Other standards referenced in this Specification:

AASHTO LRFD-US8 (2017)—LRFD Bridge Design Specifications, eighth edition

AASHTO M 182-05 (2017)—Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

AASHTO M 251-06 (2016)—Standard Specification for Plain and Laminated Elastomeric Bridge Bearings

ANSI A118.1-19—American National Standard Specifications for Dry-Set Portland Cement Mortar

ANSI A118.4-19—American National Standard Specifications for Latex-Portland Cement Mortar

ANSI A118.6-19—American National Standard Specifications for Standard Cement Grouts for Tile Installation

ASHRAE 90.1-2019—Energy Standard for Buildings Except Low-Rise Residential Buildings

AWS C5.4-93—Recommended Practices for Stud Welding

AWS D1.1/D1.1M:2015—Structural Welding Code—Steel

AWS D1.4/D1.4M:2018—Structural Welding Code—Steel Reinforcing Bars

AWS D1.6/D1.6M:2017—Structural Welding Code—Stainless Steel

CRD-C513-74—Specifications for Rubber Waterstops

CRD-C572-74—Specifications for Polyvinylchloride Waterstop

CRSI RB4.1-16—Supports for Reinforcement Used in Concrete

MPI #79-16—Primer, Alkyd, Anti-Corrosive for Metal

NAVY MIL-C-882E-89—Cloth, Duck, Cotton or Cotton-Polyester Blend, Synthetic Rubber, Impregnated, and Laminated, Oil Resistant

NAVY MIL DOD-P-21035A-91—Paint High Zinc Dust Content, Galvanizing Repair

SSPC-Paint 20-04—Zinc Rich Primers IO and O

SSPC-PA1-16—Shop, Field and Maintenance Painting of Steel

SSPC-SP3-18—Power Tool Cleaning

PCI MNL-116-99—Manual for Quality Control for Plants and Production of Structural Precast Concrete Products

PCI MNL-124-11—Design for Fire Resistance of Precast/Prestressed Concrete

PTI/ASBI M50.3-19—Specification for Multistrand and Grouted Post-Tensioning

PTI M55.1-19—Specification for Grouting of Post-Tensioned Structures

1.5—Submittals

1.5.1 General—Provide submittals as required by this Specification in accordance with Contract Documents.

1.5.2 Substitution—Substitution requests shall specifically identify proposed substitution and demonstrate compliance with performance requirements.

1.5.3 Contractor's quality control—If specified, submit quality control plan showing means and methods to control purchase, use, and placement of materials. Provide information related to quality control in accordance with 1.7.2.

1.6—Preconstruction conference

1.6.1 If specified, schedule and attend preconstruction conference with Architect/Engineer, Owner, or Owner's Representative to review project requirements, acceptance criteria, and responsibilities.

1.7—Testing and inspection

1.7.1 General—Concrete materials and operations may be tested and inspected as Work progresses. Failure to detect defective Work will not prevent later rejection if discovered nor shall it obligate Architect/Engineer for final acceptance.

1.7.2 Quality control: Duties and responsibilities of Contractor

1.7.2.1 Field technicians—Field tests of concrete required in 1.7.2 shall be performed by ACI Concrete Field Testing Technician Grade I or acceptable equivalent. Equivalent certification programs shall include acceptable requirements for written and performance examinations.

1.7.2.2 Unless otherwise specified, Contractor assumes duties and responsibilities specified in 1.7.2.2(a) through 1.7.2.2(e).

1.7.2.2(a) Provide Owner's testing agency with access to project site or to source of materials to perform testing and inspection activities and assist Owner's testing agency in obtaining and handling samples at project site or at source of materials. Provide Owner's testing agency with requested documentation.

1.7.2.2(b) Advise Owner's testing agency at least 24 hours in advance of operations that require services specified in 1.7.3.2 through 1.7.3.5 to allow for scheduling of quality assurance tests, review of project requirements, and assignment of personnel.

1.7.2.2(c) Provide secure location and sources of water and electrical power on project site acceptable to Owner.

testing agency for initial curing of concrete strength test specimens as required by **ASTM C31/C31M**.

1.7.2.2(d) Submit information on concrete materials and documentation that properties of proposed concrete mixtures meet requirements in Contract Documents.

1.7.2.2(e) Submit concrete supplier's quality control program.

1.7.3 *Quality assurance: Duties and responsibilities of Owner's testing agency*

1.7.3.1 Owner's testing agencies that perform required tests of concrete materials will meet the requirements of **ASTM C1077**, which includes certification requirements for technicians. Owner's testing agencies that test or inspect placement of reinforcement will meet the requirements of ASTM E329.

1.7.3.2 Unless otherwise specified, Owner's testing agency will provide services specified in 1.7.3.2(a) through 1.7.3.2(c).

1.7.3.2(a) Owner's testing agency will inspect, sample, and test fresh and hardened concrete for conformance to requirements in Contract Documents. If material furnished or Work performed by Contractor fails to conform to Contract Documents, testing agency will report deficiency to Architect/Engineer, Owner, Contractor, and concrete supplier.

1.7.3.2(b) Owner's testing agency and its representatives are not authorized to revoke, alter, relax, enlarge, or release requirements in Contract Documents, or to accept or reject portions of Work.

1.7.3.2(c) Owner's testing agency will report test and inspection results of Work to Owner, Architect/Engineer, Contractor, and concrete supplier within 7 days after tests and inspections are performed. Strength test reports will include location in Work where concrete represented by each strength test was deposited, date and time sample was obtained, and batch ticket number. Strength test reports will include information on storage and curing of specimens before testing.

1.7.3.3 *Testing services*—If required by Owner or Architect/Engineer, Owner's testing agency will perform testing services specified in 1.7.3.3(a) through 1.7.3.3(e) at no cost to Contractor.

1.7.3.3(a) Review and test to verify Contractor's test results on proposed materials for compliance with Contract Documents.

1.7.3.3(b) Review and test to verify Contractor's test results on proposed concrete mixture for compliance with Contract Documents.

1.7.3.3(c) Obtain production samples of materials at plants or stockpiles during the course of Work and test for compliance with Contract Documents.

1.7.3.3(d) For each concrete mixture cast in 1 day, obtain samples of fresh concrete in accordance with **ASTM C172/C172M**. Truckloads or batches of concrete will be sampled on a random basis. Unless otherwise specified, at least one composite sample will be obtained for consecutive 110 m³ of concrete or 460 m² of surface area of slabs or walls, or fractions thereof. At least five strength tests for a given concrete mixture will be required for Work. If total quantity of a given

concrete mixture is less than 38 m³, strength tests may be waived.

Sampled concrete used to mold strength test specimens (**ASTM C31/C31M**) will be tested for slump (**ASTM C143/C143M**) or slump flow (**ASTM C1611/C1611M**), air content (**ASTM C231/C231M** or **ASTM C173/C173M**), temperature (**ASTM C1064/C1064M**), and density (**ASTM C138/C138M**).

1.7.3.3(e) Owner's testing agency will conduct concrete strength tests by making and standard curing test specimens in accordance with ASTM C31/C31M and testing them according to **ASTM C39/C39M**. Unless otherwise specified, concrete strength test specimens for acceptance will be tested at 28 days.

1.7.3.4 *Additional testing and inspection services*—If specified, Owner's testing agency will perform additional testing and inspection services (a) through (e) to verify compliance with Contract Documents:

(a) Inspect concrete batching, mixing, and delivery operations.

(b) Inspect forms, foundation preparation, reinforcement, embedded items, reinforcement placement, 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 manufacturer's report for shipment of cement, reinforcement, and prestressing tendons, and conduct laboratory tests or spot checks of materials received for compliance with specifications.

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

1.7.3.5 *Other testing services as needed*—Contractor shall pay for the following testing services performed 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 because of failure to meet specification requirements.

1.7.4 *Tests on hardened concrete in place*

1.7.4.1 *General*—If necessary, Owner's testing agency will perform tests on hardened concrete. Testing shall be at Contractor's expense if this Specification requires tests to verify strength of concrete in structure and subsequent testing confirms concrete does not meet acceptance criteria.

Contractor shall not be responsible for costs if tests are not required by this Specification or subsequent testing confirms concrete meets acceptance criteria.

1.7.4.2 *Nondestructive tests for uniformity*—Use of the rebound hammer in accordance with **ASTM C805/C805M** or the pulse-velocity method in accordance with **ASTM C597** may be specified by Architect/Engineer to evaluate uniformity of in-place concrete or to select areas to be cored. These methods shall not be used to evaluate in-place strength.

