

An ACI Standard

Specifications for Concrete Construction (ACI 301-20)

Reported by ACI Committee 301

ACI 301-20

Specifications for Concrete Construction

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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.

@seismicisolation

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 anchorages,

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

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, or Special

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 @seismicisolation

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's

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 concrete is less than 110 m³, strength tests may be waived.

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 as defined in 7.6.1(b) or core testing is required for other reasons, cores

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 to

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 C896/C896M**.

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

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**.

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 and curing.

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

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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 ^b
Total of fly ash or natural pozzolans and silica fume	35 ^c

^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.

^bFly 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 susceptible to alkali-

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 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.

Table 4.2.2.6(c)—Requirements for Exposure Category F: Freezing-and-thawing exposure

Exposure class	Maximum w/cm^*	Minimum f'_c , MPa	Air content	Additional requirements
F0	NA	17	NA	
F1	0.55	24	Table 4.2.2.6(c)1	NA
F2	0.45	31	Table 4.2.2.6(c)1	NA
F3	0.40	35	Table 4.2.2.6(c)1	Table 4.2.1.1(b)
F3 plain concrete	0.45	31	Table 4.2.2.6(c)1	Table 4.2.1.1(b)

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

Table 4.2.2.6(c)1—Total air content for concrete exposed to cycles of freezing and thawing

Nominal maximum aggregate size, mm	Total air content, percent**	
	Exposure Classes F2 and F3	Exposure Class F1
9.5	7.5	6.0
12.5	7.0	5.5
19.0	6.0	5.0
25.0	6.0	4.5
37.5	5.5	4.5
50	5.0	4.0
75	4.5	3.5

**Tolerance on air content as delivered shall be ± 1.5 percent.

†For f'_c equal to or greater than 35 MPa, it is acceptable to reduce air content by 1.0 percentage point.

4.2.2.6(d) In contact with water—Unless otherwise specified, provide concrete meeting the requirements of Table 4.2.2.6(d) based on exposure class assigned to members in contact with water, or meeting other requirements specified in Contract Documents. Submit documentation verifying compliance with specified requirements.

Table 4.2.2.6(d)—Requirements for Exposure Category W in contact with water

Exposure class	Maximum w/cm^*	Minimum f'_c , MPa	Additional minimum requirements
W0	NA	17	None
W1	NA	17	4.2.2.6(a)
W2	0.50	28	4.2.2.6(a)

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

4.2.2.6(e) Corrosion protection of reinforcement—Unless otherwise specified, provide concrete meeting the requirements of Table 4.2.2.6(e) based on the exposure class assigned to members requiring protection against reinforcement corrosion, or meeting other requirements specified in Contract Documents. Submit documentation verifying compliance with specified chloride ion limits using either one of the following:

(1) Total chloride ion content calculated from measured chloride ion content of concrete materials and mixture proportions. Chloride ion contents of cementitious materials and mixing water shall be determined in accordance with **ASTM C114**; of aggregates on samples prepared as specified for concrete samples and tested in accordance with **ASTM C1152/C1152M**; and of admixtures as reported by the manufacturer. Total chloride content so determined shall be less than the limit for water-soluble chloride ions in Table 4.2.2.6(e).

(2) Water-soluble chloride ion content of a hardened sample from the concrete mixture determined in accordance with **ASTM C1218/C1218M** at an age between 28 and 42 days.

Table 4.2.2.6(e)—Requirements for Exposure Category C: Conditions requiring corrosion protection of reinforcement

Exposure class	Maximum w/cm^*	Minimum f'_c , MPa	Maximum water-soluble chloride ion (Cl ⁻) content in concrete, percent by mass of cementitious materials†
Nonprestressed concrete			
C0	NA	17	1.00
C1	NA	17	0.30
C2	0.40	35	0.15
Prestressed concrete			
C0	NA	17	0.06
C1	NA	17	0.06
C2	0.40	35	0.06

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

†The maximum cementitious materials content used in determining chloride content shall not exceed two times the mass of portland cement.

4.2.2.6(f) Corrosion protection of stay-in-place galvanized forms—Unless otherwise specified, the maximum water-soluble chloride ion content in concrete cast on stay-in-place galvanized forms shall comply with the limits for Exposure Class C1.

4.2.2.7 Strength and w/cm —The compressive strength and, if required, maximum w/cm of the concrete for each portion of Work, shall be as specified in Contract Documents.

4.2.2.7(a) Unless otherwise specified, strength requirements shall be based on compressive strength tests at 28 days. Compressive strength is measured using 150 x 300 mm or 100 x 200 mm cylindrical specimens 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**. A strength test at designated age is the average of at least two 150 x 300 mm cylinders or the average of at least three 100 x 200 mm cylinders made from the same concrete sample.

4.2.2.8 Modulus of elasticity—If specified, submit test data for modulus of elasticity of proposed concrete mixtures. Modulus of elasticity shall be determined as the average of at least three cylinders made and cured in accordance with **ASTM C192/C192M** from the same concrete sample and tested in accordance with **ASTM C469/C469M**. Unless

otherwise specified, test age shall be 28 days. Unless otherwise specified, average modulus of elasticity shall be equal to or exceed the specified value.

4.2.2.9 Steel fiber-reinforced concrete—If steel fiber-reinforced concrete is specified for providing shear resistance, the concrete mixture shall conform to **ASTM C1116/C1116M**. Unless otherwise specified, the mixture shall contain at least 60 kg of steel fibers per cubic meter of concrete and shall meet the requirements of **1.7.7**. Steel fiber-reinforced concrete for other applications shall be in accordance with Contract Documents.

4.2.3 Proportioning

4.2.3.1 Proportion concrete to comply with 4.2.2 and so concrete can be worked readily into forms and around reinforcement without segregation, and to provide an average compressive strength to meet acceptance requirements of **1.7.6.1**.

4.2.3.2 Sample standard deviation

4.2.3.2(a) Field strength test records—Field strength test records used to calculate sample standard deviation shall represent materials, mixture proportions, quality-control procedures, and climatic conditions similar to those expected in Work. Field strength test records shall have been obtained within the past 24 months and spanning no less than 45 calendar days for a class of concrete within 7 MPa of that specified for Work. Test records shall comply with one of the following:

- (a) Data from a single group of at least 15 consecutive compressive-strength tests with the same mixture proportions.
- (b) Data from two groups of consecutive compressive-strength tests totaling at least 30 compressive-strength tests. Neither of the two groups shall consist of fewer than 10 tests.

4.2.3.2(b) Calculate sample standard deviation—Calculate the sample standard deviation s_s of strength test records as follows:

- (a) For a single group of consecutive strength test results

$$s_s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{(n-1)}} \quad (4.2.3.2(b)a)$$

where s_s is sample standard deviation; n is number of test results considered; \bar{X} is average of n test results considered; and X_i is a test result

- (b) For two groups of consecutive strength test results

$$s_s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{(n_1+n_2-2)}} \quad (4.2.3.2(b)b)$$

where s_s is standard deviation for the two groups combined; s_1 and s_2 are standard deviations for Groups 1 and 2, respectively, calculated in accordance with Eq. (4.2.3.2(b)a); and n_1 and n_2 are number of test results in Groups 1 and 2, respectively.

4.2.3.3 Required average compressive strength f_{cr}' —Calculate f_{cr}' for specified class of concrete in accordance with 4.2.3.3(a) or 4.2.3.3(b).

4.2.3.3(a) Use the sample standard deviation calculated in accordance with 4.2.3.2 to establish f_{cr}' in accordance with Table 4.2.3.3(a)1. Use the k -factor in Table 4.2.3.3(a)2 to adjust for total number of test results considered in calculating the sample standard deviation. Use larger of two values of f_{cr}' calculated.

Table 4.2.3.3(a)1—Required average compressive strength f_{cr}' if data are available to establish a sample standard deviation, MPa

f_c' , MPa	f_{cr}' , MPa
	Use the larger of:
35 or less	$f_{cr}' = f_c' + 1.34ks_s$
	$f_{cr}' = f_c' + 2.33ks_s - 3.5$
Over 35	$f_{cr}' = f_c' + 1.34ks_s$
	$f_{cr}' = 0.90f_c' + 2.33ks_s$

Notes: f_{cr}' is required average compressive strength; f_c' is specified concrete strength; k is factor from Table 4.2.3.3(a)2; and s_s is standard deviation calculated in accordance with 4.2.3.2.

Table 4.2.3.3(a)2— k -factor for increasing sample standard deviation for number of strength tests considered in calculating standard deviation

Total number of tests considered	k -factor for increasing sample standard deviation
15	1.16
20	1.08
25	1.03
30 or more	1.00

Note: Linear interpolation for intermediate number of tests is acceptable.

4.2.3.3(b) If field strength test records are not available to calculate sample standard deviation, establish required average compressive strength f_{cr}' in accordance with Table 4.2.3.3(b).

Table 4.2.3.3(b)—Required average compressive strength f_{cr}' if data are not available to establish standard deviation

f_c' , MPa	f_{cr}' , MPa
Less than 21	$f_c' + 7$
21 to 35	$f_c' + 8.3$
Over 35	$1.1f_c' + 5$

4.2.3.4 Documentation of average compressive strength—Provide documentation indicating proposed concrete proportions will produce an average compressive strength equal to or greater than required average compressive strength. Documentation shall consist of field strength test records in accordance with 4.2.3.4(a) or 4.2.3.4(b), or test results of trial mixtures in accordance with 4.2.3.4(c).

4.2.3.4(a) Field strength test data for single group of strength tests—If field strength test data are available and represent a single group of at least 10 consecutive strength

tests for one mixture, using materials and conditions similar to those expected for Work, and encompassing a period of not less than 45 days, the average of field strength tests shall equal or exceed f_{cr}' .

4.2.3.4(b) Field strength test data for groups of strength tests—If field strength test data represent two or more groups of strength tests for two or more mixtures with average strengths that encompass f_{cr}' , plot the average strength of each group versus the w/cm or cementitious material content of the corresponding mixture proportions and interpolate between them to establish the required w/cm or cementitious material content to achieve f_{cr}' . Establish mixture proportions for f_{cr}' based on the required w/cm or cementitious material content.

4.2.3.4(c) Trial mixtures—Establish proportions for concrete mixtures proposed for Work based on laboratory or production trial mixtures to comply with the following:

- (a) Use materials that conform to 4.2.1.1 through 4.2.1.7.
- (b) Determine f_{cr}' in accordance with 4.2.3.3(a) if suitable field strength test data are available, or use Table 4.2.3.3(b).
- (c) Make at least three trial mixtures for each concrete class with a range of proportions that will produce a range of compressive strengths that will encompass f_{cr}' . For concrete made with more than one type of cementitious material, the concrete supplier shall establish the w/cm and the relative proportions of the cementitious materials and admixtures, if any, that will produce required average compressive strength.
- (d) Proportion trial mixtures to produce a slump as specified for proposed Work, and for air-entrained concrete, air content within the tolerance specified for proposed Work.
- (e) For each trial mixture, make and cure three compressive strength cylinders for each test age in accordance with **ASTM C192/C192M** for laboratory trial mixtures or **ASTM C31/C31M** for production trial mixtures. Test for compressive strength in accordance with **ASTM C39/C39M** at 28 days or at the designated test age for f_c' .
- (f) Establish mixture proportions based on trial mixture data to achieve an average compressive strength of at least f_{cr}' as determined in 4.2.3.3 and to not exceed maximum w/cm . The proposed concrete mixture shall meet other applicable requirements of 4.2.2.6 and trial mixture records shall have been developed less than 24 months from the date of submittal.

4.2.3.5 Field verification of selected mixture proportions—If required, conduct field verification of the effects of placement methods on concrete mixture characteristics. Using materials and mixture proportions accepted for use in Work, verify that concrete can be placed using the intended placing method. Place concrete mixture using project equipment and personnel. Evaluate the effect of placement methods on slump and air content. Make suitable corrections to placing methods or to mixture proportions, if needed. Submit adjustments to mixture proportions.

4.2.3.6 Revisions to concrete mixtures—When 15 consecutive compressive strength tests become available from the field, calculate the average compressive strength and standard

deviation. Calculate a revised value for f_{cr}' in accordance with 4.2.3.3(a).

4.2.3.6(a) If actual average compressive strength \bar{X} exceeds the revised value of f_{cr}' and requirements of 1.7.6.1 are met, it is acceptable to modify mixture proportions to achieve an average strength equal to the revised value of f_{cr}' . The revised mixture shall meet requirements of 4.2.2.

4.2.3.6(b) If actual average compressive strength \bar{X} is less than revised value of f_{cr}' or if either of the two requirements in 1.7.6.1 is not met, take immediate steps to increase average compressive strength of the concrete.

4.2.3.6(c) Submit revised mixture proportions for acceptance before placing modified concrete in Work.

4.3—Execution

4.3.1 Measuring, batching, and mixing—Production facilities shall produce concrete of specified quality and conforming to this Specification.

4.3.1.1 Ready mixed and site-produced concrete—Unless otherwise specified, measure, batch, and mix concrete materials and concrete in conformance to **ASTM C94/C94M**. Unless otherwise specified, concrete production facilities and delivery vehicles shall be certified by the NRMCA Program for Certification of Ready Mixed Concrete Facilities, approved by a state highway agency, or certified by an equivalent program that audits for conformance to requirements of **ASTM C94/C94M** for production and delivery.

4.3.1.2 Concrete produced by volumetric batching and continuous mixing—Concrete produced by volumetric batching and continuous mixing shall conform to **ASTM C685/C685M**.

4.3.1.3 Prepackaged dry materials used in concrete—If packaged dry-combined materials are used, they shall conform to **ASTM C387/C387M** and satisfy requirements of this Specification.

4.3.2 Delivery—Transport and deliver concrete in equipment conforming to **ASTM C94/C94M**.

4.3.2.1 Adjustments—Unless otherwise specified, if concrete slump, slump flow, or air content determined on a preliminary sample in accordance with **ASTM C94/C94M** is less than required, adjustments are permitted by using admixtures or adding water up to amount allowed in accepted mixture proportions. Adjustment of mixture using admixtures or water shall be in accordance with **ASTM C94/C94M**. Do not exceed specified maximum w/cm or w/cm used in proportioning the concrete. Do not add water to concrete after discharge of more than 5 percent of delivered quantity. Measure slump, or slump flow, and air content of air-entrained concrete after adjustments to verify compliance with specified requirements.

4.3.2.2 Limits on discharge—Unless otherwise specified, discharge limits shall comply with **ASTM C94/C94M**. If discharge is acceptable after more than 1-1/2 hours have elapsed since batching, verify that air content of air-entrained concrete, slump, and temperature of concrete are as specified.

SECTION 5—HANDLING, PLACING, AND CONSTRUCTING

5.1—General

5.1.1 Scope—This Section covers the construction of cast-in-place concrete. Included are procedures for handling, placing, finishing, curing, and repair of surface defects.

5.1.2 Submittals

5.1.2.1 Submit the information specified in 5.1.2.1(a) through 5.1.2.1(j).

5.1.2.1(a) Resolution of nonconformance—Documentation of resolution of nonconformance identified on quality assurance test and inspection reports.

5.1.2.1(b) Temperature measurement—Proposed method for complying with requirements for measuring concrete temperatures.

5.1.2.1(c) Qualifications of finishers—Qualifications, as specified in 5.3.4.1, of finishing contractor and of flatwork finishers who will perform Work.

5.1.2.1(d) Placement notification—Notification of concrete placement at least 24 hours before placement.