1.7.4.3 *Core tests*

1.7.4.3(a) If concrete strength is in doubt and a core is required for other reasons, cores 1.7.6.1(b) or core testing is required.

will be obtained, moisture conditioned, prepared, and tested in accordance with **ASTM C42/C42M**, unless otherwise specified. Cores will be tested no earlier than 5 days after drilling or last wetting and no later than 7 days after cores were drilled from structure, unless otherwise specified.

1.7.4.3(b) At least three cores will be taken from each area of in-place concrete that is considered potentially deficient as defined in 1.7.6.1(b). Architect/Engineer determines location of cores. If, before testing, cores show evidence of having been damaged, replacement cores will be taken.

1.7.4.3(c) Unless otherwise specified, fill core holes with concrete or mortar of strength equal to or greater than original concrete, and provide curing as specified in **5.3.6.5** for at least 3 days.

1.7.4.4 Floor flatness and levelness—Unless otherwise specified, floor flatness and levelness will be measured in accordance with **ASTM E1155**.

1.7.5 Evaluation of concrete strength tests

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

1.7.5.2 Core tests—Core test results will be evaluated by Architect/Engineer and are valid only if tests are conducted in accordance with **ASTM C42/C42M**. Do not use core tests in place of standard-cured specimens specified in 1.7.5.1 for initial acceptance testing of concrete.

1.7.5.3 In-place strength tests

1.7.5.3(a) Results of in-place strength tests will be evaluated by Architect/Engineer and are valid only if tests are conducted using properly calibrated equipment in accordance with recognized standard procedures and an acceptable correlation between test results and concrete compressive strength is established and submitted.

1.7.5.3(b) The use of cast-in-place cylinders in accordance with **ASTM C873/C873M** does not require correlation; however, measured strengths shall be corrected using factors in **ASTM C39/C39M** if length-diameter ratio is less than 1.75.

1.7.6 Acceptance of concrete strength

1.7.6.1 Standard-cured strength test specimens—Strength of concrete is satisfactory provided that the criteria of 1.7.6.1(a) and 1.7.6.1(b) are met.

1.7.6.1(a) Every average of three consecutive strength tests equals or exceeds specified compressive strength, f'_c .

1.7.6.1(b) No strength test result falls below f'_c by more than 3.5 MPa if f'_c is 35 MPa or less, or by more than $0.10f'_c$ if f'_c is greater than 35 MPa.

1.7.6.2 If either of the two requirements in 1.7.6.1 is not met, steps shall be taken to increase the average of subsequent strength test results.

1.7.6.3 Core tests—Strength of concrete in area represented by core tests is considered satisfactory if average compressive strength of cores is at least 85 percent of f'_c , and if no single core strength is less than 75 percent of f'_c . Addi-

tional testing of cores extracted from locations represented by erratic core strength results will be permitted.

1.7.6.4 In-place tests—In-place tests shall not be used as the sole basis for accepting or rejecting concrete, but may be used, if specified, to evaluate concrete if strength test results of standard molded and cured cylinders fail to meet the criteria in 1.7.6.1.

1.7.7 Acceptance of steel fiber-reinforced concrete—Unless otherwise specified, steel fiber-reinforced concrete designated in Contract Documents for use in members to provide shear resistance is satisfactory if the criteria of 1.7.7.1 through 1.7.7.3 are met.

1.7.7.1 Compressive strength of cylinders prepared and tested in accordance with 1.7.3.3(e) comply with the criteria of 1.7.6.1.

1.7.7.2 Residual strength obtained from flexural testing in accordance with **ASTM C1609/C1609M** at midspan deflection of 1/300 of span length is not less than 1.7.7.2(a) and 1.7.7.2(b).

1.7.7.2(a) 90 percent of the measured first-peak strength obtained from the flexural test.

1.7.7.2(b) 90 percent of the strength corresponding to $0.62\sqrt{f'_c}$.

1.7.7.3 Residual strength obtained from flexural testing in accordance with **ASTM C1609/C1609M** at midspan deflection of 1/150 of span length is not less than 1.7.7.3(a) and 1.7.7.3(b).

1.7.7.3(a) 75 percent of the measured first-peak strength obtained from the flexural test.

1.7.7.3(b) 75 percent of the strength corresponding to $0.62\sqrt{f'_c}$.

1.7.8 Field acceptance of concrete

1.7.8.1 Air content—If measured air content at point of delivery is greater than the upper limit of **4.2.2.6(c)**, a check test of air content will be performed on a new sample from point of delivery. If check test fails, concrete has failed to meet the requirements of this Specification. If measured air content is less than lower limit of **4.2.2.6(c)**, adjustments will be permitted in accordance with **ASTM C94/C94M**, unless otherwise specified. If check test of the adjusted mixture fails, concrete has failed to meet the requirements of this Specification.

1.7.8.2 Slump and slump flow—If measured slump or slump flow at point of delivery is greater than specified in **4.2.2.1** or **4.2.2.2**, respectively, a check test will be performed on a new sample from point of delivery. If check test fails, concrete is considered to have failed to meet the requirements of this Specification. If measured slump or slump flow is less than specified in **4.2.2.1** or **4.2.2.2**, respectively, adjustments will be permitted in accordance with **ASTM C94/C94M**, unless otherwise specified. If the test of slump or slump flow of the adjusted mixture fails, concrete is considered to have failed to meet the requirements of this Specification.

1.7.8.3 Temperature—If measured concrete temperature at point of delivery is not within the limits of **4.2.2.4**, or as otherwise specified, a check test will be performed at a new location in the sample. If check test fails, concrete is considered to have failed to meet the requirements of this Specification.

1.8—Acceptance of structure

1.8.1 General—Completed concrete Work shall conform to applicable requirements of this Specification and Contract Documents.

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

1.8.1.2 Concrete Work that fails to meet one or more requirements in Contract Documents and cannot be brought into compliance is subject to rejection.

1.8.1.3 Repair rejected concrete Work by removing and replacing or by additional construction to strengthen or otherwise satisfy project requirement as directed by Architect/Engineer. To bring rejected Work into compliance, use repair methods that meet applicable requirements for function, durability, dimensional tolerances, and appearance as determined by Architect/Engineer.

1.8.1.4 Submit proposed repair methods, materials, and modifications needed to repair concrete Work to meet requirements in Contract Documents.

1.8.1.5 Repair concrete Work as necessary to be in compliance with Contract Documents.

1.8.2 Dimensional tolerances

1.8.2.1 Unless otherwise specified, construction tolerances shall conform to **ACI 117M**.

1.8.2.2 Concrete members with dimensions smaller than permitted tolerances may be considered deficient in strength and subject to provisions of 1.8.4.

1.8.2.3 Concrete members with dimensions larger than permitted tolerances are subject to rejection. Remove excess materials if required by Architect/Engineer.

1.8.2.4 Concrete surfaces that do not meet tolerances are subject to rejection.

1.8.2.5 Slabs not meeting tolerances may be corrected, provided they are brought into compliance with 1.8.3, 1.8.4, and 1.8.5.

1.8.2.6 Concrete members cast against formwork surfaces not meeting slope or planeness limitations are subject to rejection.

1.8.3 Finishes

1.8.3.1 Concrete surfaces not meeting the requirements of 5.3.3 shall be brought into compliance in accordance with 1.8.1.

1.8.4 Strength of structure

1.8.4.1 Criteria for determining potential strength deficiency—Strength may be considered deficient if Work fails to comply with requirements that control strength of structure including, but not limited to, conditions given in 1.8.4.1(a) through 1.8.4.1(f).

1.8.4.1(a) Concrete strength not meeting requirements of 1.7.6.1(b) and Contract Documents.

1.8.4.1(b) Reinforcement size, quantity, grade, position, or arrangement not meeting requirements in Contract Documents.

1.8.4.1(c) Concrete elements exceeding tolerances specified in Contract Documents.

1.8.4.1(d) Curing and protection not meeting requirements in Contract Documents.

1.8.4.1(e) Mechanical injury, construction fires, or premature removal of formwork resulting in deficient strength.

1.8.4.2 Action required if strength is potentially deficient—If structure strength is considered potentially deficient, actions given in 1.8.4.2(a) through 1.8.4.2(e) may be required by Architect/Engineer.

1.8.4.2(a) Structural analysis, additional testing, or both.

1.8.4.2(b) Core tests in accordance with **ASTM C42/C42M**.

1.8.4.2(c) Load tests may be required if core testing is inconclusive or impractical or if structural analysis does not confirm the safety of the structure.

1.8.4.2(d) Strengthening with additional construction or replacement of concrete Work shown to be deficient by structural analysis or by results of a load test.

1.8.4.2(e) Submittal of documentation for repair work proposed to bring strength-deficient Work into compliance with Contract Documents.

1.8.5 Durability

1.8.5.1 Criteria for determining potential durability deficiency—Durability of concrete Work may be considered deficient if it fails to comply with requirements that control structure durability, including, but not limited to, conditions given in 1.8.5.1(a) through 1.8.5.1(f).

1.8.5.1(a) Strength failing to comply with 1.7.6.1(b) or Contract Documents.

1.8.5.1(b) Materials for concrete not conforming to requirements in 4.2.1.1 to 4.2.1.7 or Contract Documents.

1.8.5.1(c) Concrete not conforming to durability requirements in 4.2.2.6 or Contract Documents.

1.8.5.1(d) Curing and protection not meeting requirements in 5.3.6 or Contract Documents.

1.8.5.1(e) If measured, internal early-age concrete temperatures or temperature differences greater than specified in **Sections 8 and 13** or in Contract Documents.

1.8.5.1(f) Concrete exceeding the maximum allowable chloride ion content requirements in Table 4.2.2.6(e) or Contract Documents.

1.8.5.2 Action required if durability is potentially deficient—If structure durability is considered potentially deficient, actions given in 1.8.5.2(a) through 1.8.5.2(e) may be required by Architect/Engineer.

1.8.5.2(a) Obtain and test samples of constituent materials used in the concrete.

1.8.5.2(b) Obtain concrete samples from structure by coring, sawing, or other acceptable means.

1.8.5.2(c) Laboratory evaluation of concrete and concrete materials to assess concrete's resistance to weathering, chemical attack, abrasion, or other deterioration causes, and to protect reinforcement and metallic embedments from corrosion.

1.8.5.2(d) Repair or replace concrete rejected for durability deficiency as directed by Architect/Engineer.

1.8.5.2(e) Submittal of documentation for repair work proposed to bring durability-deficient Work into compliance with Contract Documents.

1.9—Protection of in-place concrete

1.9.1 Loading and support of structural member or structure—Do not allow construction loads to exceed loads that a structural member or structure is capable of supporting safely without damage. Provide supplemental support if construction loads are expected to exceed safe load capacity.

1.9.2 Protection from mechanical damage—Protect concrete from damage due to construction traffic, equipment, and materials. During the curing period, protect concrete from damage by mechanical disturbances, including load-induced stresses, shock, and vibration.

1.9.3 Protection from environmental conditions—During the curing period, protect concrete from damage due to weather.

SECTION 2—FORMWORK AND FORMWORK ACCESSORIES

2.1—General

2.1.1 Scope—This Section covers requirements for design and construction of formwork.

2.1.2 Submittals

2.1.2.1 Unless otherwise specified, comply with 2.1.2.1(a) through 2.1.2.1(f).

2.1.2.1(a) Form-facing materials—Submit product information on proposed form-facing materials if different from that specified in 2.2.1.1.

2.1.2.1(b) Construction and movement joints—Submit location and detail of construction and movement joints if different from those indicated in Contract Documents.

2.1.2.1(c) Testing for formwork removal—Submit method and correlation data for determining concrete strength for formwork removal if test methods of 2.3.4.2(b) through 2.3.4.2(d) are specified or proposed.

2.1.2.1(d) Reshoring and backshoring procedure—Submit procedure for reshoring and backshoring, including drawings signed and sealed by a licensed design engineer. Include on shop drawings the formwork removal procedure and magnitude of construction loads used for design of reshoring or backshoring system. Indicate in procedure the magnitude of live and dead loads assumed for required capacity of structure at time of reshoring or backshoring and in-place concrete strength required at time of execution.

2.1.2.1(e) Submit manufacturer's product data sheet on formwork release agent for use on each form-facing material.

2.1.2.1(f) Submit manufacturer's product data sheet on form liner proposed for use with each formed surface.

2.1.2.2 Comply with 2.1.2.2(a) through 2.1.2.2(f) if specified in Contract Documents.

2.1.2.2(a) Submit shop drawings for formwork, shoring, reshoring, and backshoring. If specified in Contract Documents or mandated by jurisdiction where Work will be performed, shop drawings shall be signed and sealed by a licensed design engineer.

2.1.2.2(b) Submit design calculations for formwork, shoring, reshoring, and backshoring. If specified in Contract Documents or mandated by jurisdiction where Work will be

performed, design calculations shall be signed and sealed by a licensed design engineer.

2.1.2.2(c) Submit manufacturer's data sheet on form ties.

2.1.2.2(d) Submit manufacturer's data sheet on expansion joint materials.

2.1.2.2(e) Submit manufacturer's data sheet on waterstop materials and splices.

2.1.2.2(f) Submit manufacturer's data sheet for formwork materials not listed in 2.1.2.1 or 2.1.2.2(c) through 2.1.2.2(e) that are to be left in place within Work.

2.2—Products

2.2.1 Materials

2.2.1.1 Form-facing materials—Unless otherwise specified, form-facing material in contact with concrete shall be lumber, plywood, tempered concrete-form-grade hardboard, metal, plastic, or treated paper that creates specified appearance and texture of concrete surface.

2.2.1.2 Formwork accessories—Use commercially manufactured formwork accessories, including ties and hangers. Use form ties with ends or end fasteners that can be removed without damage to concrete. Where indicated in Contract Documents, use form ties with integral water barrier plates or other acceptable positive water barriers in walls. Unless otherwise specified, the break-back distance for ferrous ties shall be at least 20 mm for surface finish SF-2 or surface finish SF-3, as defined in 5.3.3.2. Where indicated in Contract Documents or if specified break-back distance is less than 20 mm, use coated or corrosion-resistant ties.

2.2.1.3 Formwork release agent—Use commercially manufactured formwork release agent that reduces formwork moisture absorption, inhibits bond with concrete, and does not stain exposed concrete surfaces.

2.2.1.4 Expansion joint filler—Preformed expansion joint filler shall conform to **ASTM D994/D994M, D1751, or D1752**.

2.2.1.5 Other embedded items—Use waterstops, sleeves, inserts, anchors, and other embedded items of material and design as indicated in Contract Documents. Waterstop materials shall conform to **CRD-C513** for rubber waterstop or **CRD-C572** for polyvinyl chloride waterstop. Use factory-manufactured premolded mitered corners.

2.2.1.6 Chamfer—Unless otherwise specified, use lumber materials with dimensions of 20 x 20 mm.

2.2.2 Performance and design requirements

2.2.2.1 Contractor is responsible for design of formwork.

2.2.2.2 Design formwork, shores, reshores, and backshores to support loads transmitted to them and to comply with applicable building code requirements. Design formwork and shoring for load redistribution resulting from stressing of post-tensioned reinforcement. Design formwork to maintain specified tolerances while withstanding pressures resulting from placement method, rate of placement, and vibration of concrete.

2.2.2.3 Unless otherwise specified, do not use earth cuts as forms for vertical or sloping surfaces.

2.2.2.4 Unless otherwise specified, limit deflection of facing materials for concrete surfaces exposed to view.

1/240 of center-to-center spacing of facing supports. For architectural concrete, refer to 6.2.2.1(a).

2.2.2.5 Construction and movement joints

2.2.2.5(a) Unless otherwise specified, submit details and locations of construction joints in accordance with the following requirements:

- (a) Locate joints within middle one-third of spans of slabs, beams, and girders. If a beam intersects a girder within the middle one-third of girder span, the distance between the construction joint in the girder and the edge of the beam shall be at least twice the width of the larger member.
- (b) For members with post-tensioning tendons, locate joints where tendons pass through centroid of concrete section.
- (c) Locate joints in walls and columns at underside of slabs, beams, or girders and at tops of footings or slabs.
- (d) Make joints perpendicular to main reinforcement.

2.2.2.5(b) Provide movement joints as indicated in Contract Documents or in accepted alternative locations.

2.2.2.5(c) Provide keyways as indicated in Contract Documents. Unless otherwise specified, longitudinal keyways indicated in Contract Documents shall be at least 40 mm deep, measured perpendicular to the plane of the joint.

2.2.2.5(d) Design formwork to accommodate waterstop materials in joints at locations indicated in Contract Documents.

2.2.2.6 Provide temporary openings in formwork if needed to facilitate cleaning and inspection.

2.2.2.7 For post-tensioned applications, ensure that formwork allows movement resulting from application of prestressing force.