5.1.2.1(e) Preplacement plan—Planned actions before concrete placement.

5.1.2.1(f) Preplacement meeting—Agenda for preplacement meeting to be held before start of placement activities.

5.1.2.1(g) Temporary form spreaders—Request to leave form spreaders in place.

5.1.2.1(h) Qualifications of Adhesive Anchor Installers—Qualifications of personnel who install adhesive anchors as described in 5.3.8.

5.1.2.1(i) Contraction or expansion joints—If contraction or expansion joints other than those indicated in Contract Documents are proposed, submit locations.

5.1.2.1(j) Sawed joints in slabs—Submit request to saw joints in slabs or cut reinforcement at sawn joints in a manner that is not indicated in Contract Documents.

5.1.2.2 If specified, submit information specified in 5.1.2.2(a) through 5.1.2.2(m).

5.1.2.2(a) Conveying equipment—Description of conveying equipment.

5.1.2.2(b) Surface cleaning—If removal of stains, rust, efflorescence, and surface deposits is specified as described in 5.3.7.6, submit proposed method of removal.

5.1.2.2(c) Wet-weather protection—Wet-weather protection activities.

5.1.2.2(d) Hot-weather placement—Request for concrete temperature limit different than specified in 5.3.2.1(c), including documentation and procedures to demonstrate compliance with other requirements in Contract Documents.

5.1.2.2(e) Cold-weather placement and protection activities—Request for acceptance of proposed cold-weather placement, temperature-measuring methods, and protection activities.

5.1.2.2(f) Initial curing—Methods to be used for initial curing.

5.1.2.2(g) Retarder for exposed-aggregate surface—Manufacturer's data on retarder and proposed method of use

if surface retarder is proposed for specified exposed-aggregate surface.

5.1.2.2(h) Bonding agent—If bonding material other than cement grout is proposed for two-course slabs or construction joints, submit applicable specification and manufacturer's data on bonding agent.

5.1.2.2(i) Underwater placement—If underwater placement is planned, submit proposed method.

5.1.2.2(j) Curing method—If a moisture-preserving method other than specified in 5.3.6 is proposed, submit the proposed method.

5.1.2.2(k) Surface repair materials—If a surface repair material other than that described in 5.2.1.6 is proposed, submit applicable repair material specification, manufacturer's data on the proposed repair material, and proposed preparation and application procedure.

5.1.2.2(l) Installing sawed joints—If proposed installation of sawed joints differs from 5.3.5.1, submit alternative.

5.1.2.2(m) Preparing surfaces at construction joints—If preparation methods needed to bond fresh concrete to hardened concrete are different from methods in 5.3.2.6(c) or 5.3.4.2(a), submit proposed methods.

5.1.2.3 Joints not shown in Contract Documents

5.1.2.3(a) Submit information on proposed location and treatment of construction joints not indicated in Contract Documents.

5.1.2.3(b) If movement joints other than those indicated in Contract Documents are proposed, submit locations.

5.1.3 Delivery, storage, and handling—Deliver, store, and handle products in accordance with manufacturer's recommendations. Do not use products stored beyond manufacturer's recommended shelf life.

5.2—Products

5.2.1 Materials

5.2.1.1 Water for curing—Unless otherwise specified, do not use seawater or water containing substances that will discolor or impair the durability of the concrete member.

5.2.1.2 Curing compounds—Unless otherwise specified, use membrane-forming curing compounds that conform to **ASTM C309** or **ASTM C1315**. Silicate-based liquid surface densifiers are prohibited as curing compounds.

5.2.1.3 Sheet materials for curing—Unless otherwise specified, use sheet materials that conform to **ASTM C171**.

5.2.1.4 Absorbent materials—Unless otherwise specified, absorbent materials shall meet the requirements of **AASHTO M 182**.

5.2.1.5 Evaporation reducers—Liquid-applied evaporation reducers shall form a continuous film and reduce moisture loss from fresh concrete surface.

5.2.1.6 Surface repair materials—Unless otherwise specified, use repair mortar to repair surface defects. For concrete exposed to view, repair mortar shall match adjacent concrete color.

5.2.1.7 Bonding material—Accepted bonding agent applied in accordance with the manufacturer's requirements or portland-cement grout of the same proportions as the mortar in the concrete.

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5.2.1.8 Scrub coat—For scrub coat material, mix one part portland cement and one part sand by loose volume with water. Use sand meeting the requirements of **ASTM C144** or **ASTM C404**.

5.3—Execution

5.3.1 Preparation

5.3.1.1 Do not place concrete until data on materials and mixture proportions are accepted.

5.3.1.2 Remove hardened concrete and foreign materials from inner surfaces of conveying equipment.

5.3.1.3 Before placing concrete in forms, complete the following:

- (a) Comply with formwork requirements specified in **Section 2**.
- (b) Remove snow, ice, frost, water, and other foreign materials from surfaces against which concrete will be cast, and from reinforcement and embedded items.
- (c) Comply with reinforcement placement requirements specified in **Section 3**.

5.3.1.4 Before placing a concrete slab-on-ground, remove contaminating materials from contact surface and complete the following:

- (a) Subgrade and base shall be prepared in accordance with Contract Documents.
- (b) Tolerance for the base material elevation shall be in accordance with **ACI 117M**.

5.3.1.5 Make provisions in advance of concrete placement to limit the rate of evaporation of water from concrete surface during or immediately after placing or finishing.

5.3.1.6 During ambient temperature conditions described in **4.2.2.5(a)**, cure and protect the concrete in accordance with 5.3.6.5. Use heating, covering, or other means to maintain required temperature without drying of concrete. Do not use unvented combustion heaters.

5.3.2 Placement of concrete

5.3.2.1 Weather considerations

5.3.2.1(a) Wet weather—Do not place concrete while rain, sleet, or snow is falling unless protection is provided. Do not allow precipitation to increase mixing water or to damage concrete surface.

5.3.2.1(b) Cold weather—Concrete temperatures at delivery shall meet the requirements of **4.2.2.5(a)**. Unless otherwise specified, massive metallic embedded items in concrete, including piping and conduit equal to or less than 6 mm wall thickness and individual or bundled metallic embedded items with a cumulative cross-sectional area less than 2580 mm², shall be above −12°C. Maintain formwork contact surface temperature above −12°C and insulate or heat formwork as required to protect concrete from freezing. Maintain contact surface temperature above 0°C if placing concrete in contact with ground, subbase, or mud mat.

5.3.2.1(c) Hot weather—Unless otherwise specified, concrete temperature as placed shall meet the requirements of **4.2.2.5(b)**. If temperature of reinforcement, embedments, or forms is greater than 50°C, use a fine mist of water to moisten and cool hot surfaces. Remove standing water before placing concrete.

5.3.2.2 Conveying—Convey concrete from mixer to final deposition using equipment in 5.3.2.3 by methods that do not result in segregation or loss of constituents.

5.3.2.3 Conveying equipment—Use conveying equipment of sufficient capacity to meet the requirements of 5.3.2.4. Conveying equipment in contact with concrete shall not be made of aluminum.

5.3.2.3(a) Use belt conveyors with a discharge baffle or hopper at discharge end. Slope of conveyors shall not cause segregation on belt.

5.3.2.3(b) Use metal or metal-lined chutes having rounded bottoms, and sloped between 1:2 and 1:3. Chutes longer than 6 m and chutes not meeting slope requirements may be used, provided discharge is into a hopper before distributing into forms.

5.3.2.3(c) Use pumping equipment that has sufficient capacity so that:

- (a) Discharge of pumped concrete does not result in segregation.
- (b) Modification of accepted concrete mixture is not required.

5.3.2.4 Depositing

5.3.2.4(a) Deposit concrete as near as practicable to its final position in the placement in a manner that does not cause segregation.

5.3.2.4(b) Deposit concrete in one layer or in multiple layers. Do not place fresh concrete against concrete that would result in cold joints unless construction joint requirements of 5.3.2.6 are met.

5.3.2.4(c) Do not place concrete that is contaminated with materials that are not specified or accepted.

5.3.2.4(d) Do not place concrete if it cannot be consolidated by available methods.

5.3.2.4(e) If temporary spreaders are used in forms, remove spreaders as the concrete is placed. Spreaders may be left in place if prior acceptance is obtained.

5.3.2.4(f) Unless otherwise specified, if placing beams, girders, or slabs monolithically with columns or walls, place horizontal elements after the underlying concrete is consolidated and there is no bleed water on the surface of vertical supporting member.

5.3.2.4(g) Place concrete for beams, girders, brackets, column capitals, haunches, and drop panels at same time as concrete for adjacent slabs.

5.3.2.4(h) If underwater placement is required, place concrete by an acceptable method. Deposit fresh concrete so concrete enters the mass of previously placed concrete and not in contact with water.

5.3.2.4(i) As indicated in Contract Documents, where higher-strength concrete used for columns and walls is required to be integrated with floor systems, extend higher-strength concrete through full floor system depth at least 600 mm past each face of columns and walls. Integrate and consolidate the concretes to achieve a monolithic mass.

5.3.2.5 Consolidating—Unless otherwise specified, consolidate concrete by vibration. Consolidate concrete around reinforcement, embedded items, and into corners of

for consolidating concrete around epoxy-coated or zinc and epoxy dual-coated reinforcing bars. Do not use vibrators to move concrete in a manner that will result in segregation. Spacing of immersion vibrator insertions shall not exceed 1-1/2 times the vibrator's radius of action in concrete being consolidated.

5.3.2.6 Construction joints—Install construction joints in accordance with 2.2.2.5. Remove laitance, clean, and dampen construction joints before placement of fresh concrete. If bond is required, use one of the following methods:

- (a) Use a bonding material in accordance with 5.2.1.7.
- (b) Use an acceptable surface retarder in accordance with manufacturer's recommendations.
- (c) Finish the first concrete placement in accordance with 5.3.4.2(a) or roughen surface in a manner that exposes coarse aggregate and does not leave laitance, loosened aggregate particles, or damaged concrete at surface.

5.3.3 Finishing formed surfaces

5.3.3.1 General—Unless otherwise specified, provide surface finish on formed concrete surfaces in accordance with 5.3.3.1(a) or 5.3.3.1(b).

5.3.3.1(a) Provide surface finish SF-1 as defined in 5.3.3.2(a) for metal lap pan deck formed surfaces or if Contract Documents indicate that surfaces are buried or covered with subsequently installed building systems. Subsequently installed building systems hide the concrete surface from view in the completed structure, and do not include paints, sealers, or other materials that do not hide underlying concrete surface imperfections.

5.3.3.1(b) Provide surface finish SF-2, as defined in 5.3.3.2(b), for concrete surfaces other than those described in 5.3.3.1(a).

5.3.3.2 As-cast finishes—Use form-facing materials meeting the requirements of 2.2.1.1. Provide as-cast formed finishes to comply with 5.3.3.2(a), 5.3.3.2(b), or 5.3.3.2(c) as indicated in Contract Documents.

5.3.3.2(a) Surface finish SF-1:

- (a) No formwork facing material is specified
- (b) Patch voids larger than 40 mm wide or 13 mm deep
- (c) Remove projections larger than 25 mm
- (d) Tie holes need not be patched
- (e) Surface tolerance Class D as specified in ACI 117M

5.3.3.2(b) Surface finish SF-2:

- (a) Patch voids larger than 20 mm wide or 13 mm deep
- (b) Remove projections larger than 6 mm
- (c) Patch tie holes

- (d) Surface tolerance Class B as specified in ACI 117M

5.3.3.2(c) Surface finish SF-3:

- (a) Patch voids larger than 20 mm wide or 13 mm deep
- (b) Remove projections larger than 3 mm
- (c) Patch tie holes

- (d) Surface tolerance Class A as specified in ACI 117M

5.3.3.3 Rubbed finish—Provide a rubbed finish in accordance with Contract Documents. Rubbed finishes are permitted at time of form removal or delayed until work areas are accessible.

5.3.3.3(a) If finish is applied at form removal, wet the surface and rub it with an abrasive stone to draw out mortar and fill surface voids.

5.3.3.3(b) If rubbing is delayed or insufficient cement paste can be drawn from the concrete, mix grout consisting of 1 part by volume portland cement, 1-1/2 parts sand meeting the requirements of ASTM C144 or ASTM C404, and sufficient water to produce the consistency of thick paint. If accepted, packaged repair mortar or mortar additives are permitted. Scrub grout into voids and remove excess grout. Apply final finish using burlap, floating, or troweling.

5.3.3.4 Special finishes—If required, produce special finishes in accordance with Contract Documents

5.3.4 Finishing unformed surfaces

5.3.4.1 Finisher qualifications—Unless otherwise specified, at least one finisher or finishing supervisor shall be a certified ACI Advanced Concrete Flatwork Finisher or a certified ACI Flatwork Associate or equivalent.

5.3.4.2 Finishes and tolerances—Unformed surfaces shall receive finish defined in 5.3.4.2(a) through 5.3.4.2(h), as indicated in Contract Documents. If finish is not specified, finish surfaces as required by 5.3.4.2(h).

5.3.4.2(a) Scratch finish—Place, consolidate, strike off, and level concrete; cut high spots; and fill low spots. Roughen the surface with stiff brushes or rakes before concrete becomes too stiff to brush or rake.

5.3.4.2(b) Float finish—Place, consolidate, strike off, and level concrete; cut high spots; and fill low spots. Do not perform further finishing operations until concrete is ready for floating. Begin floating with hand float, bladed power float equipped with float shoes, or powered disk float when bleed water sheen has disappeared and surface has stiffened sufficiently to permit operation of the specific float apparatus. Unless otherwise specified, produce a finish that will meet tolerance requirements of ACI 117M for a conventional surface.

5.3.4.2(c) Trowel finish—Float concrete surface, then trowel the surface. Unless otherwise specified, tolerances for concrete floors shall be for a flat surface in accordance with ACI 117M. Addition of water to surface to facilitate finishing is prohibited. Do not apply hard-troweled finish to concrete with total air content greater than 3 percent.

5.3.4.2(d) Broom or belt finish—After concrete has received float finish, give concrete surface a coarse-scored texture by drawing a broom or burlap belt across the surface.

5.3.4.2(e) Dry-shake finish—Blend metallic or mineral aggregate, as indicated in Contract Documents, with portland cement in the proportions recommended by the aggregate manufacturer. Finishing operations shall not seal the surface before the end of bleeding to minimize potential of delamination or blistering. Float-finish concrete surface and make initial application of dry material by mechanical spreader or by broadcasting with shovels. Begin final floating after final dry-shake application. Following floating, provide a hard-troweled finish. Alternatively, if specified in Contract Documents, use bagged, premixed material applied in accordance with manufacturer's recommendations.

5.3.4.2(f) Topping for two-course slabs—Prepare base slab, install bonding and topping materials, finish, cure, and install joints as indicated in Contract Documents. Unless otherwise specified, special wear-resistant aggregate is not required.

5.3.4.2(g) Nonslip finish—Unless otherwise specified, apply a broom or belt finish as indicated in 5.3.4.2(d).

5.3.4.2(h) Unspecified unformed surface finishes—If finish is not specified, apply the following finishes to unformed concrete surface:

- (a) Scratch finish—For surfaces intended to receive bonded cementitious or setting beds
- (b) Float finish—For walks; steps; and surfaces intended to receive waterproofing, roofing, insulation, or sand-bed terrazzo
- (c) Trowel finish—For interior floors
- (d) Broom finish—For parking structures and exterior surfaces, including slabs, ramps, walkways, and steps

5.3.4.3 Slab surface measurement—If slab surface measurement is indicated in Contract Documents, allow for measurement within 72 hours after finishing, before stressing post-tensioning reinforcement, and before removing supporting formwork or shoring.