2.2.2.8 Fabricate formwork joints to inhibit leakage of mortar.

2.3—Execution

2.3.1 Construction and erection of formwork

2.3.1.1 Construct formwork to inhibit leakage of mortar from fresh concrete at joints in formwork and produce surface finish in accordance with 5.3.3.2. Remove leaked mortar from formwork joints before reuse.

2.3.1.2 Unless otherwise specified, place chamfer strips in corners of formwork to produce beveled edges on permanently exposed surfaces. Unless otherwise specified, do not bevel reentrant corners or edges of formed joints in concrete.

2.3.1.3 Inspect formwork and remove foreign material before concrete is placed.

2.3.1.4 At construction joints, lap form-facing materials over the concrete of previous placement. Place formwork against hardened concrete so offsets at construction joints conform to specified tolerances.

2.3.1.5 Unless otherwise specified, construct formwork so concrete surfaces conform to tolerances in ACI 117M. Unless otherwise specified, class of surface for offset between adjacent pieces of formwork facing material shall be in accordance with 5.3.3.

2.3.1.6 Provide positive means, such as wedges or jacks, to adjust shores and struts. Do not make adjustments in

formwork after concrete has reached initial setting. Brace formwork to resist lateral deflection and lateral instability.

2.3.1.7 To maintain specified elevation and thickness within tolerances, install formwork to compensate for deflection and anticipated settlement in formwork during concrete placement. Set formwork and intermediate screed strips for slabs to produce designated elevation, camber, and contour of finished surface before formwork removal. If using vibrating screeds or roller pipe screeds, edge forms and screed strips shall be strong enough to support such equipment.

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

2.3.1.9 Provide anchoring and bracing to control upward and lateral movement of formwork system.

2.3.1.10 Construct formwork for openings to facilitate removal and to produce opening dimensions as specified and within tolerances.

2.3.1.11 Provide runways for mobile equipment. Support runways directly on formwork or structural members. Do not support runways on reinforcement. Loading applied by runways shall not exceed capacity of formwork or structural members.

2.3.1.12 Position and secure sleeves, inserts, anchors, and other embedded items so that embedded items are positioned within ACI 117M tolerances.

2.3.1.13 Position and support expansion joint materials, waterstops, and other embedded items to prevent displacement. Fill voids in sleeves, inserts, and anchor slots temporarily with removable material to prevent concrete entry into voids.

2.3.1.14 Clean surfaces of formwork and embedded materials of mortar, grout, and foreign materials before placing concrete.

2.3.1.15 Cover formwork surfaces with an acceptable material that inhibits bond with concrete. If formwork release agent is used, apply to formwork surfaces in accordance with manufacturer's recommendations before placing reinforcement. Remove excess release agent on formwork before placing concrete. Do not allow formwork release agent to contact reinforcement or hardened concrete against which fresh concrete is to be placed.

2.3.1.16 Erect form-facing materials to produce surface finish in accordance with 5.3.3. Repair or replace used form-facing materials that do not produce surface finish in accordance with 5.3.3.

2.3.1.17 Install formwork to accommodate waterstop materials. Locate waterstops in joints where indicated in Contract Documents. Minimize number of splices in waterstop. Splice waterstops in accordance with manufacturer's written instructions. Install factory-manufactured premolded mitered corners.

2.3.2 Removal of formwork

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

2.3.2.2 If formed sloping surfaces require finishing, remove top forms as soon as removal will not allow concrete

to sag. Perform repairs and finishing operations required. If forms are removed before end of specified curing period, provide curing and protection in accordance with **Section 5**.

2.3.2.3 Do not damage concrete during removal of vertical formwork for columns, walls, and sides of beams. Perform repair and finishing operations required on vertical surfaces. If forms are removed before end of specified curing period, provide curing and protection in accordance with **Section 5**.

2.3.2.4 Unless otherwise specified, 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 .

2.3.2.5 Unless otherwise specified, form-facing material and horizontal facing support members are permitted to be removed in accordance with accepted formwork shop drawings before in-place concrete reaches specified compressive strength if formwork system is designed to allow facing removal without removing shores or other vertical supports. If forms are removed before end of specified curing period, provide curing and protection in accordance with **Section 5**.

2.3.2.6 Unless otherwise specified for post-tensioned structures, do not remove formwork supports until stressing records have been accepted by Architect/Engineer.

2.3.2.7 After ends or end fasteners of form ties have been removed, repair tie holes in accordance with **5.3.7.2**.

2.3.3 Reshoring and backshoring

2.3.3.1 If the reshoring and backshoring procedure described in 2.1.2.1(d) is submitted, do not allow structural members to be loaded with combined dead and construction loads in excess of loads indicated in the accepted procedure.

2.3.3.2 If the reshoring and backshoring procedure described in 2.1.2.1(d) is submitted, install and remove reshores or backshores in accordance with accepted procedure.

2.3.3.3 In multistory buildings, place reshoring or backshoring over a sufficient number of stories to distribute weight of newly placed concrete, forms, and construction live loads in accordance with reshoring and backshoring procedure in 2.1.2.1(d).

2.3.3.4 Locate reshores and backshores in accordance with the reshoring and backshoring procedure in 2.1.2.1(d).

2.3.4 Strength of concrete required for removal of formwork

2.3.4.1 If removal of formwork, reshoring, or backshoring is based on concrete reaching a specified in-place strength, mold and field-cure cylinders in accordance with **ASTM C31/C31M**. Test cylinders in accordance with **ASTM C39/C39M**.

2.3.4.2 Alternatively, if specified, use one or more of the methods listed in 2.3.4.2(a) through 2.3.4.2(d) to evaluate in-place concrete strength for formwork removal.

2.3.4.2(a) Tests of cast-in-place cylinders in accordance with **ASTM C873/C873M**. This option is limited to slabs with concrete depths from 125 to 300 mm.

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

2.3.4.2(c) Pullout strength in accordance with **ASTM C900**.

2.3.4.2(d) Maturity method in accordance with **ASTM C1074**.

2.3.5 Field survey controls

2.3.5.1 Establish and maintain survey controls and benchmarks in an undisturbed condition until completion of the concrete structure and its building envelope.

2.3.5.2 Before concrete is cast, inspect formwork for conformance to Contract Documents. If specified, notify Special Inspection or Owner's quality assurance inspection.

SECTION 3—REINFORCEMENT AND REINFORCEMENT SUPPORTS

3.1—General

3.1.1 Scope—This Section covers materials, fabrication, placement, and tolerances for steel reinforcement and reinforcement supports.

3.1.2 Submittals

3.1.2.1 Unless otherwise specified, comply with 3.1.2.1(a) through 3.1.2.1(j) before fabrication and execution.

3.1.2.1(a) Reinforcement—Submit manufacturer's certified test report for reinforcement.

3.1.2.1(b) Placing drawings—Submit placing drawings showing fabrication dimensions and placement locations of reinforcement and reinforcement supports. Placing drawings shall indicate locations of splices, lengths of lap splices, and details of mechanical and welded splices.

3.1.2.1(c) Splices—Submit request with locations and details of contact and non-contact lap, end-bearing, mechanical, and welded splices not indicated in Contract Documents.

3.1.2.1(d) Mechanical splices—Submit data on mechanical splices demonstrating compliance with 3.2.1.2(d) and 3.2.1.9.

3.1.2.1(e) Column dowels—Submit request to place column dowels without using templates.

3.1.2.1(f) Field bending or straightening—Submit request and procedure to field-bend or straighten reinforcing bars partially embedded in concrete at locations not indicated in Contract Documents.

3.1.2.1(g) Epoxy-coated reinforcement—If epoxy-coated steel reinforcement is specified, submit either: 1) Concrete Reinforcing Steel Institute (CRSI) Epoxy Coating Plant Certification; or 2) inspection and quality-control program of plant applying epoxy coating if proposed plant is not certified in accordance with CRSI Epoxy Coating Plant Certification Program.

3.1.2.1(h) Field cutting of reinforcing bars—Submit request for field cutting, including location and type of bar to be cut and reason field cutting is required. For flame cutting stainless steel reinforcement, include field temperature control procedure.

3.1.2.1(i) Supports—If coated reinforcement is required, submit description of reinforcement supports and materials for fastening coated reinforcement if not in conformance with **CRSI RB4.1**.

3.1.2.1(j) Bar mats—Submit manufacturer's test report on bar mats, including test reports on bars used to fabricate bar mats.

3.1.3 Material storage and handling

3.1.3.1 Handle and store reinforcement to maintain fabricated shape and material condition as required in 3.3.1.

3.1.3.2 When handling and storing coated reinforcement, use equipment and methods that do not damage the coating. If stored outdoors for more than 2 months, cover coated reinforcement with opaque protective material.

3.2—Products

3.2.1 Materials

3.2.1.1 Steel reinforcing bars—Reinforcing bars shall be deformed, except spirals, load-transfer dowels, and welded wire reinforcement, which may be plain. Reinforcing bars shall be grades, types of steel, and sizes required by Contract Documents and shall conform to one of the following:

- (a) **ASTM A615/A615M**
- (b) **ASTM A706/A706M**
- (c) **ASTM A955/A955M**
- (d) **ASTM A996/A996M**, rail-steel bars shall be Type R; axle steel bars shall be Type A
- (e) **ASTM A1035/A1035M**

3.2.1.2 Coated reinforcing bars—If specified in Contract Documents, use zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcing bars.

3.2.1.2(a) Unless otherwise specified, zinc-coated (galvanized) reinforcing bars shall conform to **ASTM A767/A767M** and other requirements as specified in Contract Documents. Coating damage incurred during shipment, storage, handling, and placing of zinc-coated (galvanized) reinforcing bars shall be repaired in accordance with **ASTM A780/A780M**. Damaged areas shall not exceed 2 percent of surface area in each linear meter of each bar or bar shall not be used. The 2 percent limit on maximum allowed damaged coating area shall include previously repaired areas damaged before shipment as required by ASTM A767/A767M.

3.2.1.2(b) 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 Concrete Reinforcing Steel Institute (CRSI) Epoxy Coating Plant Certification Program or an equivalent program acceptable to Architect/Engineer. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated reinforcing bars shall be repaired. Repair damaged coating areas with patching material conforming to ASTM A775/A775M or ASTM A934/A934M as applicable and in accordance with material manufacturer's written recommendations. Damaged coating area shall not exceed 2 percent of surface area in each linear meter of each bar or bar shall not be used. The 2 percent limit on damaged coating area shall include repaired areas damaged before shipment as required by ASTM A775/A775M or A934/A934M as applicable. Fading of coating color shall not be cause for rejection of epoxy-coated reinforcing bars.

3.2.1.2(c) Zinc and epoxy dual-coated reinforcing bars shall conform to **ASTM A1055/A1055M**. Coating damage incurred during shipment, storage, handling, and placing of zinc and epoxy dual-coated reinforcing bars shall be

repaired. Repair damaged coating areas with patching material conforming to ASTM A1055/A1055M and in accordance with material manufacturer's written recommendations. Damaged coating area shall not exceed 2 percent of surface area in each linear meter of each bar or bar shall not be used. The 2 percent limit on damaged coating area shall include repaired areas damaged before shipment as required by ASTM A1055/A1055M. Fading of coating color shall not be cause for rejection of zinc and epoxy dual-coated reinforcing bars.

3.2.1.2(d) Mechanical splices for galvanized reinforcing bars shall be galvanized or coated with dielectric material. Mechanical splices used with epoxy-coated or dual-coated reinforcing bars shall be coated with dielectric material.

3.2.1.3 Bar mats—If specified, bar mats shall conform to **ASTM A184/A184M**. When welding bars, comply with 3.2.2.2. If coated bar mats are required, repair damaged coating in accordance with 3.2.2.2(b).

3.2.1.4 Headed reinforcing bars—Headed reinforcing bars shall conform to **ASTM A970/A970M**, including Annex A1, and other specified requirements.

3.2.1.5 Wire—Use plain or deformed wire as indicated in Contract Documents. Plain and deformed wire shall conform to 3.2.1.5(a) through 3.2.1.5(c)

3.2.1.5(a) Plain or deformed steel wire shall conform to **ASTM A1064/A1064M**.

3.2.1.5(b) Stainless steel wire shall conform to **ASTM A1022/A1022M**.

3.2.1.5(c) Epoxy-coated wire shall conform to **ASTM A884/A884M**. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated wires shall be repaired. Repair damaged coating areas with patching material in accordance with material manufacturer's written recommendations. If damaged area exceeds 2 percent of surface area in each linear meter of each wire, wire shall not be used.

The 2 percent limit on damaged coating area shall include repaired areas damaged before shipment as required by ASTM A884/A884M. Fading of coating color shall not be cause for rejection of epoxy-coated wire reinforcement.

3.2.1.6 Welded wire reinforcement—Use welded wire reinforcement specified in Contract Documents and conforming to 3.2.1.6(a) through 3.2.1.6(e).

3.2.1.6(a) Plain welded wire reinforcement shall conform to ASTM A1064/A1064M, with welded intersections spaced no greater than 300 mm apart in direction of principal reinforcement.

3.2.1.6(b) Deformed welded wire reinforcement shall conform to ASTM A1064/A1064M, with welded intersections spaced no greater than 400 mm apart in direction of principal reinforcement.

3.2.1.6(c) Epoxy-coated welded wire reinforcement shall conform to ASTM A884/A884M. Coating damage incurred during shipment, storage, handling, and placing of epoxy-coated welded wire reinforcement shall be repaired in accordance with ASTM A884/A884M. Repair damaged coating areas with patching material in accordance with material manufacturer's written recommendations. If damaged area

exceeds 2 percent of surface area in each linear meter of each wire or welded wire reinforcement, the sheet containing the damaged area shall not be used. The 2 percent limit on damaged coating area shall include repaired areas damaged before shipment as required by ASTM A884/A884M. Fading of coating color shall not be cause for rejection of epoxy-coated welded wire reinforcement.

3.2.1.6(d) Stainless steel welded wire reinforcement shall conform to **ASTM A1022/A1022M**.

3.2.1.6(e) Zinc-coated (galvanized) welded wire reinforcement shall conform to **ASTM A1060/A1060M**. Coating damage incurred during shipment, storage, handling, and placing of zinc-coated (galvanized) welded wire reinforcement shall be repaired in accordance with **ASTM A780/A780M**. Reinforcement shall not be used if area of damaged coating exceeds 2 percent of surface area in each linear meter of each wire or welded wire reinforcement, including previously repaired areas of damaged coating and excluding cut ends.

3.2.1.7 Headed shear stud reinforcement—Headed studs and headed stud assemblies shall conform to **ASTM A1044/A1044M**.

3.2.1.8 Reinforcement supports—Provide reinforcement support types within structure as required by Contract Documents. Reinforcement supports shall conform to **CRSI RB4.1**.

3.2.1.9 Mechanical splices—Mechanical splices shall develop at least 125 percent of the specified yield strength of bars being spliced.

3.2.2 Fabrication

3.2.2.1 Bending—Bend reinforcement cold. Fabricate reinforcement in accordance with fabricating tolerances of **ACI 117M**.

3.2.2.2 Welding

3.2.2.2(a) If welding steel reinforcing bars is specified, comply with **AWS D1.4/D1.4M** unless otherwise specified. Do not tack weld reinforcing bars. Welded assemblies of steel reinforcement produced under factory conditions, such as welded wire reinforcement, bar mats, and deformed bar anchors, are allowed.

3.2.2.2(b) After completing welds on zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcing bars, coat welds and repair damaged coating in accordance with requirements in 3.2.1.2(a), 3.2.1.2(b), or 3.2.1.2(c), respectively.

3.2.2.2(c) If welding stainless steel reinforcing bars, comply with **AWS D1.6/D1.6M**.

3.3—Execution

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

3.3.2 Placing

3.3.2.1 Tolerances—Place, support, and fasten reinforcement to maintain its location during concrete placement in

accordance with Contract Documents. Do not exceed tolerances specified in **ACI 117M** before concrete is placed.

3.3.2.2 Reinforcement relocation—If movement of reinforcement beyond specified placing tolerances is necessary to avoid interference with other reinforcement, conduits, or embedded items, submit resulting reinforcement arrangement. Placing concrete in area of relocated reinforcement is prohibited before receiving acceptance from Architect/Engineer.

3.3.2.3 Concrete cover—Unless otherwise specified, concrete cover for reinforcement shall conform to 3.3.2.3(a) through 3.3.2.3(e). Concrete cover tolerances shall comply with **ACI 117M**. Position tie wire ends away from exposed concrete surfaces.

3.3.2.3(a) Nonprestressed cast-in-place concrete members shall have concrete cover for reinforcement given in Table 3.3.2.3(a).

Table 3.3.2.3(a)—Concrete cover for cast-in-place nonprestressed concrete members

Concrete exposure	Member	Reinforcement	Specified cover, mm
Cast against and permanently in contact with ground	All	All	75
Exposed to weather or in contact with ground	All	No. 19 through No. 57 bars	50
		No. 16 bar, MW200 or MD200 wire, and smaller	40
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 43 and No. 57 bars	40
	Beams, columns, pedestals, and tension ties	No. 36 bar and smaller	20
		Primary reinforcement, stirrups, ties, spirals, and hoops	40

3.3.2.3(b) Cast-in-place prestressed concrete members shall have concrete cover for reinforcement, ducts, and end fittings given in Table 3.3.2.3(b).