Measurement of slab flatness and levelness shall be in accordance with 1.7.4.4, and measurement of slab elevation shall be in accordance with Contract Documents.

5.3.5 Saw-cut joints—Saw joints in slabs at locations indicated in Contract Documents or as accepted by Architect/Engineer. Do not cut reinforcement unless specifically identified in Contract Documents or as accepted by the Architect/Engineer.

5.3.5.1 Where saw-cut joints are required, start cutting as soon as concrete has gained sufficient strength to prevent dislodgement of coarse aggregate particles. Unless otherwise specified, saw a continuous slot to a depth one-fourth the thickness of the slab but not less than 25 mm.

5.3.6 Curing and protection

5.3.6.1 Curing—Unless otherwise specified, cure concrete in accordance with 5.3.6.2, 5.3.6.3, and 5.3.6.4.

5.3.6.2 Initial curing of unformed concrete surfaces—If bleed water sheen is not visible on surface of concrete after strike-off and initial bull floating, provide initial curing by means of fogging or application of evaporation reducer until final curing method is applied.

5.3.6.2(a) Fogging—Provide fogging equipment for complete coverage of area to be cured. Maintain visible water sheen without accumulation of standing water on concrete surface until final setting of concrete. Do not use fogging if temperature of air in contact with concrete is at or below 0°C.

5.3.6.2(b) Evaporation reducer—Apply in accordance with manufacturer's instructions. Apply evaporation reducer after strike-off or initial bull floating operations and do not use to increase concrete workability at the surface.

5.3.6.3 Final curing of unformed concrete surfaces—Unless otherwise specified, apply one of the methods in 5.3.6.5 after placement and finishing of concrete surfaces. Apply curing in a manner that prevents marring, marking, or discoloration of finished surface.

Provide duration of curing in accordance with 5.3.6.6.

5.3.6.3(a) For concrete containing silica fume, use a curing method in 5.3.6.5 that supplies additional water during the entire curing period.

5.3.6.4 Formed concrete surfaces—Unless otherwise specified, after formwork has been loosened or removed so that concrete surface is exposed to ambient air, continue curing by one of the methods in 5.3.6.5. Provide duration of curing in accordance with 5.3.6.6. The duration that forms remained tightly in place can be included in the duration of curing.

5.3.6.5 Curing methods—Unless otherwise specified, use one or more of the following methods for curing formed surfaces or as final curing for unformed surfaces:

5.3.6.5(a) Continuous fogging—Cure in accordance with 5.3.6.2(a), except that accumulation of standing water on concrete surface is permitted. Do not use fogging if temperature of air in contact with concrete is at or below 0°C.

5.3.6.5(b) Ponding—Build a dike around concrete and flood surface with water. Entire surface is to remain covered continuously with water for duration of curing period. Temperature of water used shall be at least 10°C and not be more than 20°C colder than surface temperature of the concrete at the time the water and concrete come in contact.

5.3.6.5(c) Continuous sprinkling—Apply water to keep surfaces continuously wet. Concrete surface shall not be eroded by running water.

5.3.6.5(d) Application of absorbent material—Predampen absorbent materials before application. Keep concrete surfaces continuously wet. Apply additional water to absorbent materials without displacing them.

5.3.6.5(e) Application of water-retention sheeting materials—Cover exposed concrete surfaces. Tape sheets together or lap sheets, repair holes and gaps, and keep sheets in place.

5.3.6.5(f) Application of a membrane-forming curing compound—Apply compound in accordance with manufacturer's recommendation for specified concrete finish as soon as water sheen has disappeared from the concrete surface. For rough surfaces, such as those specified in 5.3.4.2(a), 5.3.4.2(b), and 5.3.4.2(d), apply curing compound in two applications at right angles to each other.

5.3.6.6 Duration of curing

5.3.6.6(a) Unless otherwise specified, continue curing measures for at least 7 days after placement. Unless otherwise specified, cure high-early-strength concrete for at least 3 days after placement.

5.3.6.6(b) Unless otherwise specified, curing measures may be terminated before the specified minimum duration in 5.3.6.6(a) if one of the following conditions is satisfied:

- (a) Tests of at least two 150 x 300 mm or at least three 100 x 200 mm cylinders that have been field cured in accordance with ASTM C31/C31M indicate compressive strength of at least 70 percent of f'_c when tested in accordance with ASTM C39/C39M.
- (b) The compressive strength of laboratory-cured cylinders, representative of the in-place concrete, exceeds

85 percent f'_c , provided the temperature of the in-place concrete has been maintained at 10°C or higher during curing.

(c) Concrete strength reaches f'_c as determined by accepted in-place test methods meeting the requirements of 2.3.4.2.

5.3.6.6(c) Unless otherwise specified, if one of the curing methods in 5.3.6.5 is used initially, the curing method may be replaced by one of the other methods after concrete is 1 day old, provided the surface of concrete does not become dry before replacement method is applied.

5.3.6.7 Thermal protection against cold weather—Maintain in-place concrete temperature to prevent freezing of concrete and to ensure strength development.

5.3.6.7(a) Unless otherwise specified, duration of thermal protection shall be at least 3 days, or until one of the criteria of 5.3.6.6(b) has been met.

5.3.6.7(b) Unless otherwise specified, or if concrete is designated as mass concrete and removal of protection is addressed in thermal control plan, the maximum rate of temperature decrease, measured at the concrete surface, during thermal protection removal shall not exceed the following:

- (a) 28°C/24 hours for sections with least dimension less than 300 mm
- (b) 22°C/24 hours for sections with least dimension from 300 to 900 mm
- (c) 17°C/24 hours for sections with least dimension greater than 900 mm to 1.8 m
- (d) 11°C/24 hours for sections with least dimension greater than 1.8 m

Do not exceed these rates of temperature decrease until surface temperature of the concrete is within 11°C of ambient or surrounding temperatures, at which time all protection measures may be removed. Measure and record concrete temperature using accepted method.

5.3.7 Repair of surface defects

5.3.7.1 General—Repair tie holes and other surface defects in formed finishes in accordance with the requirements of 5.3.3 unless otherwise specified. Where concrete surface will be textured by sandblasting or bush-hammering, repair surface defects before texturing.

5.3.7.2 Repair of tie holes—Unless otherwise specified, patch tie holes. If portland-cement repair mortar conforming to 5.3.7.4 is used for patching, clean and dampen tie holes before applying mortar. If other materials are used, apply them in accordance with manufacturer's recommendations.

5.3.7.3 Repair of surface defects other than tie holes—Unless otherwise specified, repair surface defects by the following method. Outline repair area with a 13 mm deep saw cut that is perpendicular to the repair surface and remove defective concrete down to sound concrete. Dampen the area to be patched plus 150 mm around the patch area perimeter. Prepare scrub coat according to 5.2.1.8. Thoroughly brush scrub coat into the surface. When the scrub coat begins to lose water sheen, apply patching mortar prepared in accordance with 5.3.7.4 and consolidate mortar into place. Strike off mortar, finishing flush to the final surface. Leave the

patch undisturbed for 1 hour before finishing. Keep the patch damp for 7 days.

5.3.7.4 Site-mixed portland-cement repair mortar—For surface repairs in concrete exposed to view, make a trial batch and check color compatibility of repair material with surrounding concrete.

5.3.7.5 Repair materials other than site-mixed portland-cement mortar—Use accepted alternative repair material.

5.3.7.6 Removal of stains, rust, efflorescence, and surface deposits—Remove stains, rust, efflorescence, and surface deposits at locations indicated in Contract Documents.

5.3.8 Installation of adhesive anchors—Install adhesive anchors in accordance with Manufacturer's Printed Installation Instructions (MPII).

5.3.8.1 Install adhesive anchors in concrete that is at least 21 days old.

5.3.8.2 Adhesive anchors installed in holes horizontally or upwardly inclined and designated in Contract Documents to support sustained tension shall be installed by personnel certified in accordance with ACI Adhesive Anchor Installer Certification Program or other accepted equivalent program.

SECTION 6—ARCHITECTURAL CONCRETE

6.1—General

6.1.1 Scope—This Section covers construction requirements for concrete designated as architectural concrete in Contract Documents.

6.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of Section 1 through 5 are applicable for architectural concrete.

6.1.3 Submittals

6.1.3.1 Shop drawings and data—Submit shop drawings of formwork for architectural concrete, including formwork for field mockups. Show jointing of facing panels; locations and details of form ties, rustications, and recesses; and details of joints, anchorages, and other accessories.

6.1.3.2 Unless otherwise specified, comply with 6.1.3.2(a) through 6.1.3.2(e).

6.1.3.2(a) Field mockups—Mockups are required for architectural concrete. Submit location for field mockup.

6.1.3.2(b) Specified finishes—If architectural concrete reference sample(s) is not specified, submit finish sample(s) exhibiting the desired surfaces, color, and texture. Minimum size of the sample(s) shall be 450 x 450 mm.

6.1.3.2(c) Form face, form liner, and molds—Submit technical data and samples of form face, form liner, and molds.

6.1.3.2(d) Compressible tape—Submit technical data and sample of compressible tape.

6.1.3.2(e) Form joint caulking—Submit technical data and sample of form joint caulking.

6.1.3.3 Initiation of Work—Do not begin Work under this Section until submittals and completed field mockups have been reviewed and accepted. Do not construct forms or place concrete until submitted plans for batching, mixing, placing, curing, and producing specified finishes have been accepted.

6.1.3.4 Waste wash-water disposal plan—If required, submit plan for disposal of wastewater resulting from washing concrete surfaces.

6.1.3.5 Personnel experience—If required, submit records showing previous experience with architectural concrete.

6.1.4 Quality control

6.1.4.1 Manufacturer's technical specialists—If required, provide manufacturer's technical specialists to inspect and direct installation of supplied systems and products.

6.1.4.2 Architectural preconstruction conference—Attend preconstruction conference(s) specific to architectural concrete Work with Architect/Engineer and Owner, or Owner's representative to review delivery, installation, acceptance criteria, tolerances, and repair procedures.

6.1.4.3 Architectural concrete reference—If specified in Contract Documents, surface quality and appearance of mockup shall match a reference sample or portions of an existing structure designated by Architect/Engineer.

6.1.4.4 Field mockup

6.1.4.4(a) Construct field mockups using same procedures, equipment, and materials that will be used for production of architectural concrete. Accepted field mockup will serve as the reference to which architectural concrete will be compared for periodic and final acceptance. Construct field mockups at an acceptable location on site. Provide a simulated repair area to demonstrate an acceptable repair procedure. Repair procedure shall provide an acceptable color and texture match. Protect from physical damage and retain mockups until final acceptance of architectural concrete.

6.1.4.4(b) For formed architectural concrete surfaces, include vertical and horizontal rustication joints, and any sculptured features. Demonstrate color and texture. Cure the mockup as intended with the structure. If required, apply sealers and coatings to only a portion of the mockup. Construct mockup to include at least two lifts having heights planned for placement of architectural concrete.

6.1.4.4(c) For flatwork, construct at least a 3 x 3 m mockup for review and acceptance using procedures in 6.1.4.4(a).

6.1.4.5 Periodic acceptance

6.1.4.5(a) Architect/Engineer will periodically observe completed portions of architectural concrete for conformance with accepted field mockup. The frequency of periodic acceptance and acceptance criteria will be established at preconstruction conference.

6.1.4.5(b) Architectural concrete declared unacceptable during periodic observation shall be repaired or replaced. Submit a revised method of producing acceptable concrete before proceeding with additional architectural concrete construction.

6.1.5 Product delivery, storage, and handling

6.1.5.1 Store and protect forms and liners in accordance with manufacturer's recommendations. Protect forms, liners, and other forming materials from weather and other environmental detriments. Clean forms after each use and discard or repair damaged forms as required to ensure conformance of Work with accepted field mockup.

6.1.5.2 Deliver materials specified in Contract Documents to project site in manufacturer's original containers or packaging.

6.2—Products

6.2.1 Materials

6.2.1.1 Cementitious materials—Unless otherwise specified, cementitious materials shall conform to Section 4. Use one source, type, and brand of cementitious materials for architectural concrete. Ensure sufficient supply of cementitious materials.

6.2.1.2 Water

6.2.1.2(a) Concrete mixing water shall conform to requirements of Section 4 and shall be free of oil or impurities capable of discoloring concrete surface.

6.2.1.2(b) Water for waterblasting and for wash down shall be free of oil or impurities capable of staining concrete surface.

6.2.1.3 Aggregate—Aggregate shall comply with requirements of Section 4 and other requirements indicated in Contract Documents. Ensure sufficient supply of aggregate as used in accepted field mockup to complete Work.

6.2.1.4 Concrete—Concrete shall match color and finish of accepted field mockup.

6.2.1.5 Curing materials—Curing materials shall conform to requirements in Section 5. Curing method shall be the same as used to produce accepted field mockup.

6.2.1.6 Reinforcement, reinforcement supports, spacers, and tie wires

6.2.1.6(a) Use stainless steel, plastic, or plastic-coated wire-reinforcement supports and spacers near exposed surfaces. Do not use plastic-coated products if cement paste will be removed to expose aggregate.

6.2.1.6(b) Use plastic-coated tie wire for epoxy-coated reinforcement. Use stainless steel or plastic-coated tie wire for securing other reinforcement.

6.2.1.7 Formwork—Unless otherwise specified, provide formwork with a structurally rated plywood with a non-porous finished surface bonded to a sanded hardwood veneer substrate.

6.2.1.8 Form ties

6.2.1.8(a) Provide specified cone diameter for form ties, as indicated in Contract Documents.

6.2.1.8(b) Steel washers shall not be used with snap ties for architectural concrete.

6.2.1.9 Rustications—If indicated in Contract Documents, provide specified rustications and reveal strips. Rustication or reveal strips shall be nonabsorbent and of sufficient stiffness to maintain alignment during concrete casting. Fabricate metal strips from same metal as metal form face.

6.2.1.10 Form-release agents—Use form-release agents accepted for field mockup.

6.2.1.11 Miscellaneous

6.2.1.11(a) Compressible tape—Use compressible tape accepted for field mockup.

6.2.1.11(b) Form sealant—Sealant for form caulking shall conform to ASTM C920, Type A, Grade NS, or ASTM

6.2.1.11(c) Abrasive material—If applicable, use abrasive material previously tested and accepted for field mockup for the specified texture. Ensure sufficient supply to complete total amount of surface specified.

6.2.1.11(d) Surface retarders—Use surface retarders accepted on field mockup.

6.2.1.11(e) Acid—Use muriatic or phosphoric acid to produce acid etch finish on both accepted mockup and Work.

6.2.2 Performance and design requirements

6.2.2.1 Formwork

6.2.2.1(a) Design forms that produce required finish. Limit deflection of facing materials between studs and deflection of studs and walers to 0.0025 times the clear span—that is, clear span divided by 400.

6.2.2.1(b) Where as-cast surfaces, including plywood form finish, are specified, concrete surfaces shall comply with **ACI 117M** tolerances for Class A surface.

6.2.2.1(c) Form face, form liner, and molds shall result in a concrete surface matching accepted field mockup.