Table 3.3.2.3(b)—Concrete cover for cast-in-place prestressed concrete members

Concrete exposure	Member	Reinforcement	Specified cover, mm
Cast against and permanently in contact with ground	All	All	75
Exposed to weather or in contact with ground	Slabs, joists, and walls	All	25
	All other	All	40

Not exposed to weather or in contact with ground	Slabs, joists, and walls	All	20
	Beams, columns, and tension ties	Primary reinforcement	40
		Stirrups, ties, spirals, and hoops	25

3.3.2.3(c) Precast nonprestressed or prestressed concrete members manufactured under plant conditions shall have concrete cover for reinforcement, ducts, and end fittings given in Table 3.3.2.3(c).

Table 3.3.2.3(c)—Concrete cover for precast nonprestressed or prestressed concrete members manufactured under plant conditions

Concrete exposure	Member	Reinforcement	Specified cover, mm
Exposed to weather or in contact with ground	Walls	No. 43 and No. 57 bars; tendons larger than 40 mm diameter	40
		No. 36 bars and smaller; MW200 and MD200 wire, and smaller; tendons and strands 40 mm diameter and smaller	20
	All other	No. 43 and No. 57 bars; tendons larger than 40 mm diameter	50
		No. 19 through No. 36 bars; tendons and strands larger than 16 mm diameter through 40 mm diameter	40
		No. 16 bar, MW200 or MD200 wire, and smaller; tendons and strands 16 mm diameter and smaller	30
Not exposed to weather or in contact with ground	Slabs, joists, and walls	No. 43 and No. 57 bars; tendons larger than 40 mm diameter	30
		Tendons and strands 40 mm diameter and smaller	20
		No. 36 bar, MW200 or MD200 wire, and smaller	16
	Beams, columns, pedestals, and tension ties	Primary reinforcement	Greater of d_b and 16 and need not exceed 40
		Stirrups, ties, spirals, and hoops	10

3.3.2.3(d) For bundled bars, concrete cover shall be the smaller of (a) and (b):

- (a) Equivalent diameter of the bundle
- (b) 50 mm, and for concrete cast against and permanently in contact with ground, the cover shall be 75 mm.

3.3.2.3(e) For headed shear stud reinforcement, concrete cover for the heads and base rails shall be the same as for surrounding reinforcement.

3.3.2.4 Reinforcement supports—Install reinforcement supports in accordance with **CRSI RB4.1**.

3.3.2.4(a) In walls reinforced with epoxy-coated or dual-coated reinforcement, use epoxy-coated, polymer-coated, or composite spacers between reinforcement layers to maintain spacing.

3.3.2.4(b) Fasten epoxy-coated or dual-coated reinforcement with tie wires coated with epoxy or other polymer.

3.3.2.4(c) Support stainless steel reinforcement bars using stainless steel, plastic, or precast concrete bar supports. Fasten stainless steel reinforcement with stainless steel or plastic-coated tie wire.

3.3.2.5 Welded wire reinforcement—Support welded wire reinforcement in accordance with **CRSI RB4.1** to maintain positioning during concrete placement.

3.3.2.5(a) Welded wire reinforcement in slabs on composite steel deck and slabs-on-ground—Reinforcement shall be placed into position before concrete placement. Unless otherwise specified, do not extend welded wire reinforcement through movement joints. Place reinforcement as indicated in Contract Documents. If reinforcement less than MW26 or MD26 is specified, the continuous support spacing shall not exceed 300 mm. Reinforcement nearest edge of slab shall be no farther from edge of slab than the greater of specified cover or 50 mm. Unless otherwise specified, overlap parallel wires at edges of reinforcement not less than 50 mm.

3.3.2.5(b) Welded wire reinforcement in elevated formed slabs, slabs on noncomposite steel deck, and members not covered in 3.3.2.5(a)—Use sheets of welded wire reinforcement. Place and support reinforcement before concrete placement to maintain location within tolerances indicated for nonprestressed reinforcement in **ACI 117M**. If reinforcement less than MW26 or MD26 is specified, the continuous support spacing shall not exceed 300 mm perpendicular to the direction of span. Lap splice edges and ends of welded wire reinforcement sheets as indicated in Contract Documents.

3.3.2.6 Dowels—Deformed bar dowels shall be secured into position using templates or by tying into position before concrete placement.

3.3.2.7 Splices—Splice reinforcement as indicated in Contract Documents. Mechanical splices for reinforcing bars not indicated in Contract Documents shall not be used unless accepted by Architect/Engineer. Remove coating on reinforcing bar in area of mechanical splice if required by splice manufacturer. After installing mechanical splices on zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcing bars, repair damaged coating and areas of removed coating in accordance with 3.2.1.2(a), 3.2.1.2(b), or 3.2.1.2(c). Coat exposed parts of mechanical splices used on coated bars with same material used to repair damaged coating.

3.3.2.8 Field bending or straightening—Do not field bend reinforcing bars partially embedded in concrete unless otherwise specified. If bending is permitted and unless other

methods are specified, bend or straighten reinforcing bars partially embedded in concrete in accordance with 3.3.2.8(a) through 3.3.2.8(d).

3.3.2.8(a) Cold bending—Reinforcing bar sizes No. 10 through No. 16 may be bent cold one time, provided reinforcing bar temperature is above 0°C. For other bar sizes, preheat reinforcing bars before field bending or straightening.

3.3.2.8(b) Preheating—Apply heat by methods that do not harm reinforcing bar material or cause damage to concrete. Preheat length of reinforcing bar equal to at least five bar diameters in each direction from center of bend but do not extend preheating below concrete surface. Do not allow temperature of reinforcing bar at concrete interface to exceed 250°C. Preheat temperature of reinforcing bar shall be between 600 and 650°C. Maintain preheat temperature until bending or straightening is complete.

Measure preheat temperature by temperature measurement crayons or pyrometer. Do not artificially cool heated reinforcing bars until bar temperature is less than 320°C. Heat shall not be applied to low-carbon chromium reinforcement complying with **ASTM A1035/A1035M**. Epoxy- and dual-coated reinforcing bars shall be heated by a method that does not damage the epoxy coating.

3.3.2.8(c) Bend diameters—Bend diameters shall conform to requirements of Table 3.3.2.8. In addition, beginning of bend shall not be closer to concrete surface than specified bend diameter.

Table 3.3.2.8—Minimum diameter of bend

Bar size	Inside bend diameter
No. 10 through 25	Six bar diameters
No. 10 through 16 stirrups and ties	Four bar diameters
No. 29, 32, and 36	Eight bar diameters
No. 43 and 57	Ten bar diameters

3.3.2.8(d) Repair of bar coatings—After field bending or straightening zinc-coated (galvanized), epoxy-coated, or zinc and epoxy dual-coated reinforcing bars, repair damaged coating in accordance with 3.2.1.2(a), 3.2.1.2(b), or 3.2.1.2(c).

3.3.2.9 Field cutting reinforcement—Field cut after acceptance by Architect/Engineer. Do not flame cut reinforcing bars conforming to ASTM A1035/A1035M or coated reinforcement conforming to **ASTM A775/A775M**, **A934/A934M**, **A1055/A1055M**, **A884/A884M**, or **A1060/A1060M**.

3.3.2.9(a) If zinc-coated (galvanized) reinforcing bars are cut in field, coat bar ends with a zinc-rich formulation used in accordance with manufacturer's recommendations, and repair damaged coating in accordance with 3.2.1.2(a).

3.3.2.9(b) If epoxy-coated reinforcing bars are cut in field, coat bar ends with same material used for repair of damaged coating, and repair damaged coating in accordance with 3.2.1.2(b).

3.3.2.9(c) If zinc and epoxy dual-coated reinforcing bars are cut in field, coat bar ends with same material used for repair of damaged coating, and repair damaged coating in accordance with 3.2.1.2(c).

3.3.2.9(d) Flame cutting of stainless steel reinforcement shall be in accordance with field temperature control procedure included with submittal 3.1.2.1(h).

3.3.2.10 Reinforcement through expansion joint—Do not continue reinforcement or other embedded metal items bonded to concrete through expansion joints. If specified, dowels may continue through expansion joints if unbonded on one side of the joint.

SECTION 4—CONCRETE MIXTURES

4.1—General

4.1.1 Scope—This Section covers requirements for materials, proportioning, production, and delivery of concrete.

4.1.2 Submittals

4.1.2.1 Mixture proportions—Concrete mixture proportions and characteristics.

4.1.2.1(a) Indicate proposed ranges of mixture proportions and changes in concrete materials to adjust concrete mixtures to accommodate changes in project conditions and comply with Contract Documents.

4.1.2.1(b) Include selected slump at the point of delivery. For self-consolidating concrete mixtures, include selected slump flow at the point of delivery and results of passing ability and static segregation, if specified.

4.1.2.2 Mixture strength data—Field test records used to establish the required average strength in accordance with 4.2.3.3.

4.1.2.3 Concrete materials—The information for concrete materials in 4.1.2.3(a) through 4.1.2.3(g), along with evidence demonstrating compliance with 4.2.1.

4.1.2.3(a) For cementitious materials: types, manufacturing locations, shipping locations, and certificates showing compliance with **ASTM C150/C150M**, **ASTM C595/C595M**, **ASTM C618**, **ASTM C989/C989M**, **ASTM C1157/C1157M**, or **ASTM C1240**.

4.1.2.3(b) For aggregates: types, sizes, pit or quarry locations, producers' names, aggregate supplier statement of compliance with **ASTM C33/C33M**, and unless otherwise specified, **ASTM C1293** expansion data not more than 24 months old.

4.1.2.3(c) For use of aggregates derived from crushed hydraulic-cement concrete or other recycled aggregates: documentation required in Contract Documents.

4.1.2.3(d) For lightweight aggregate for internal curing: aggregate supplier statement of compliance with **ASTM C1761/C1761M**.

4.1.2.3(e) For mineral fillers: types, quarry locations, producers' names, and supplier statement of compliance with **ASTM C1797**.

4.1.2.3(f) For admixtures: types, brand names, producers' names, manufacturer's technical data sheets, and certificates showing compliance with **ASTM C260/C260M**, **ASTM C494/C494M**, **ASTM C1017/C1017M**, or **ASTM D98**.

4.1.2.3(g) For water and ice: source of supply; if nonpotable source is proposed for use, documentation on effects of water on strength and setting time in compliance with

ASTM C1602/C1602M. If specified, documentation on optional requirements of ASTM C1602/C1602M.

4.1.2.4 Field test records—Data on materials and mixture proportions with supporting test results if field test records are used as the basis for selecting proportions and documenting conformance with specified requirements, in accordance with 4.2.3.4(a) or 4.2.3.4(b).

4.1.2.5 Trial mixture records—Data on materials and mixture proportions with supporting test results if trial mixture records are used as a basis for documenting compliance with specified requirements in accordance with 4.2.3.4(c).

4.1.2.6 Durability requirements—Documentation that concrete meets durability requirements of 4.2.2.6.

4.1.2.7 Resistance to alkali-silica reaction—Information on one of the options for resistance to alkali-silica reaction listed in 4.2.2.6(a).

4.1.2.8 Modulus of elasticity—If specified, modulus of elasticity test results in accordance with 4.2.2.8.

4.1.2.9 Mixture proportion adjustments—Except for those submitted in 4.1.2.1, requests for adjustments to mixture proportions or changes in materials made during the course of Work, along with supporting documentation showing conformance with Contract Documents.

4.1.2.10 Calcium chloride—Request to use calcium chloride and data demonstrating compliance with 4.2.2.6(e).

4.1.2.11 Volumetric batching—Request and description of method if concrete production by the volumetric batching method is proposed.

4.1.2.12 Limits on discharge—Request if maximum time limit or limit on mixer revolutions for discharge of concrete permitted by **ASTM C94/C94M** are proposed to be exceeded.

4.1.2.13 Certification of production facilities and delivery vehicles—Documentation of certification or approval.

4.1.3 Quality control

4.1.3.1 Maintain records verifying that materials used are of types and sizes specified or accepted and are in conformance with 4.2.1.

4.1.3.2 Ensure that production and delivery of concrete conform to 4.3.1 and 4.3.2.

4.1.3.3 Ensure concrete has the specified characteristics in the freshly mixed state at delivery.

4.1.4 Material storage and handling

4.1.4.1 Cementitious materials—Keep cementitious materials dry and free from contaminants.

4.1.4.2 Aggregates—Store and handle aggregate in a manner that avoids segregation and prevents contamination by other materials or other sizes of aggregates. Store aggregates in locations that permit them to drain freely. Do not use aggregates that contain frozen lumps.

4.1.4.3 Water and ice—Protect mixing water and ice from contamination during storage and delivery.

4.1.4.4 Admixtures—Protect stored admixtures against contamination, evaporation, or damage. To ensure uniform distribution of constituents, provide agitating equipment for admixtures used in the form of suspensions or unstable solutions. Protect liquid admixtures from freezing and from temperature changes that would adversely affect their characteristics.

4.2—Products

4.2.1 Materials

4.2.1.1 Cementitious materials—Unless otherwise specified, cementitious materials shall conform to 4.2.1.1(a) through 4.2.1.1(g). Use cementitious materials that meet the durability criteria of 4.2.2.6.

4.2.1.1(a) Portland cement conforming to **ASTM C150/C150M**.

4.2.1.1(b) Blended hydraulic cement, excluding Type IS (>70), conforming to **ASTM C595/C595M**. For sections of structure that are assigned Exposure Class F3, submit certification on cement composition verifying that concrete mixture conforms to Table 4.2.1.1(b).

Table 4.2.1.1(b)—Limits on supplementary cementitious materials for concrete assigned to Exposure Class F3

Supplementary cementitious material	Maximum percent of total cementitious material by mass ^a
Fly ash or natural pozzolans conforming to ASTM C618	25
Slag cement conforming to ASTM C989/C989M	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or natural pozzolans, slag cement, and silica fume	50 [†]
Total of fly ash or natural pozzolans and silica fume	35 [†]

^aTotal cementitious material also includes ASTM C150/C150M, C595/C595M, and C1157/C1157M cement. The maximum percentages above shall include:

(a) Fly ash or natural pozzolans present in ASTM C1157/C1157M or C595/C595M Type IP blended cement.

(b) Slag cement present in ASTM C1157/C1157M or C595/C595M Type IS blended cement.

(c) Silica fume conforming to ASTM C1240 present in ASTM C1157/C1157M or C595/C595M Type IP blended cement.

[†]Fly ash or natural pozzolans and silica fume shall constitute no more than 25 percent and 10 percent, respectively, of the total mass of the cementitious materials.

4.2.1.1(c) Hydraulic cement conforming to **ASTM C1157/C1157M**. For sections of structure that are assigned Exposure Class F3, submit certification on cement composition verifying that concrete mixture conforms to Table 4.2.1.1(b).

4.2.1.1(d) Fly ash or natural pozzolans conforming to **ASTM C618**.

4.2.1.1(e) Slag cement conforming to **ASTM C989/C989M**.

4.2.1.1(f) Silica fume conforming to **ASTM C1240**.

4.2.1.1(g) Use cementitious materials of same brand and type and from same manufacturing plant as cementitious materials used in concrete represented by submitted field test records or used in trial mixtures.

4.2.1.2 Aggregates—Unless otherwise specified, aggregates shall conform to **ASTM C33/C33M**. Aggregates used in concrete shall be obtained from the same sources and have the same size range as aggregates used in concrete represented by submitted field test records or used in trial mixtures. Aggregates determined to be satisfactory shall

carbonate reactions in accordance with **ASTM C1778** shall not be used.

4.2.1.2(a) Unless otherwise specified, aggregate derived from crushed hydraulic-cement concrete or other recycled aggregate is permitted if documentation required by Architect/Engineer is submitted and its use is accepted.

4.2.1.3 *Lightweight aggregate for internal curing*—Lightweight aggregate for internal curing shall be limited to prewetted fine aggregate conforming to **ASTM C1761/C1761M**.

4.2.1.4 *Water and ice*—Unless otherwise specified, mixing water for concrete and water used to make ice shall comply with **ASTM C1602/C1602M**.

4.2.1.5 *Mineral fillers*—Unless otherwise specified, mineral fillers shall conform to **ASTM C1797**. Mineral fillers used in concrete shall be obtained from the same sources and be of the same types as those used in concrete represented by submitted field test records or used in trial mixtures. Unless otherwise specified, mineral filler derived from carbonate sources shall not be used in concrete for members assigned to Exposure Classes S1, S2, and S3.