6.2.2.1(d) Where panels for as-cast surfaces are separated by recessed or emphasized joints, provide, in the structural design of forms, the locations of ties within joints so patches of tie holes will be in the recessed or emphasized joints, unless otherwise specified.

6.2.2.1(e) Do not reuse forms with surface wear, tears, or defects that would produce concrete surfaces not conforming to accepted mockup. Clean and coat forms before reuse.

6.2.3 Proportioning concrete mixtures—For a concrete mixture of a specified color, use materials and proportions used in accepted field mockup. For architectural concrete exposed to cycles of freezing and thawing, use air-entrained concrete complying with 4.2.2.6(c) for the designated exposure class. Proportion concrete for specified compressive strength of at least 35 MPa if acid etch, mechanical tooling, or waterblasting is required.

6.3—Execution

6.3.1 Preparation—Clean and inspect formwork and batching, mixing, conveying, and placing equipment before use.

6.3.2 Formwork—Erect forms in accordance with Contract Documents and accepted shop drawings. Provide rustication joints and chamfers in accordance with Contract Documents and accepted shop drawings. Seal form joints, chamfers, and rustication joints. Provide closure backing materials if indented rustication is used over a ribbed form liner, and seal joint between rustication strip and form with nonabsorbent caulking.

6.3.3 Placement of reinforcement—Provide specified concrete cover over reinforcement and steel embedments. Use reinforcement supports in sufficient number, size, and location to prevent displacement of reinforcement and gouging of forming materials. Use reinforcement supports or spacers in walls and columns that maintain cover between reinforcement and face of concrete within **ACI 117M** tolerances. Bend back and keep tie wires from form face. Before placement of concrete, remove tie wire clippings from hori-

zontal surfaces that will be sandblasted, exposed to view, or exposed to weather.

6.3.4 Batching, mixing, and transporting—Mix and transport architectural concrete in equipment that results in completed Work having color and texture of accepted field mockup.

6.3.5 Conveying and placement—Schedule arrival of concrete to avoid delays in placement. Support runs or gangways for the concrete transporters, pump lines, wheelbarrows, other similar equipment, and foot traffic that will not displace reinforcement or interfere with concrete placing operations.

6.3.6 Form surface preparation

6.3.6.1 Prepare untreated natural wood forms with cement, lime slurry, or other methods or materials to condition the wood surface. Remove any cement or lime slurry residue from form face after treatment is dry.

6.3.6.2 Seal form joints and tie holes by taping or with nonabsorbent caulking. Clean taper ties and she-bolts and lubricate with nonstaining grease or form-release agent before each use.

6.3.6.3 Keep form face clean until concrete is placed.

6.3.7 Formwork removal—Schedule formwork removal in accordance with 2.3.2.1 through 2.3.2.5 and maintain surface appearance matching accepted field mockup. Prevent damage to concrete during formwork removal.

6.3.8 Surface repair and patching of tie holes

6.3.8.1 General—Repair surface and patch tie holes to match adjacent surface before surface treatments are applied. Proceed with repair work after form removal and surface finishing.

6.3.8.2 Color and texture match—Repairs in as-cast architectural concrete shall match color and texture of surrounding surfaces as performed on simulated repair area of the accepted field mockup.

6.3.8.3 Exposed aggregate—Any finishing process intended to expose aggregate on the surface shall show aggregate faces in repaired areas. Repaired areas shall contain the same aggregates as the surrounding concrete for a depth of at least 25 mm. In exposed-aggregate finish, the repair mixture shall contain the same selected colored aggregates. After repair has reached minimum compressive strength required by 6.3.9.2, 6.3.9.3, and 6.3.9.4 for the method of aggregate exposure, expose aggregates together with aggregates of adjoining surfaces by a process of mortar removal so that appearance matches accepted field mockup.

6.3.8.4 Curing repairs—Cure repairs in accordance with procedures used on accepted field mockup.

6.3.9 Finish—Finishes shall be as specified in Contract Documents.

6.3.9.1 Textured finishes—If specified, use textured forms or textured form liners of plastic, wood, or sheet metal. Secure liner panels in forms in accordance with manufacturer's recommendations. Do not use nail heads, screw heads, or washers that transfer impressions to the surface of the concrete. Seal edges of textured panels to each other or to divider strips to prevent leakage of cement paste. Use a sealant that will not discolor concrete surface.

6.3.9.2 Exposed-aggregate finishes—Expose aggregate to match accepted field mockup.

6.3.9.2(a) Retarded vertical surfaces—If specified, use accepted surface retarder. After form removal, remove the retarded outer layer of cement paste by hand brushing, high-pressure water washing, or light abrasive blasting. Schedule procedures and adjust timing for weather conditions to achieve aggregate exposure matching that of the mockup. The retarded surface shall not be removed until the unretarded concrete has reached an in-place compressive strength of at least 7 MPa.

6.3.9.2(b) Retarded horizontal unformed surfaces—If specified, use accepted surface retarder. Spray retarder on fresh cast horizontal surfaces after concrete consolidation, seeding of architectural aggregate if specified, and final finishing. Apply chemical retarder in accordance with manufacturer's recommendations. Remove the retarded surface cement paste after the mortar retaining the aggregate has set sufficiently to prevent dislodgment of the aggregate.

6.3.9.2(c) Waterblast—If specified, waterblast vertical surfaces when compressive strength exceeds 10 MPa. Expose aggregate to match accepted field mockup. If required, dispose of water used for blasting in accordance with submitted disposal plan.

6.3.9.2(d) Acid etch—If specified, use acid etching on horizontal surfaces only. Do not acid etch until concrete has a compressive strength of at least 21 MPa and is at least 14 days old. Wet concrete surface before applying acid. Continue application to match accepted field mockup. When acid bubbling stops, flush acid and debris from concrete surface by applying water under pressure. Protect adjacent materials, surfaces, and finishes from acid and waste wash-water during application and cleanup. If required, dispose of waste wash-water in accordance with submitted disposal plan.

6.3.9.3 Abrasive blast—If specified, begin abrasive blasting when concrete has a compressive strength of at least 14 MPa and after safe removal of forms and supports. Achieve degree of abrasive blasting exhibited in approved field mockup. Repair cracks before abrasive blasting. If abrasive grits contain free water for dust abatement, wash abrasive blasting debris off finished wall surface before drying occurs.

6.3.9.4 Mechanical tooling (bush-hammering)—If specified, begin mechanical tooling when concrete has a compressive strength of at least 31 MPa. Multiple bush-hammers used for tooling shall have equal wear on teeth. Maintain control of concrete chips, dust, and debris in each work area. Limit migration of airborne materials by using tarpaulins, wind-breaks, and similar devices.

6.3.9.5 As-cast formed finish—If specified, produce as-cast formed finish in accordance with Contract Documents and to meet the surface finish requirements SF-3 as defined in 5.3.3.2(c).

6.3.10 Curing architectural concrete—Cure architectural concrete in accordance with Section 5. Use curing methods from accepted field mockup that are compatible with any specified sealers or coating that may be applied to architectural concrete surface.

6.3.11 Final cleanup—Protect architectural concrete surfaces from damage, staining, or contaminants from subsequent construction. Do not apply additional sealers or coatings unless accepted by Architect/Engineer. Clean concrete surfaces before final submittal for acceptance. Use cleaning materials and processes that were used on approved mockup. Protect adjacent materials during cleaning operations.

6.3.12 Final acceptance of architectural concrete—Upon completion of architectural concrete, including surface repairs and patching of tie holes, final acceptance is based on matching the architectural cast-in place concrete with accepted field mockup when viewed at 6 m in daylight. Defective Work not conforming to Contract Documents, including repair areas not accepted, shall be removed and replaced.

SECTION 7—LIGHTWEIGHT CONCRETE

7.1—General

7.1.1 Scope—This Section covers construction requirements for concrete designated as lightweight concrete in Contract Documents.

7.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements in Sections 1 through 5 are applicable for lightweight concrete.

7.1.3 Submittals—Comply with 4.1.2 and 7.1.3.1 through 7.1.3.3.

7.1.3.1 Concrete density—Submit results of concrete density tests performed in accordance with ASTM C567/C567M. Include correlation between fresh density and equilibrium density.

7.1.3.2 Batching and mixing—Submit batching and mixing procedures that vary from requirements in 4.3.1.

7.1.3.3 Review of submittals—Obtain Architect/Engineer's acceptance of required submittals before placing lightweight concrete.

7.1.4 Aggregate storage and handling—Maintain lightweight aggregate at a moisture condition before batching that ensures concrete can be placed at required slump. Do not handle aggregate in a manner that causes degradation or segregation.

7.2—Products

7.2.1 Aggregates—Fine and coarse lightweight aggregates shall conform to ASTM C330/C330M. Normalweight aggregate used in lightweight concrete shall conform to 4.2.1.2.

7.2.2 Mixtures

7.2.2.1 Density—Proportion lightweight concrete to meet equilibrium density specified in Contract Documents. Unless otherwise specified, calculate the approximate equilibrium density of mixture from measured or calculated oven-dry density in accordance with ASTM C567/C567M.

Correlate equilibrium density with fresh density of concrete. Fresh density will be used as the basis for acceptance during construction.

7.3—Execution

7.3.1 Field quality acceptance

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7.3.1.1 Density—Acceptance of lightweight concrete in field will be based on fresh density measured in accordance with **ASTM C138/C138M**. Required fresh density is based on specified equilibrium density and correlation with fresh density, as established in 7.1.3.1. Unless otherwise specified, do not use concrete for which fresh density varies by more 65 kg/m^3 from the required fresh density.

7.3.1.2 Air content—Air content of lightweight concrete will be determined in accordance with **ASTM C173/C173M**.

SECTION 8—MASS CONCRETE

8.1—General

8.1.1 Scope—This Section covers construction requirements for concrete designated as mass concrete in Contract Documents.

8.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of **Sections 1** through **5** are applicable for mass concrete.

8.1.3 Temperature limits—Unless otherwise specified, the following temperature limits shall apply for mass concrete placements:

- (a) Maximum temperature in concrete after placement shall not exceed 70°C .
- (b) Maximum temperature difference between center and surface of placement shall not exceed 20°C .

8.1.4 Submittals—Comply with **4.1.2** and, unless otherwise specified, submit a thermal control plan for each mass concrete placement. Unless otherwise specified, the thermal control plan shall include:

- (a) Concrete materials, mixture proportions, and ranges of chemical admixture dosages
- (b) Permissible changes to concrete materials and mixture proportions that do not require the thermal control plan to be updated
- (c) Calculated or measured adiabatic temperature rise of concrete
- (d) Upper limit for concrete temperature at time of placement
- (e) Description of specific measures and equipment that will be used to ensure maximum temperature in placement will not exceed specified maximum temperature limit
- (f) Calculated maximum temperature in placement based on expected conditions at time of placement and use of proposed measures to control temperatures
- (g) Description of specific measures and equipment that will be used to ensure temperature difference will not exceed specified temperature difference limit
- (h) Calculated maximum temperature difference in placement based on expected conditions at time of placement and use of proposed measures to control temperature differences
- (i) Description of equipment and procedures that will be used to monitor and log temperatures and temperature differences
- (j) Drawing of locations for temperature sensors in placement
- (k) Description of format and frequency of reporting temperature data

(l) Description of measures to address and reduce excessive temperatures and temperature differences, if they occur

(m) Description of curing procedures, including materials and methods, and curing duration

(n) Description of formwork removal procedures to ensure temperature difference at temporarily exposed surface will not exceed temperature difference limit, and how curing will be maintained.

Update thermal control plan if changes in concrete materials or mixture proportions affect compliance with temperature limits.

8.2—Products

8.2.1 Materials

8.2.1.1 Cementitious materials—Unless otherwise specified, cementitious materials shall comply with **4.2.1.1**.

8.3—Execution

8.3.1 Curing and protection

8.3.1.1 Preservation of moisture

8.3.1.1(a) If strength criterion in **5.3.6.6(b)** is used to terminate curing, strength shall be evaluated at a formed or finished exterior surface using **2.3.4.2(b)**, **2.3.4.2(c)**, or **2.3.4.2(d)**. If **2.3.4.2(d)** is used, temperature sensors for measuring maturity shall be installed 50 to 75 mm below concrete surface.

8.3.1.1(b) Unless otherwise specified, preserve moisture by maintaining forms in place. For surfaces not in contact with forms, apply one of the methods specified in **5.3.6.5(e)** and **5.3.6.5(f)**. Unless otherwise specified, do not use methods specified in **5.3.6.5(a)** through **5.3.6.5(d)**.

8.3.1.2 Controlling concrete temperature—Control concrete temperature and temperature difference within concrete from time concrete is placed until time internal temperature has cooled from its maximum so that difference between average daily ambient temperature and internal temperatures at time of protection removal is less than specified temperature difference limit.

8.3.1.2(a) Monitoring temperatures—Unless otherwise specified or required in the thermal control plan, place one temperature sensor at the center of largest portion of placement and one temperature sensor at a depth 50 to 75 mm at center of exterior surface that is nearest to the center of the placement. Place a backup sensor at each sensor location. In addition, provide a temperature sensor in a shaded location for monitoring ambient on-site temperature.

Unless otherwise specified, monitor temperatures hourly using electronic sensors capable of measuring temperature from 0 to 100°C to an accuracy of 1°C . Ensure temperature sensors are operational before placing concrete. Unless otherwise specified, provide data from sensors to Architect/Engineer daily, until requirements of **8.3.1.2** are met.

8.3.1.2(b) Excessive temperatures or temperature differences—Compare temperatures and temperature differences with maximum limits specified in **8.1.3** every 12 hours or at intervals in the accepted thermal control plan. If either exceeds specified limits, take immediate action as described

in accepted thermal control plan to remedy situation. Do not place additional mass concrete until cause of excessive temperature or temperature difference has been identified and corrections are accepted.

SECTION 9—POST-TENSIONED CONCRETE

9.1—General

9.1.1 Scope—This Section covers construction requirements for structural members designated as post-tensioned concrete in Contract Documents.

9.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements in **Sections 1** through **5** are applicable for post-tensioned concrete.

9.1.3 Submittals

9.1.3.1 Required submittals before execution of Work—Submit information specified in 9.1.3.1(a) through 9.1.3.1(c).

9.1.3.1(a) Drawings—Shop drawings of post-tensioned structural concrete members providing the following information in addition to that required by **Sections 2** and **3**:

- (a) Sizes and heights of tendon supports, including bars and chairs
- (b) Location of tendons throughout their length
- (c) Size, details, location, materials, and grade of prestressing steel for tendons and accessories
- (d) Jacking procedures, stressing sequence, and tensioning forces
- (e) Wobble and curvature friction coefficients and anchor set
- (f) Calculated prestressing steel elongations
- (g) Details of reinforcement to prevent bursting and spalling
- (h) Prestressing steel trimming procedures and details of anchorage capping procedure
- (i) Duct characteristics, including size, material, thickness, support spacing, vents, inlets, and outlets
- (j) If specified, shop drawings shall be signed and sealed by a licensed design engineer and reviewed by Architect/Engineer.

9.1.3.1(b) Contractor proposed substitution—Contractor proposed deviations from post-tensioning design shall be indicated, in proposed substitution request, and include drawings and calculations signed and sealed by a licensed design engineer.

9.1.3.1(c) Grout certification—For grouted tendons, provide written certification that grout constituents comply with 9.2.2 and any other requirements in Contract Documents.

Unless otherwise specified, test reports to be submitted include the following:

- (a) Cement mill test reports
- (b) Admixtures test reports
- (c) Test reports for other constituents used in the grout
- (d) Manufacturer's current certified mill test reports for prepackaged grouts, if used

9.1.3.2 Optional submittals—If specified, submit the information in 9.1.3.2(a) through 9.1.3.2(h).

9.1.3.2(a) Test data substantiating expected curvature and wobble coefficients and expected anchorage set.

9.1.3.2(b) Results of tests required in 9.1.5.1, including demonstration of compliance with 9.2.1.1 and 9.2.1.2.

9.1.3.2(c) Duct stiffness test data.

9.1.3.2(d) Elongation calculations and tendon group final effective force calculations that account for loss of prestress due to anchorage set, friction, and long-term effects. Calculations shall be signed and sealed by a licensed design engineer.

9.1.3.2(e) If Contract Documents delegate structural design of post-tensioned concrete members to Contractor, submit drawings and design criteria used for designing post-tensioning, signed and sealed by a licensed design engineer. Submit design calculations.

9.1.3.2(f) Jack clearances.

9.1.3.2(g) Written grouting procedures at least 4 weeks before the start of construction of post-tensioned members. Develop grouting procedures to ensure the annular space in the ducts will be completely filled by grout. These procedures shall cover the following:

- (a) Type, quantity, and brand of materials used in grouting, including certifications required
- (b) Type of equipment to be used, including capacity as well as provisions for backup equipment and spare parts
- (c) Types and locations of grout vents, both inlets and outlets
- (d) Types and sizes of grout hoses and connections
- (e) Duct cleaning methods before grouting
- (f) Mixing and pumping procedures, including means to measure volume of grout pumped
- (g) Direction of grouting
- (h) Sequence of use for inlets and outlets
- (i) Procedures for handling blockages, including duct flushing
- (j) Procedures for possible regrouting
- (k) Names of the persons in charge and other personnel who will perform the grouting operation, including their relevant experience and skill

9.1.3.2(h) Results of grouting field trial and field mockup tests.

9.1.3.3 Required submittals during execution of Work—Submit information specified in 9.1.3.3(a) through 9.1.3.3(d).

9.1.3.3(a) Certified mill test reports for samples taken from the production lot of prestressing steel used in Work.

9.1.3.3(b) Stressing jack calibration certificates, including gauge pressure readings and calibration charts, for each set of equipment that will be used in Work. Certificates shall be submitted before stressing.

9.1.3.3(c) Stressing records are required for review before trimming prestressing steel that extends past anchorages. Submit the following data:

- (a) Project name
- (b) Floor number and concrete placement number
- (c) Tendon identification mark
- (d) Calculated elongation
- (e) Calculated gauge pressure reading to achieve specified stressing force based on supplied calibration chart

- (f) Elongation achieved
- (g) Actual gauge pressure reading
- (h) Date of stressing operation
- (i) Name and signature of stressing operator and inspector
- (j) Serial or identification number of jacking equipment
- (k) Date of accepted shop drawings used for installation and stressing
- (l) Weather conditions, including temperature and rainfall
- (m) If applicable, summary of problems encountered and corrective action taken

9.1.3.3(d) Record grouting operation and submit grouting records within 72 hours of grouting completion. Information in grouting records shall include:

- (a) Date of grouting
- (b) Number of days from stressing to grouting
- (c) Type of grout mixture and additives
- (d) Lot numbers of prepackaged tendon grout, if used
- (e) Tendon(s) grouted, injection end, and applied grouting pressure
- (f) If applicable, summary of problems encountered and corrective action taken
- (g) Volume of grout pumped into duct compared with volume of duct adjusted for grout displaced by prestressing tendon

9.1.4 Personnel qualifications

9.1.4.1 Installer certification—Unless otherwise specified, installation shall be performed by personnel certified in accordance with the Post-Tensioning Institute (PTI) training and certification programs.

9.1.4.1(a) Multistrand and grouted post-tensioning—At least 50 percent of installation personnel shall be certified in accordance with PTI Level 1 Multistrand and Grouted PT Installation Program. Crew foreman shall be certified in accordance with PTI Level 2 Multistrand and Grouted PT Specialist Program. Submit qualifications of installation personnel.

9.1.4.1(b) Unbonded post-tensioning—At least 50 percent of installation personnel shall be certified in accordance with PTI Level 1 Unbonded PT Installation Program. Crew foreman shall be certified in accordance with PTI Level 2 Unbonded PT—Installer, Inspector or Ironworker Program. Submit qualifications of installation personnel.

9.1.4.2 Tensioning personnel certification—Unless otherwise specified, tensioning shall be performed by personnel certified in accordance with PTI training and certification programs.

9.1.4.2(a) Multistrand and grouted post-tensioning—The tensioning crew foreman and at least 50 percent of tensioning personnel shall be certified in accordance with PTI Level 2 Multistrand and Grouted PT Specialist Program and remainder of tensioning personnel shall be certified in accordance with PTI Level 1 Multistrand and Grouted PT Installation Program. Submit qualifications of tensioning personnel.

9.1.4.2(b) Unbonded post-tensioning—The tensioning crew foreman and at least 50 percent of tensioning personnel shall be certified in accordance with PTI Level 2 Unbonded PT Installer, Inspector or Ironworker Program and remainder of tensioning personnel shall be certified in accordance with PTI Level 1 Unbonded PT Installation Program. Submit qualifications of tensioning personnel.

of tensioning personnel shall be certified in accordance PTI Level 1 Unbonded PT Installation Program. Submit qualifications of tensioning personnel.

9.1.4.3 Grouting personnel certification—Unless otherwise specified, grouting shall be performed by personnel certified in accordance with PTI Level 1 Multistrand and Grouted PT Installation Program. Unless otherwise specified, grouting operations shall be supervised and under immediate control of a person certified in accordance with PTI Level 2 Multistrand and Grouted PT Specialist Program and in accordance with ASBI Grouting Certification Program. The supervisor shall provide close observation and control of grouting operations necessary for compliance with specified requirements. If specified, supervisor shall be named and shall furnish proof of experience. Submit qualifications of grouting personnel.

9.1.4.4 Inspection personnel certification—Unless otherwise specified, inspection shall be performed by personnel certified in accordance with PTI training and certification programs.

9.1.4.4(a) Multistrand and grouted post-tensioning—Inspection shall be performed by personnel certified in accordance with the PTI Level 2 Multistrand and Grouted PT Inspector Program. Submit documentation of inspector certification. Inspection shall include:

- (a) Material cleanliness
- (b) Location and quantity of materials
- (c) Tensioning of prestressing tendons
- (d) Length of strand tails after trimming
- (e) Permanent grout caps
- (f) Tendon grouting

9.1.4.4(b) Unbonded post-tensioning—Inspection shall be performed by personnel certified in accordance with the PTI Level 2 Unbonded PT Inspector Program. Submit documentation of inspector certification. Inspection shall include:

- (a) Material cleanliness
- (b) Location and quantity of materials
- (c) Tensioning of prestressing
- (d) Length of strand tails after trimming
- (e) Installation of encapsulation caps
- (f) Grouting of stressing pockets

9.1.5 Quality control

9.1.5.1 Testing

9.1.5.1(a) Testing of multistrand and grouted tendon components—Test components of multistrand and grouted tendon systems in accordance with system approval testing requirements of **PTI/ASBI M50.3**.

9.1.5.1(b) Testing of unbonded tendon components—Test components of unbonded tendon systems in accordance with the requirements of **ACI 423.7**.

9.1.5.1(c) Grout quality-control testing—Test grout in accordance with laboratory and field testing requirements of PTI M55.1 for the grout class provided.

9.1.6 Product delivery, handling, and storage—Deliver, handle, and store materials to prevent mechanical damage and corrosion.

9.1.6.1 Handling

9.1.6.1(a) Identify wedges and anchorages by individual concrete placement area, floor sequence, or both. Use materials only in their identified concrete placement areas. In the event materials intended for one concrete placement area are exchanged into another concrete placement area, notify Architect/Engineer of exchanges for tracking purposes.

9.1.6.1(b) Protect tendons, accessories, and equipment from exposure to water and deicing salts. Do not damage sheathing or anchorages during handling and storage.

9.1.6.1(c) Unload tendons as close as practicable to the designated storage area to avoid excessive handling.

9.1.6.1(d) Do not use chains or hooks.

9.1.6.2 Storage

9.1.6.2(a) Store materials and equipment in a dry area on dunnage. Do not expose materials to water, snow, deicing salts, or other corrosive elements. If storage longer than 1 month is required, protect sheathing and other plastics from exposure to direct sunlight.

9.1.6.2(b) Store cement and prepackaged tendon grout to prevent hydration during storage. Use only cement or prepackaged grout that has been stored in accordance with manufacturer's requirements for grouting. Do not use prepackaged grout that has exceeded its shelf life.

9.1.6.2(c) Inspect tendons and accessory items before installation.

9.2—Products

9.2.1 Materials—Use materials that conform to the requirements of 9.2.1.1 through 9.2.1.3.

9.2.1.1 Multistrand and grouted tendon materials—Use materials that conform to the requirements of **PTI/ASBI M50.3**. Post-tensioning system tendon protection level shall be as indicated in Contract Documents.

9.2.1.2 Unbonded tendon materials—Use materials that conform to the requirements of **ACI 423.7**. For unbonded tendons, provide full encapsulation of prestressing steel conforming to ACI 423.7. If specified, submit encapsulation system test data to demonstrate compliance with watertightness requirements of **ACI 423.7**. If specified, non-encapsulated tendons are allowed in slabs-on-ground that:

- (a) Are not exposed to external sources of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources; or
- (b) Do not have stressing pockets subject to wetting or direct contact with soil during service.

9.2.1.3 Prestressing steel—Prestressing steel shall be of the type and minimum tensile strength specified in Contract Documents and shall conform to one of the following specifications:

- (a) **ASTM A416/A416M**
- (b) **ASTM A421/A421M**
- (c) **ASTM A722/A722M**
- (d) **ASTM A779/A779M**
- (e) **ASTM A882/A882M**

Prestressing steel shall be clean and free of scale, oil, dirt, and pitting. Surface rust shall be removable with a fine steel wool pad or by vigorous rubbing with a cloth. Pits on steel surface shall not exceed 0.05 mm in diameter or length.

9.2.2 Grout mixtures for grouted tendons—Unless otherwise specified, use grout materials, admixtures, and testing that conform to **PTI M55.1** with the following exception: water-soluble chloride ion content of grout shall not exceed 0.06 percent by mass of cement when tested in accordance with **ASTM C1218/C1218M**.

9.2.2.1 Grout classes for grouted tendons—Use grout class defined in 9.2.2.1(a) through 9.2.2.1(d) as indicated in Contract Documents.

9.2.2.1(a) Class A grout—Cement and water.

9.2.2.1(b) Class B grout—Cement, water, and field added admixtures

9.2.2.1(c) Class C grout—Prepackaged materials and water added in the field

9.2.2.1(d) Class D grout—Special materials, blended to achieve specific properties for a particular project as specified in Contract Documents.

9.2.2.2 Field testing

9.2.2.2(a) Field trial tests—If specified, conduct field trial batching and testing in accordance with **PTI M55.1** for the grout class with the same materials, personnel, and equipment to be used in production grouting.

Unless otherwise specified, conduct field trial tests at least 1 week before start of production grouting. If field mockup tests are specified, conduct field trial tests at the same time as field mockup tests.

9.2.2.2(b) Field mockup tests—If specified, conduct field mockup tests of grouting in accordance with **PTI M55.1**. Field mockup tests shall verify and demonstrate that materials, outlets, inlets, mixer, grouting equipment, methods, and procedures are appropriate and will result in complete filling of duct.

Schedule field mockup tests in advance of production grouting. At least 4 weeks before the scheduled start of field mockup tests, submit a written field mockup test plan that covers test setup, materials, ducts, inlets, outlets, anchorages, prestressing element, and grouting and dissection procedures. Supervisory personnel and equipment used for mockup tests shall be the same as those used for production grouting.

9.2.3 Tape for repair of sheathing—Tape used shall:

- (a) Be self-adhesive and moisture-proof
- (b) Be nonreactive with sheathing, coating, or prestressing steel
- (c) Have ability to conform to sheathing surface
- (d) Have at least 50 mm width
- (e) Have a contrasting color to the tendon sheathing

9.3—Execution

9.3.1 Inspection—Conduct and document a visual inspection of applicable installation, tensioning, grouting, and finishing for conformance to requirements of this Specification and Contract Documents.

9.3.2 Multistrand and grouted tendon installation

9.3.2.1 Bearing surface between anchorage and concrete shall be concentric with the tendon. Bearing plate or anchorage shall be perpendicular to direction of tendon at

9.3.2.2 Keep tendons and ducts dry. Do not start grouting until concrete temperature around tendon is 4°C or higher. Maintain concrete temperature around bonded tendons at 4°C or higher for at least 3 days after grouting.

9.3.2.3 If the tendon extends beyond member ends or if tendons are outside the concrete of post-tensioned concrete member, cover exposed and other specified parts of the tendon with additional corrosion protection coating. Coating shall be shop-applied or field-applied and shall be plastic, epoxy, or other acceptable material.

9.3.2.4 Keep end anchorages protected from concrete and free of loose rust, grease, oil, and other debris.

9.3.2.5 Ducts

9.3.2.5(a) Keep ducts, anchorage block-outs, openings, vents, inlets, and outlets clean and free of debris, fuel, oil, other contaminants, and site trash before and after installing tendons. Use temporary plugs, seals, and covers as needed.

Before placing concrete, repair damaged ducts by removing locally damaged duct and splicing duct or couplers onto the damaged section, or by other means acceptable to Architect/Engineer.

9.3.2.5(b) Before grouting, ducts shall be blown with oil-free, compressed air to remove water and debris blockages that interfere with grout injection. If specified, test ducts using pressurized air to locate potential grout leaks.

9.3.2.5(c) Duct support spacing—Duct support spacing (ℓ) shall conform the following values:

- (a) Galvanized metal round duct: $\ell \leq 1.2$ m
- (b) Plastic round duct: $\ell \leq 600$ mm
- (c) Plastic flat duct (with strand preinstalled in duct): $\ell \leq 600$ mm
- (d) Plastic flat duct (without strand preinstalled in duct): $\ell \leq 300$ mm

9.3.3 Unbonded tendon installation

9.3.3.1 Support prestressing tendons at intervals not exceeding 1.2 m.

9.3.3.2 Attach tendons to reinforcement supports or reinforcement without damaging sheathing.

9.3.3.3 Keep tendons and accessories clean and undamaged. Unless otherwise specified, protect exposed components within 1 working day after their exposure during installation.

9.3.3.4 Prevent water from entering tendons during installation.

9.3.3.5 Stressing-end anchorage

9.3.3.5(a) Install stressing-end anchorages perpendicular to tendon axis. The transition curvature in tendon profile shall not start closer than 300 mm from stressing-end anchorage.

9.3.3.5(b) Attach stressing-end anchorages to bulkhead forms. Connections shall be sufficiently rigid to avoid accidental loosening. Attach anchor to form edge using fasteners that will not corrode or are protected from corrosion by other means.

9.3.3.5(c) Top, bottom, and edge concrete cover for anchorages shall not be less than specified cover to reinforcement. Unless otherwise specified, concrete cover from exterior edge of concrete to wedge cavity area of anchor shall be at least 40 mm for non-encapsulated tendons and at least 50 mm for encapsulated tendons.