4.2.1.6 *Admixtures*—Unless otherwise specified, admixtures shall conform to the following:

- (a) Air-entraining admixtures conforming to **ASTM C260/C260M**.
- (b) Chemical admixtures conforming to **ASTM C494/C494M** or **ASTM C1017/C1017M**.
- (c) Calcium chloride conforming to **ASTM D98**. Use calcium chloride admixtures in solution form only.

4.2.1.6.1 Admixtures used in concrete shall be the same as those used in the concrete represented by submitted field test records or used in trial batches.

4.2.1.6.2 Calcium chloride admixtures shall not be used for concrete in members assigned to Exposure Classes S2 or S3. Use of chemical admixtures containing chloride ions shall be subject to limitations in 4.2.2.6(e).

4.2.1.7 *Steel fibers*—If steel fiber-reinforced concrete is specified in Contract Documents for providing shear resistance, steel fibers shall be deformed and conform to **ASTM A820/A820M**. Steel fibers shall have a length-to-diameter ratio of at least 50 and not exceed 100. Steel fibers for other applications shall be in accordance with Contract Documents.

4.2.1.8 *Change of materials*—If changes to brand, type, size, or source of cementitious materials; aggregates; water; ice; or admixtures are proposed, submit new field data, data from new trial batches, or other evidence that the change will not adversely affect relevant properties of concrete. Submit data before changes are made.

4.2.2 *Performance and design requirements*

4.2.2.1 *Slump*—Unless otherwise specified, select a target slump at the point of delivery for concrete mixtures used for Work. Selected target slump shall not exceed 230 mm. Concrete shall not show visible signs of segregation. The target slump indicated on the submittal shall be used as the basis for acceptance during the project. Determine the slump by **ASTM C143/C143M**. Slump tolerances shall be in accordance with **ACI 117M**.

4.2.2.2 *Self-consolidating concrete*—Unless otherwise specified, select a target slump flow at the point of delivery for self-consolidating concrete mixtures. Selected target slump flow shall not exceed 750 mm. Concrete shall not show visible signs of segregation. The target slump flow value indicated on the submittal shall be used as the basis for acceptance during the project. Determine slump flow in accordance with **ASTM C1611/C1611M**. Slump flow tolerances shall be in accordance with **ASTM C94/C94M**. If specified, evaluate during the mixture qualification stage, proposed concrete mixtures for passing ability in accordance with **ASTM C1621/C1621M** and for static segregation in accordance with **ASTM C1610/C1610M** to meet criteria indicated in Contract Documents.

4.2.2.3 *Size of coarse aggregate*—Unless otherwise specified, nominal maximum size of coarse aggregate shall not exceed three-fourths of the minimum clear spacing between reinforcement, one-fifth of the narrowest dimension between sides of forms, or one-third of the thickness of slabs or toppings.

4.2.2.4 *Air content*

4.2.2.4(a) Concrete shall be air entrained for members assigned to Exposure Class F1, F2, or F3. The total air content shall be in accordance with 4.2.2.6(c), unless otherwise specified.

4.2.2.4(b) Unless otherwise specified, measure air content in accordance with **ASTM C173/C173M** or **ASTM C231/C231M**.

4.2.2.4(c) Unless otherwise specified, measure air content at point of delivery.

4.2.2.4(d) Concrete for slabs to receive a hard-troweled finish shall not contain an air-entraining admixture or have a total air content greater than 3 percent.

4.2.2.5 *Concrete temperature*

4.2.2.5(a) *Minimum temperature*—If the average of highest and lowest ambient temperature from midnight to midnight is expected to be less than 4°C for more than 3 successive days, deliver concrete to meet the following minimum temperatures immediately after placement unless otherwise specified:

- (a) 13°C for sections with least dimension less than 300 mm.
- (b) 10°C for sections with least dimension 300 to 900 mm.
- (c) 7°C for sections with least dimension 900 mm to 1.8 m.
- (d) 4°C for sections with least dimension greater than 1.8 m.

Temperature of concrete as placed shall not exceed these values by more than 11°C. These minimum temperature requirements may be terminated if temperatures above 10°C occur during more than half of any 24-hour duration.

4.2.2.5(b) *Maximum temperature*—Unless otherwise specified, temperature of concrete as delivered shall not exceed 35°C.

4.2.2.6 *Durability*

4.2.2.6(a) *Resistance to alkali-silica reaction*—Unless otherwise specified, or unless members are designated as being dry in service and not in contact with ground, or assigned to Exposure Class W0, use one of the three following options for qualifying concrete mixtures to reduce the potential of alkali-silica reaction.

Table 4.2.2.6(b)—Requirements for Exposure Category S: sulfate exposure

Exposure class	Maximum w/cm^*	Minimum f'_c , MPa	Required cementitious materials [†] —types			Calcium chloride admixture
			ASTM C150/C150M	ASTM C595/C595M	ASTM C1157/C1157M	
S0	NA	17	NA	NA	NA	No restriction
S1	0.50	28	II ^{‡§}	Types with (MS) designation	MS	No restriction
S2	0.45	31	V [§]	Types with (HS) designation	HS	Not permitted
S3	Option 1	0.45	V plus pozzolan or slag cement	Types with (HS) designation plus pozzolan or slag cement	HS plus pozzolan or slag cement	Not permitted
	Option 2	0.40	V [#]	Types with (HS) designation	HS	Not permitted

*The maximum w/cm limits do not apply to lightweight concrete.

[†]Alternative combinations of cementitious materials of those listed in this table are acceptable if tested for sulfate resistance and meeting the criteria in Table 4.2.2.6(b)1.

[‡]For seawater exposure, other types of portland cements with tricalcium aluminate (C_3A) contents up to 10 percent are acceptable if the w/cm does not exceed 0.40.

[§]Other available types of cement, such as Type III or Type I, are acceptable in Exposure Classes S1 or S2 if the C_3A contents are less than 8 or 5 percent, respectively.

^{||}The amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag used shall not be less than the amount tested in accordance with ASTM C1012/C1012M and meeting the requirements of Table 4.2.2.6(b)1.

[#]If Type V cement is used as the sole cementitious material, the optional sulfate resistance requirement of 0.040 percent maximum expansion in ASTM C150/C150M is applicable.

Option (c) shall not be used with natural pozzolan or fly ash that has a CaO content greater than 18 percent, or for aggregate with expansion at 1 year greater than or equal to 0.24 percent when tested in accordance with **ASTM C1293**. Fly ash with an alkali content greater than 4.0 percent shall not be used in option (b) or (c).

(a) For each aggregate used in concrete, expansion determined in accordance with ASTM C1293 shall not exceed 0.04 percent at 1 year.

(b) For each aggregate used in concrete, expansion of the aggregate and cementitious materials combination determined in accordance with **ASTM C1567** shall not exceed 0.10 percent at an age of 16 days. Submit supporting data for each aggregate showing expansion in excess of 0.10 percent at 16 days when tested in accordance with **ASTM C1260**.

(c) Alkali content in concrete (LBA), excluding that from supplementary cementitious materials and pozzolan and slag cement in blended cements, shall not exceed 2.4 kg/m³ for aggregate with expansion greater than or equal to 0.04 percent and less than 0.12 percent or not exceed 1.8 kg/m³ for aggregate with expansion greater than or equal to 0.12 percent and less than 0.24 percent. Reactivity shall be determined by testing in accordance with **ASTM C1293**. Alkali content in concrete (LBA) shall be calculated as follows:

$$LBA = (\text{cement content, kg/m}^3) \times (\text{equivalent alkali content of portland cement in percent/100 percent})$$

4.2.2.6(b) Sulfate resistance—Unless otherwise specified, provide concrete meeting the requirements of Table 4.2.2.6(b), based on the exposure class assigned to members for sulfate exposure, or meeting other requirements specified in Contract Documents. Submit documentation verifying compliance with specified requirements.

Table 4.2.2.6(b)1—Requirements for establishing suitability of cementitious materials combinations exposed to water-soluble sulfate

Exposure class At 6 months	Maximum expansion when tested in accordance with ASTM C1012/C1012M, percent		
	At 6 months	At 12 months	At 18 months
S1	0.10	NA	NA
S2	0.05	0.10*	NA
S3	Option 1	NA	0.10
	Option 2	0.05	0.10*

*The 12-month expansion limit applies only if the measured expansion exceeds the 6-month maximum expansion limit.

4.2.2.6(c) Freezing-and-thawing resistance—Unless otherwise specified, provide concrete meeting the requirements of Table 4.2.2.6(c) based on exposure class assigned to members for freezing-and-thawing exposure, or meeting other requirements specified in Contract Documents. Submit documentation verifying compliance with specified requirements.