9.3.3.5(d) Pocket formers used to provide a void form at stressing-end and intermediate anchorages shall prevent intrusion of concrete or cement paste into wedge cavity. At angled slab edges, concrete cover given in 9.3.3.5(c) shall be maintained to anchor edges.

9.3.3.5(e) Cap wedge cavity and install sleeves and seals connecting sheathing to anchorage to completely seal the area against moisture. Install cap after coating the tendon end and wedge area with post-tensioning coating material conforming to ACI 423.7. For non-encapsulated applications, capping of wedge cavity and installing sleeves and seals is not required.

9.3.3.5(f) Unless otherwise specified, concrete cover from the exterior edge of concrete shall be at least 20 mm to strand tail for non-encapsulated tendons and at least 25 mm to encapsulation cap for encapsulated tendons.

9.3.3.6 Intermediate anchorages

9.3.3.6(a) Embed intermediate anchorages in the first concrete placed at a construction joint. Unless otherwise specified, make the joint watertight.

9.3.3.6(b) Install intermediate anchorages perpendicular to tendon axis. The transition curvature in tendon profile shall be at least 300 mm from intermediate anchorage.

9.3.3.6(c) Top and bottom cover requirements given in 9.3.3.5(c) shall apply to intermediate anchorages.

9.3.3.6(d) Cap wedge cavity and install sleeves and seals connecting sheathing to anchorage on both sides of anchorage to completely seal the area against moisture. Coat exposed prestressing steel and wedge area with post-tensioning coating material conforming to requirements of ACI 423.7. Protection of intermediate anchorage shall be completed within 1 working day of exposure. For non-encapsulated applications, capping of wedge cavity and installing sleeves and seals is not required.

9.3.3.7 Fixed-end anchorages

9.3.3.7(a) Wedge-type anchorages—Fixed-end anchorages using wedges for gripping strand shall be seated onto prestressing steel by any method that permanently attaches anchorage onto strand. These methods shall include one of the following: pulling wedges into the anchor cavity; pushing wedges into the anchor cavity without applying force on the strand; or other method that will prevent release of prestressing steel and satisfies these requirements.

Temporary force applied to seat wedges shall be limited to a percentage of the minimum breaking strength of the prestressing steel as follows:

- (a) Strand pull method = 80 to 85 percent
- (b) Strand push method = 85 to 90 percent
- (c) Wedges push method = 85 to 120 percent

9.3.3.7(b) Install fixed-end anchorages perpendicular to tendon axis. The transition curvature in tendon profile shall not start closer than 300 mm from fixed-end anchorage.

9.3.3.7(c) Place fixed-end anchorages in formwork at locations indicated on shop drawings and secure them to maintain their position during concrete placement. Concrete cover requirements given in 9.3.3.5(f) apply to fixed-end anchorages.

9.3.3.7(d) Cap wedge cavity and install sleeves and seals connecting sheathing to anchorage to seal the area against moisture. Install cap after coating tendon end and wedge area with same post-tensioning coating material used over tendon length and conforming to requirements of ACI 423.7. For non-encapsulated applications, capping of wedge cavity and installing sleeves and seals is not required.

9.3.3.8 Sheathing inspection and repair

9.3.3.8(a) After installing tendons in forms, inspect sheathing for damage. Repair damaged areas, including any breach or split, by restoring post-tensioning coating in the damaged area and repairing sheathing in conformance with 9.3.3.8(b).

9.3.3.8(b) Sheathing repairs shall be watertight, without air spaces, and performed using tape conforming to 9.2.3 and sheathing repair procedures acceptable to Architect/Engineer.

9.3.4 Tendon tolerances

9.3.4.1 Unless otherwise specified, deviations between profiles of bonded tendons and design profiles shall be in accordance with **PTI/ASBI M50.3**.

9.3.4.2 For unbonded post-tensioning, place tendons within the tolerances of **ACI 117M** for reinforcement placement, distance between reinforcement, and concrete cover except that in slabs, straight tendon runs shall not deviate horizontally more than 25 mm in 4.6 m of tendon length.

9.3.4.2(a) Unless otherwise specified, deviations between profiles of single-strand unbonded tendons and design profile shall not exceed:

- (a) 6 mm for member depth less than or equal to 200 mm
- (b) 10 mm for member depth greater than 200 mm and less than or equal to 600 mm
- (c) 13 mm for member depth greater than 600 mm

9.3.4.2(b) Lateral deviations in unbonded tendon location are allowed if necessary to avoid openings, ducts, chases, and inserts. Lateral deviations shall have a radius of curvature no less than 480 strand diameters. If radius of curvature less than 480 strand diameters is necessary, provide additional hairpin reinforcement that is accepted by Architect/Engineer.

9.3.5 Concrete placement

9.3.5.1 General—Prevent water and cementitious paste from entering tendons during concrete placing and curing.

9.3.5.2 Placement—Maintain position of post-tensioning tendons and nonprestressed reinforcement within tolerance during concrete placement. Ensure formwork and tendon supports maintain tendon profile within tolerance during concrete placement.

9.3.5.3 Protection of tendons—Support pump lines, chutes, and other concrete placing equipment above tendons.

9.3.6 Tensioning

9.3.6.1 Sequence—Stress tendons in sequence and construction stages specified in Contract Documents. In-place concrete strength at stressing shall not be less than required in Contract Documents.

9.3.6.2 Tensioning multistrand tendons—Tension tendons composed of multiple strands in a common duct simulta-

neously, unless the tendon system requires that strands are stressed individually.

9.3.6.3 Tendon stressing—Tension prestressing steel using a hydraulic jack equipped with a gauge calibrated with the jack. The calibrated jack-gauge system shall be capable of measuring jacking force within an accuracy of 2 percent.

Apply required jacking force to produce the prestressing force indicated in Contract Documents or shop drawings and measure prestressing steel elongation. Verify that prestressing force is sufficient by comparing measured elongations to calculated elongations.

If measured elongations differ from calculated elongations by more than 7 percent, determine the cause of discrepancy and resolve.

Maintain and submit a record of elongations and gauge pressure readings for each tendon. Do not remove stressing tails, grout ducts, or grout stressing pockets until Architect/Engineer has accepted elongation records.

9.3.6.4 Loss of prestressing force—The total loss of prestressing force in any post-tensioned structural concrete member due to unreplaced broken tendons shall not exceed 2 percent of the total prestressing force.

9.3.6.5 Formwork removal—Refer to **2.3.2.6** for requirements for removal of formwork supports.

9.3.6.6 Prevention of damage to tendons—Protect tendons from mechanical damage, welding sparks, flame, or electric ground currents. Do not conduct burning and welding operations in the vicinity of tendons, except as allowed by 9.3.8.1 and 9.3.8.2.

9.3.7 Grouting

9.3.7.1 Time between application of prestressing and grouting—Grout as soon as practicable after stressing prestressing steel in ducts. Time from installing prestressing steel in ducts to grouting after stressing shall not exceed the intervals indicated in Table 9.3.7.1 unless temporary corrosion protection measures are accepted by Architect/Engineer.

Table 9.3.7.1—Permissible intervals between prestressing steel installation and grouting without the use of corrosion protection for different exposures

Over saltwater or damp atmosphere (relative humidity greater than 70 percent)	7 days
Moderate atmosphere (relative humidity between 40 percent and 70 percent)	20 days
Dry atmosphere (relative humidity less than 40 percent)	40 days

9.3.7.2 Grout mixing—Mix grout in a mechanical mixer capable of continuous mixing that will produce a grout free of lumps and undispersed cement. Pass grout through the No. 16 sieve into pumping equipment that has provisions for recirculation.

9.3.7.3 Apply grout under positive pressure—Grouting pressure at the inlet shall not exceed 1.0 MPa for internal plastic, or oval or flat metal ducts, or 1.7 MPa for internal circular metal ducts without written acceptance of Architect/Engineer.

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9.3.7.4 Grouting procedure—The method of injecting grout shall ensure complete filling of ducts and complete surrounding of strand or bar with grout. Inject grout from lowest grout inlet in an uphill direction. Use grout within 30 minutes of first addition of water. Maintain a continuous, one-way flow of grout within a grouting stage. Perform grouting of tendon(s) in one operation. Pump grout through duct so it flows continuously out of the first outlet after the inlet. Continue pumping until no visible slugs of water or air eject from vents and outlets and consistency of grout flowing out is similar to injected grout, at which time the outlet shall be closed. Unless otherwise specified, grout injection rate shall be between 5 and 15 m of duct per minute.

If one-way grout flow cannot be maintained, grouting shall be continued from next available outlet that has steady grout outflow with no visible air or water. Discard grout when it loses consistency required for pumping.

9.3.7.5 Grouting vertical tendons—For vertical tendons, provide a standpipe at tendon upper end to store bleed water and grout. The standpipe shall maintain grout level at an elevation that prevents bleeding from causing grout level to drop below the highest point of the uppermost anchorage device. Provide a standpipe that allows bleed water to rise into standpipe, and not into the uppermost part of the tendon and anchorage device.

Maintain grout level above bearing plate and anchorage.

For vertical tendons longer than 30 m or if the grouting pressure exceeds the maximum specified pumping pressure, grout shall be introduced into one or more of the uppermost intermediate grout vents where air and water has been completely purged. Procedure for pumping from intermediate grout vents shall maintain a one-way flow of grout.

9.3.7.6 Record keeping—Maintain record of grouting operations for each tendon and submit a written report in accordance with 9.1.3.3(d) to Architect/Engineer within 72 hours after grouting.

9.3.7.7 Completion of grouting—Fill voids between prestressed reinforcement, ducts, and anchorage fittings. Continue injection until grout of the same consistency as grout injected flows from vent and drain openings without presence of water or air bubbles. Close vent and drain openings progressively in the direction of flow. After vent and drain openings have been closed, raise grouting pressure to at least 350 kPa and plug injection hole.

9.3.7.8 Measures taken after grouting—Not less than 24 hours after grouting, grout level in outlets and grout caps shall be inspected and topped as necessary with freshly mixed grout.

9.3.8 Tendon finishing

9.3.8.1 Tendon finishing for multistrand and grouted post-tensioned tendons—Within 1 day after acceptance of stressing records described in 9.1.3.3(c), cut tendon tails. Strand tails protruding beyond wedges after cutting shall be at least 13 mm. If cutting is delayed, seal tendon openings and temporarily weatherproof exposed tendon ends according to the specified tendon protection level.

Unless otherwise specified, remove tendon tails by plasma cutting, abrasive wheel, or mechanical shearing.

connection for plasma cutting shall be placed directly on strand bundle being cut off.

If specified, install permanent grout caps, and close grout vents within 1 day of cutting tendon tails.

9.3.8.2 Tendon finishing for unbonded post-tensioned tendons

9.3.8.2(a) Trimming tendons—After acceptance of stressing records described in 9.1.3.3(c), cut excess tendon tails. Strand tails shall be at least 13 mm from face of anchor casting after cutting.

For encapsulated tendons, strand length protruding from face of anchor casting after cutting shall not be more than maximum specified by encapsulation system manufacturer and shall not interfere with proper sealing of end cap. Concrete cover for the tendon shall comply with 9.3.3.5(f).

Cut tendon tails within 1 working day after acceptance of stressing records by Architect/Engineer. For encapsulated tendons, install encapsulation caps within 8 hours after cutting off tendon tails.

For tendons with encapsulated anchorages, remove excess lengths of tendons beyond anchorages to ensure proper fit of encapsulation cap. Cutting of tendons shall not damage wedges or compromise encapsulation system.

9.3.8.2(b) Tendon protection—If cutting or capping is delayed more than 7 days after stressing, provide protection to prevent moisture from reaching anchorages.

9.3.8.2(c) Sealing anchorages—Before grouting stressing pockets, seal encapsulated stressing-end anchorages in unbonded construction with watertight cap filled with post-tensioning coating.

9.3.8.2(d) Filling stressing pockets—Fill stressing pockets with nonmetallic, nonshrink grout within 1 day after cutting prestressing steel. Grout used for pocket filling shall not contain chlorides or other chemicals known to be deleterious to prestressing steel and shall be nonreactive with prestressing steel, anchorage materials, and concrete.

SECTION 10—SHRINKAGE-COMPENSATING CONCRETE FOR INTERIOR SLABS

10.1—General

10.1.1 Scope—This Section covers requirements for concrete made with cementitious material conforming to **ASTM C845/C845M** for interior slabs designated in Contract Documents to be constructed of shrinkage-compensating concrete.

10.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of Sections 1 through 5 are applicable for shrinkage-compensating concrete for interior slabs.

10.1.3 Submittals

10.1.3.1 Obtain Architect/Engineer's acceptance of required submittals before placing concrete.

10.1.3.2 Submit expansion test results determined in accordance with **ASTM C878/C878M** for proposed concrete mixture proportions. Include intermediate expansion data so that age at which 70 percent of 7-day laboratory expansion occurs can be determined.

10.1.3.3 Submit placing sequence that shall include sequence of placements, minimum time between placements, and layout of each placement.

10.2—Products

10.2.1 Materials

10.2.1.1 Cementitious materials—Unless otherwise specified, cementitious material shall conform to ASTM C845/C845M.

10.2.1.2 Admixtures—Unless otherwise specified, do not use accelerating admixtures or admixtures containing calcium chloride.

10.2.2 Performance and design requirements

10.2.2.1 Air content—Concrete for interior slabs to receive a hard-troweled finish shall not contain an air-entraining admixture or have total air content greater than 3 percent.

10.2.2.2 Expansion—Unless otherwise specified, concrete expansion, determined in accordance with ASTM C878/C878M, shall be at least 0.03 percent and not more than 0.06 percent at 7 days of soaking.

10.2.2.3 Slump—Unless otherwise specified, slump at point of placement shall not exceed 6 in.

10.2.3 Proportioning—Conform to 4.2.3 and 10.2.3.1 through 10.2.3.3.

10.2.3.1 If laboratory trial mixtures are used, procedures of ASTM C192/C192M shall be modified as follows: stop the concrete mixer after initial mixing cycle and cover mixer for 20 minutes, unless otherwise specified. After this time period, add water as necessary to produce a slump within 20 mm of specified slump. Concrete shall then be mixed for an additional 2 minutes.

10.2.3.2 For proposed concrete mixture, provide laboratory test results for three expansion specimens cast and tested in accordance with ASTM C878/C878M. Submit expansion test results.

10.2.3.3 Revisions to concrete mixtures—If concrete materials are changed or mixture proportions are revised in accordance with 4.2.3.6, evaluate the effect on expansion in accordance with ASTM C878/C878M and submit test results.

10.2.4 Reinforcement—Use reinforcement as specified in Contract Documents.

10.2.5 Isolation-joint filler materials—Unless otherwise specified, use compressible isolation-joint filler material that does not develop a stress greater than 170 kPa at 50 percent strain when tested in accordance with ASTM D1621 or ASTM D3575.

10.3—Execution

10.3.1 Reinforcement

10.3.1.1 Unless otherwise specified, provide 40 mm cover from top surface for reinforced slabs-on-ground.

10.3.2 Placing

10.3.2.1 Placing sequence—Sequence of concrete placements shall be in accordance with accepted placement sequence and shall permit previous placements to have two adjacent edges free to expand.

10.3.2.2 Unless otherwise specified, time between casting adjoining sections shall be at least that required to produce 70 percent of 7-day laboratory expansion of the concrete mixture as determined in accordance with ASTM C878/C878M and as submitted in accordance with 10.1.3.2.

10.3.3 Isolation joints—Provide isolation joints at junctions with columns, walls, drains, or other rigid obstructions in the structure in accordance with Contract Documents.

10.3.4 Curing—Unless otherwise specified, water-cure shrinkage-compensating concrete for at least 7 days in accordance with 5.3.6.5(a) or 5.3.6.5(b).

SECTION 11—INDUSTRIAL FLOOR SLABS

11.1—General

11.1.1 Scope—This Section covers construction requirements for concrete slabs-on-ground that are designated as industrial floor slabs in Contract Documents.

11.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of Sections 1 through 5 are applicable for industrial floor slabs.

11.1.3 Submittals

11.1.3.1 Obtain acceptance of required submittals from Architect/Engineer before placing concrete.

11.1.3.2 In addition to submittal requirements of Sections 2 through 5, submit information specified in 11.1.3.2(a) through 11.1.3.2(e).

11.1.3.2(a) Manufacturer's data sheet for load-transfer devices at joints.

11.1.3.2(b) Manufacturer's data sheet on saw used to install contraction joints.

11.1.3.2(c) Manufacturer's data sheet for sheet materials for curing, liquid-applied membrane-forming curing compounds, or other materials for curing. If curing compound is specified, submit method of removal if used in areas to receive subsequent finish flooring.

11.1.3.2(d) Plan for protecting concrete against anticipated ambient conditions during transportation, placement, finishing, and specified curing period.

11.1.3.2(e) Plan for joint layout.

11.1.3.3 Submit 11.1.3.3(a) through 11.1.3.3(g), if specified.

11.1.3.3(a) Drying shrinkage test results, for proposed concrete mixture determined in accordance with ASTM C157/C157M, except that instead of storage for 28 days in lime-saturated water, specimens are subjected to 7 days of moist curing followed by at least 21 days of air drying, unless a longer drying period is specified in Contract Documents. The initial length of specimens used as the basis for length change shall be measured at 24 hours \pm 1/2 hour upon demolding specimens and drying-shrinkage measurements shall begin at completion of 7-day moist-curing period.

11.1.3.3(b) Manufacturer's data sheet for vapor retarder.

11.1.3.3(c) Manufacturer's data sheet for joint filler.

11.1.3.3(d) Manufacturer's data sheet for liquid-applied surface densifiers.

11.1.3.3(e) Manufacturer's data sheet for mineral or metallic shake hardeners.

11.1.3.3(f) Plan showing extent of each placement, placing sequence, and schedule for each placement.

11.1.3.3(g) Design of construction joint forms.

11.2—Products

11.2.1 Materials—Materials used for industrial slab construction shall conform to Sections 2, 3, and 4, except as modified in this Section.

11.2.1.1 Cementitious materials—Conform to **4.2.1.1. ASTM C150/C150M** Type III, or other high-early-strength hydraulic cement shall not be used.

11.2.1.2 Aggregates

11.2.1.2(a) Unless otherwise specified, use aggregates with a nominal maximum size of 40 mm conforming to requirements of **4.2.1.2**.

11.2.1.2(b) Unless otherwise specified, use aggregate base course conforming to **ASTM D2940/D2940M**.

11.2.1.3 Admixtures

11.2.1.3(a) Unless otherwise specified, calcium chloride or admixtures containing chloride from sources other than impurities in admixture ingredients are prohibited.

11.2.1.3(b) Air-entraining admixtures are prohibited in concrete mixtures for use in slabs to receive a hard-troweled finish.

11.2.2 Concrete mixture—Unless otherwise specified, proportion concrete mixture to satisfy the following:

- (a) Specified compressive strength of 24 MPa at 28 days
- (b) Slump between 100 and 150 mm
- (c) Shrinkage limit, if specified in Contract Documents

11.2.2.1 Air content—Concrete for slabs to receive a hard-troweled finish shall not have total air content greater than 3 percent.

11.2.2.2 Concrete temperature—Unless otherwise specified, maximum temperature of concrete, as delivered, shall be 35°C.

11.2.3 Field verification of selected mixture proportions—Comply with **4.2.3.5** to verify the concrete mixture can be finished to achieve a hard-troweled finish.

11.2.4 Vapor retarder—Unless otherwise specified, vapor retarder shall conform to **ASTM E1745** Class A and shall be at least 0.25 mm thick.

11.2.5 Reinforcement—If specified, use deformed reinforcing bars, tendons, or deformed or plain welded wire reinforcement in conformance with Contract Documents. Supports shall be used at a spacing to result in reinforcement placement in accordance with Contract Documents. If used, welded wire reinforcement shall have a wire spacing of at least 350 mm in both directions.

11.2.6 Fibers—If specified, use fibers in concrete mixture in accordance with Contract Documents.

11.2.7 Load-transfer devices—If specified, provide load-transfer devices at joints indicated in Contract Documents.

11.2.8 Joint filler materials—Unless otherwise specified, use a two-component semi-rigid joint filler material. Joint filler shall have 100 percent solids, a Shore A hardness of at least 85 when measured in accordance with **ASTM D2240** at 21 to 25°C, and an elongation below 90 percent when measured in accordance with **ASTM D638**. @seismicisolation

11.2.9 Isolation-joint filler materials—Unless otherwise specified, use joint material that prevents bond and allows for horizontal and vertical movement of slab relative to fixed abutting elements and penetrations. Use compressible isolation-joint filler material that does not exceed a stress of 170 kPa at 50 percent strain when tested in accordance with **ASTM D1621** or **ASTM D3575**.

11.2.10 Curing materials

11.2.10.1 Curing compounds—Membrane-forming curing compounds shall meet requirements of **5.2.1.2**.

11.2.10.2 Sheet materials—Moisture-retaining sheet materials shall meet requirements of **ASTM C171**. Sheet material shall be non-staining and absorbent.

11.2.11 Liquid surface densifier—If specified, use an acceptable liquid surface densifier in areas where indicated.

11.2.12 Mineral or metallic shake surface hardeners—If specified, use an acceptable dry-shake hardener in areas where indicated.

11.3—Execution

11.3.1 Preparation—Proof-roll prepared base in accordance with Contract Documents. Unless otherwise specified, compact aggregate base course to at least 95 percent of maximum density determined in accordance with **ASTM D698**. Comply with requirements of **5.3.1** and verify that base surface elevation is within a tolerance of +0 mm and 13 mm of planned elevation. This base surface elevation tolerance shall be maintained during casting of concrete. If specified, install acceptable vapor retarder in accordance with **ASTM E1643** directly beneath slab in areas as indicated in Contract Documents. Lap seams at least 150 mm and tape continuously. Repair punctures in vapor retarder.

11.3.2 Measuring, batching, and mixing—Conform to **4.3.1**.

11.3.3 Delivery—Conform to **4.3.2**.

11.3.4 Concrete placement—Conform to **5.3.2**.

11.3.5 Finishing and initial curing of slab surface—Unless otherwise specified, comply with **5.3.4.2(c)** and **5.3.6.2** to provide a hard-troweled finish. Water shall not be added to slab surface during finishing. If required, apply shake surface hardener according to manufacturer's recommendation.

11.3.5.1 Surface flatness and levelness—Unless otherwise specified, overall surface flatness shall be $F_F 35$, and overall levelness shall be $F_L 25$. Local area minimum values shall be $F_F 23$ and $F_L 17$ as determined in accordance with **ASTM E1155**.

11.3.6 Joints—Construct movement joints as indicated in Contract Documents.

11.3.6.1 Isolation joints—Install isolation joint material to full depth of slab.

11.3.6.2 Construction joints—Comply with **2.2.2.5**, **2.3.1.4**, and **5.3.2.6**. Construction joints shall be perpendicular to slab surface; include load-transfer devices, but do not include keyways. Unless otherwise specified, doweled construction joints designed to allow joint widening shall be saw cut to one-fourth slab thickness or 50 mm, whichever is smaller. Align saw cut with joint. Remove concrete dust

from saw-cut operation and protect joints from damage due to construction activities.

11.3.6.3 Contraction joints—Unless otherwise specified, saw cut all contraction joints and comply with 5.3.5. If early-entry dry-cutting saws are used, replace skid plate and blade as recommended by equipment manufacturer to minimize saw-cut raveling. Install saw cuts perpendicular to slab surface. Remove concrete dust from saw-cut operation. Protect joints from damage due to construction activities.

11.3.6.4 Consolidation and load-transfer devices—Comply with 5.3.2.5. Install devices at slab mid-depth and secure to avoid displacement. Consolidate concrete around load-transfer devices by vibration adjacent to the devices.

11.3.7 Curing and protection—Comply with 5.3.6 and provide curing for at least 7 days unless otherwise specified. If a sheet material is used, apply as soon as practicable without marring finished surface. Place moisture-retaining sheet materials in a manner to prevent surface discoloration or marking. Keep slab continuously wet after final finishing is completed and during curing period. If a curing compound is used, including those considered self-dissipating, do not apply where subsequent finish flooring or surface densifier is to be installed unless compound is compatible with flooring system or it will be removed by method acceptable to finish flooring or surface densifier manufacturer.

11.3.8 Liquid surface densifier—If specified, apply liquid surface densifier in accordance with manufacturer's recommendations. If applied after curing period, remove curing cover or curing compound, allow slab surface to air-dry for at least 7 days, and apply product.

11.3.9 Joint filling—Unless otherwise specified, fill joints with a semi-rigid joint filler. Install joint filler full depth of saw cuts. Unless otherwise specified, do not install joint filler earlier than recommended by filler manufacturer. Joints shall be overfilled and shaved flush. During project warranty period, monitor joint filler for separation, sagging, bulging, or other deformation and monitor concrete deterioration along joints as joints widen. Separations, sagging, bulging, or other deformations, and joint deterioration shall be corrected within project warranty period.

SECTION 12—TILT-UP CONSTRUCTION

12.1—General

12.1.1 Scope—This Section covers construction requirements for concrete panels designated as tilt-up construction in Contract Documents.

12.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of Sections 1 through 5 are applicable for tilt-up construction.

12.1.3 Submittals—Unless otherwise specified, submit items specified in 12.1.3.1 through 12.1.3.8.

12.1.3.1 Bearing shims—Manufacturer's product data sheet for bearing shims to be used.

12.1.3.2 Coloring agents—Data on coloring agents.

12.1.3.3 Bond breaker—Data on bond breaker.

12.1.3.4 Drawings

12.1.3.4(a) Lifting and bracing design drawings—These panel drawings include locations for lifting inserts, brace inserts, minimum concrete strength for lifting, added reinforcement for lifting, and bracing design. Panel design shall include bracing to maintain panel tolerances until final structural connections are made. Lifting and bracing design drawings shall be signed and sealed by a licensed design engineer. If specified, submit design calculations signed and sealed by licensed design engineer.

12.1.3.4(b) Reinforcement placing drawings—These drawings shall include reinforcing bar sizes, locations, lengths, splices, and quantities.

12.1.3.5 Field mockups—If specified, field mockups shall be two panels unless otherwise specified. Each panel shall be at least 1.2 x 2.4 m, constructed and erected using materials and methods detailed in panel shop drawings. Include edge and reveal procedures, special finishes, color, repair, and aggregate sizes. Maintain field mockups until completion of Work.

12.1.3.6 Grout—Panel grout manufacturer's data sheet or producer's mixture proportions.

12.1.3.7 Sandwich panel insulation system—Details of wythe connections, and thickness and type of insulation to be used to construct insulated sandwich panels.

12.1.3.8 Defects repair—Methods and materials for repair of defects.

12.1.4 Tilt-up contractor qualifications—Provide documentation of tilt-up contractor's qualifications. Workers shall be proficient in production and erection operations and shall be under direct supervision of an ACI-certified Tilt-Up Supervisor. The tilt-up concrete erector shall submit documentation of at least 2 years of experience in tilt-up product erection, including projects similar in size and scope.

12.2—Products

12.2.1 Aggregates—Unless otherwise specified, aggregates shall conform to requirements of Section 4.

12.2.1.1 Facing aggregates—Provide fine and coarse aggregate for each type of exposed finish from a single source pit or quarry.

12.2.2 Bearing shims—Unless otherwise specified, plastic bearing shims with adequate capacity to support the applied loads before grouting panels.

12.2.3 Bond breaker—Bond breaker shall be compatible with curing compound and with coating applied to interior or exterior concrete panels or floor slab.

12.2.4 Cast-in anchors and connections

12.2.4.1 Lifting inserts—Provide, from a single-source manufacturer, structural inserts and components to engage lifting inserts for lifting tilt-up panels.

12.2.4.2 Bracing inserts—Provide structural inserts from a single-source manufacturer for temporary bracing of tilt-up panels.

12.2.5 Coloring agent—Coloring agent shall conform to ASTM C979/C979M.

12.2.6 Curing compound and bond breaker—Curing compound and bond breaker may be same product, if curing compound is not same product as bond

breaker, compatibility shall be determined before application of curing compound.

12.2.7 Face thickness—Minimum thickness of face shall be the largest of 25 mm, 1-1/2 times nominal maximum size of aggregate used, and minimum thickness to provide 20 mm cover over reinforcement.

12.2.8 Grout—Portland cement used in grout shall conform to **ASTM C150/150M**. Nonshrink grout shall conform to **ASTM C1107/C1107M**.

12.2.9 Sandwich panel insulation systems—Unless otherwise specified, wythe connectors used in construction of insulated concrete sandwich panels shall maintain effective acceptable material *R*-value of panels as specified in **ASHRAE 90.1**.

12.3—Execution

12.3.1 Casting bed—Cast panels on floor slab or waste slab. Waste slabs, if specified or used, shall be at least 50 mm thick if cast on compacted base or at least 75 mm if compacted base is not used. Compressive strength of waste slab concrete shall be at least 17 MPa at 28 days.

12.3.1.1 Casting bed and side forms shall be free of debris that would affect the surface finish.

12.3.1.2 Seal joints between casting bed and side forms.

12.3.1.3 Treat saw cuts, cracks, or joints in casting bed with a filler material that will minimize mirroring of casting surface on tilt-up panel surface.

12.3.1.4 For panels cast in a vertical stack, consider the troweled surface of a panel a casting bed.

12.3.2 Bond breaker—Apply bond breaker to casting surface in accordance with manufacturer's recommendations.

12.3.3 Reveals—Fasten reveals (rustication) or false joints to prevent movement or floating during concrete placement operations.

12.3.3.1 Reveals shall be located within **ACI 117M** tolerances for cast-in-place concrete.

12.3.3.2 Verify correct alignment between adjacent reveals before placement of concrete.

12.3.4 Panel identification—Each panel shall have a panel mark that corresponds to identification marks on shop drawings. Mark test cylinders and test beams with the same identification.

12.3.5 Side forms—Side forms shall remain in place and be braced until panels achieve compressive strength of 3.5 MPa.

12.3.6 Placing concrete—Do not place concrete until side forms and reinforcement placement have been accepted.

12.3.7 Anchorage devices—Set anchorage devices into fresh concrete and consolidate concrete around anchorage devices.

12.3.8 Finishes—Concrete finishes shall be as indicated in Contract Documents.

12.3.8.1 Repair panels and casting bed with acceptable concrete repair material.

12.3.8.2 Exposed faces shall match accepted mockup panel.

12.3.9 Smooth panel finish (SPF)—Smooth finishes shall be the result of casting on a hard-troweled surface. Unless

otherwise specified, the requirements of finish SPF-2 shall apply.

12.3.9(a) Smooth Panel Finish-3 Architectural (SPF-3)—Mockup panels are required and shall be prepared in accordance with 12.1.3.5. Surfaces of completed panels shall comply with (a) through (d).

(a) Panel surfaces shall have no surface voids, or surface offsets greater than 3 mm. Floor slab surface texture defects showing on panel surface shall be ground or patched flush with panel surface.

(b) Repair cracks that allow water to seep through the panel to the interior surfaces after the panel has been installed in its designed location and the final surface finish has been applied.

(c) Surface voids and offsets greater than 3 mm shall be ground or filled with patching material.

(d) Upon completion of surface repairs and patching, for final acceptance, panels shall match the appearance of the accepted mockup panel when viewed from a distance of 3 m in daylight.

12.3.9(b) Smooth Panel Finish-2 Standard (SPF-2)—Surfaces of completed panels shall comply with (a) through (c).

(a) Floor contraction joints showing on panel surface shall be ground or patched flush with the panel surface.

(b) Repair cracks that allow water to seep through the panel to the interior surfaces after the panel has been installed in its designed location and the final surface finish has been applied.

(c) Surface voids and offsets greater than 6 mm shall be ground or filled with patching material to present a finished surface ready for painting. Patches shall match panel texture. Patches shall also match panel color for surfaces not to be painted.

12.3.9(c) Smooth Panel Finish-1 Utility (SPF-1)—Unless otherwise specified, surfaces of completed panels shall comply with (a) and (b).

(a) Panel surfaces shall not have voids or other surface deformations greater than 13 mm diameter or depth.

(b) Repair cracks that allow water to pass through the panel to the interior surface after the panel has been installed in its designed location and the final surface finish has been applied.

12.3.10 Textured finishes—Textured finishes shall be the result of casting on fluted, sculptured, or textured form liners.

12.3.11 Treated textured finishes—Treated textured finishes shall be the combined result of casting on fluted, sculptured, or textured form liners followed by breaking off portions of surface projections.

12.3.11.1 Achieve uniformity of cleavage by alternately striking opposite sides of flute.

12.3.12 Retarded exposed-aggregate finishes—To achieve retarded exposed-aggregate finishes, apply surface retarder to face of casting bed in accordance with manufacturer's recommendations.

12.3.12.1 Expose coarse aggregate by washing and brushing, lightly abrasive blasting, or waterblasting surface mortar in accordance with surface retarder manufacturer's directions. Use corrosion-resistant supports. Unless other-

wise specified, expose aggregate to produce 10 mm aggregate exposure.

12.3.13 Bush-hammered exposed-aggregate finish—Concrete shall achieve lifting strength stated in panel design drawings before applying bush-hammered finish.

12.3.14 Hand-placed aggregate for exposed-aggregate finish—Secure hand-placed facing aggregate, natural stone, or cobblestone over casting bed with a concrete or cement-sand grout mixture.

12.3.14.1 Roughen exposed surface of facing concrete for bond with backing concrete. Fill remaining panel thickness with backing concrete.

12.3.14.2 Do not place backing concrete directly on facing aggregate.

12.3.14.3 The backing concrete shall be placed within 3 hours of facing concrete or cement-sand grout mixture placement. Facing concrete or cement-sand grout mixture shall be wet cured.

12.3.14.4 Do not use curing compound between facing concrete or cement-sand grout mixture and backing concrete.

12.3.15 Abrasive finish—Unless otherwise specified, abrasive blast mortar to produce a 3 mm aggregate reveal. If abrasive medium contains water, wash abrasive blasting debris from finished wall surface before drying occurs.

12.3.16 Veneer faced finish—Place veneer brick, tile, terracotta, or natural stone on casting bed.

12.3.16.1 Provide accepted means for mechanical connection of natural stone face material to backing concrete. Unless otherwise specified, provide bond-break material between face material and backing concrete.

12.3.16.2 Place backing concrete to achieve specified panel thickness.

12.3.17 Erection of panels

12.3.17.1 Concrete strength at time of erection shall be in accordance with lifting and bracing design drawings.

12.3.17.2. Brace panels in accordance with lifting and bracing design drawings.

12.3.17.3 Unless otherwise specified, panels shall be braced in position until the lateral-load-resisting system of the structure is complete and final panel attachments are made.

12.3.17.4 Welding to attach panels to building frame and to each other shall be performed by certified welder in accordance with **AWS D1.1/D1.1M**.

12.3.17.5 Repair erection damage to concrete tilt-up panels in accordance with accepted repair procedure.

12.3.18 Tolerances—Tolerances shall conform to **ACI 117M**.

12.3.19 Testing for panel erection

12.3.19.1 Unless otherwise specified, cast and field cure cylinders in accordance with **ASTM C31/C31M** and test cylinders in accordance with **ASTM C39/C39M**. Alternatively, use accepted methods of determining in-place strength in accordance with **2.3.4.2**.

12.3.19.2 If test cylinders are used, for each concrete casting, make at least four cylinders for each 38 m³ or fraction thereof. Specimens shall be field cured. Mark specimens

for proper identification with associated panels. If alternative testing is used, conduct one test per panel.

12.3.19.3 One strength test shall be performed before panel erection. The strength test result shall equal or exceed the minimum strength required for erection. Remaining specimens shall be kept in reserve for additional testing, if required.

SECTION 13—PRECAST STRUCTURAL CONCRETE

13.1—General

13.1.1 Scope—This Section covers construction requirements for members designated as precast structural concrete in Contract Documents.

13.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of **Sections 1** through **5** are applicable for precast structural concrete.

13.1.2.1 If lightweight precast concrete members are specified, comply with Section 7 in addition to provisions of this Section.

13.1.3 Submittals

13.1.3.1 Submittals requirements before execution of Work are given in 13.1.3.1(a) through 13.1.3.1(g).

13.1.3.1(a) Shop drawings—Submit shop drawings for erection of precast concrete members, including member locations, plan views, elevations, dimensions, handling procedures, and connection details. Shop drawings shall indicate structural design criteria. If specified, submit shop drawings for fabrication in accordance with Contract Documents.

13.1.3.1(b) Structural design calculations—If specified, submit structural calculations prepared, signed, and sealed by an engineer licensed in the jurisdiction of the project. Calculations shall include design of systems, members, and connections in accordance with 13.2.1.

If analysis and design use computer programs, submitted calculations shall include design assumptions, input data, and computer-generated output.

13.1.3.1(c) Erection plan—If specified, submit an erection plan indicating erection sequence, temporary bracing, and connection and grouting sequences.

13.1.3.1(d) Design modifications—If modifications to design in Contract Documents are proposed, notify Architect/Engineer and submit drawings. If specified, submit design calculations conforming to 13.1.3.1(b). Maintain specified design requirements if altering size of members and alignment.

13.1.3.1(e) Erector certification—Unless otherwise specified, submit a current certificate furnished by Precast/Prestressed Concrete Institute (PCI) designating erector certification.

13.1.3.1(f) Plant certification—Unless otherwise specified, submit current certificates furnished by Precast/Prestressed Concrete Institute (PCI) designating plant and personnel certification.

13.1.3.1(g) Welding procedure and certificates—Submit welding procedure reference specifications and personnel certificates meeting the requirements of 13.1.4.5.

13.1.3.2 If specified, submit material test reports or material certificates, signed by manufacturers or suppliers, certifying that the following items comply with reference specification requirements:

- (a) Cementitious materials
- (b) Concrete aggregates
- (c) Reinforcement and prestressing steel
- (d) Admixtures
- (e) Bearing pads
- (f) Structural-steel shapes and hollow structural sections
- (g) Insulation
- (h) Other components specified in Contract Documents with applicable standards

13.1.4 Quality control and quality assurance

13.1.4.1 Erector qualifications—Unless otherwise specified, precast concrete erector shall be qualified by the PCI Erector Certification Program in the category specified in Contract Documents before beginning work at the project site.

If an erector is not qualified by PCI, erector shall have acceptable experience in precast concrete erection on at least three projects comparable in scope to Work. Erector not qualified by PCI shall retain a PCI Certified Field Auditor to conduct a field audit of a project in the same category as this project before start of erection.

13.1.4.2 Fabricator qualifications—Unless otherwise specified, fabricator shall be certified in accordance with PCI Plant Certification program for specified group and category specified in Contract Documents.

Unless otherwise specified, testing and inspection shall be performed by PCI-certified personnel. Unless otherwise specified, fabricator shall have at least 5 years of experience in producing precast concrete members similar to those required in Work.

13.1.4.3 Owner testing—Owner may employ an independent testing agency to evaluate fabricator's quality control and testing methods.

13.1.4.3(a) Allow Owner's testing agency access to material storage areas, concrete production equipment, concrete casting, and curing facilities. Cooperate with and provide necessary facilities for Owner's testing agency and provide samples of materials and concrete mixtures as requested for additional testing and evaluation.

13.1.4.4 Field testing and inspections—Owner's testing agency may perform testing and inspections given in 13.1.4.4(a) through 13.1.4.4(c) at no cost to Contractor.

13.1.4.4(a) Visually inspect welds in accordance with **AWS D1.1/D1.1M** and **AWS D1.4/D1.4M**. Remove, reweld, or repair unsatisfactory welds.

13.1.4.4(b) Field welds will be subject to visual inspection and dye penetrant or magnetic particle testing in accordance with **ASTM E165/E165M** or **ASTM E1444/E1444M**.

13.1.4.4(c) Grout will be tested for compressive strength in accordance with **ASTM C109/C109M** for sand-cement and non-shrink grout. Strength of grout is satisfactory if

28-day compressive strength is equal to or exceeds specified grout strength.

13.1.4.4.1 Testing agency will report test results within 7 days from inspection and in writing as directed by Owner.

13.1.4.4.2 Additional testing and inspection, at Contractor's expense, will be performed to determine compliance of corrected Work with Contract Documents.

13.1.4.5 Welding—Unless otherwise specified, use certified welders. Comply with AWS D 1.1/D 1.1M and AWS D1.4/D1.4M.

13.1.4.6 Preconstruction conference—Unless otherwise specified, schedule a preconstruction conference at the project site. Design and construction representatives, including special inspector, shall be invited to attend the conference.

13.1.4.7 Retention of records—Unless a longer period is specified, retain quality-control records and compliance certificates for each type of precast member for at least 6 years.

13.1.5 Product delivery, storage, and handling

13.1.5.1 Store members to prevent contact with soil, to prevent permanent staining, to control cracking, and to maintain dimensions within specified product tolerance.

13.1.5.2 Place stored members so identification marks are visible and units can be inspected.

13.1.5.3 Deliver precast concrete members in such quantities and at such times to comply with precast installation sequence to ensure stability of structure.

13.1.5.4 Handle and transport members in a position consistent with their shape and design as indicated on shop drawings.

13.1.5.5 Lift and support members only at designated points indicated on shop drawings.

13.2—Products

13.2.1 Performance requirements

13.2.1.1 Structural design—Unless otherwise specified, design each member for required loads, handling, transportation, erection, and other design criteria indicated in Contract Documents.

13.2.1.2 Fire resistance—Provide precast concrete members with fire resistance as indicated in Contract Documents. If fire resistance is determined by calculation, submit calculation of fire resistance rating determined in accordance with **PCI MNL-124** or **ACI 216.1M**.

13.2.2 Form materials and accessories

13.2.2.1 Forms—Use forms that are dimensionally stable and non-absorptive and that will provide continuous precast concrete surfaces within fabrication tolerances. Use forms that are nonreactive with materials in concrete and are suitable for producing specified finishes in accordance with 13.2.13.

13.2.3 Prestressing steel

13.2.3(a) General—Use materials as specified in Contract Documents and conforming to **Section 3**, unless otherwise specified. Prestressing steel shall be clean and free of scale, oil, dirt, and pitting. A light coating of rust that can be removed with fine steel wool is acceptable.

13.2.3(b) Prestressing strand

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- (a) **ASTM A416/A416M**
- (b) **ASTM A886/A886M**
- (c) **ASTM A910/A910M**

13.2.3(c) Unbonded post-tensioning tendons—ASTM A416/A416M with corrosion inhibitor coating conforming to **ACI 423.7**.

13.2.3(d) Post-tensioning bars—**ASTM A722/A722M**.

13.2.4 Concrete materials

13.2.4.1 General—Unless otherwise specified, materials shall conform to Section 4 and the following supplemental requirements.

13.2.4.2 Aggregates—Aggregates used for exposed-aggregate finish shall comply with **ASTM C33/C33M**, except for gradation. Obtain adequate quantities of fine and coarse aggregate for each type of exposed finish for entire project. Aggregates shall be from the same source to match the approved finish sample. If lightweight aggregates are specified, comply with **Section 7** except as modified in Contract Documents.

13.2.5 Bearing pads and other accessories

13.2.5.1 Unless otherwise specified, provide one of the bearing pads for precast concrete members listed in 13.2.5.1(a) through 13.2.5.1(e).

13.2.5.1(a) Elastomeric pads—**AASHTO M 251**, plain, vulcanized, 100 percent polychloroprene (neoprene) elastomer, molded to size or cut from a molded sheet, 50 to 70 Shore A Durometer measured according to **ASTM D2240**, with a tensile strength of at least 16 MPa measured according to **ASTM D412**.

13.2.5.1(b) Random-oriented, fiber-reinforced elastomeric pads—Preformed, randomly oriented synthetic fibers set in elastomer. Surface hardness of 70 to 90 Shore A Durometer measured according to **ASTM D2240**. Capable of supporting a compressive stress of 21 MPa without cracking, splitting, or delaminating in the internal portions of the pad.

13.2.5.1(c) Cotton-duck-fabric-reinforced elastomeric pads—Preformed, horizontally-layered, cotton-duck fabric bonded to an elastomer. Surface hardness of 80 to 100 Shore A Durometer measured according to **ASTM D2240**. Conforming to Division II, Section 18.10.2 of **AASHTO LRFD-US8** or **NAVY MIL-C-882E**.

13.2.5.1(d) Low-friction pads—Tetrafluoroethylene, glass-fiber-reinforced, bonded to stainless or mild-steel plates, or random-oriented, fiber-reinforced elastomeric pads.

13.2.5.1(e) High-density plastic—Multimonomer, nonleaching, plastic strip or shim capable of supporting design loads with no visible expansion.

13.2.5.2 Other accessories

13.2.5.2(a) Reglets—If specified, provide surface-mounted reglets meeting the requirements in Contract Documents.

13.2.6 Grout materials

13.2.6.1 Sand-cement grout—Unless otherwise specified, use portland cement **ASTM C150/C150M** Type I, natural or manufactured sand conforming to **ASTM C144** or **ASTM C404**, to produce a grout strength as specified in Contract Documents. If more than one grout type is required, the materials to be used on project, to provide lightweight

type shall be used in specified locations. If grout will be in contact with prestressing steel, constituent materials used shall be such that the water-soluble chloride ion (Cl^-) content of grout shall not exceed 0.06 percent of mass of cement as tested in accordance with **ASTM C1218/C1218M**.

13.2.6.2 Nonshrink grout—If specified, use premixed, prepackaged nonshrink grout complying with **ASTM C1107/C1107M**. Unless otherwise specified, use nonferrous grouts. If specified, submit field installation procedures. If grout will be in contact with prestressing steel, constituent materials used shall be such that the water-soluble chloride ion (Cl^-) content of grout shall not exceed 0.06 percent of mass of cement as tested in accordance with **ASTM C1218/C1218M**.

13.2.6.3 Epoxy-resin grout—If specified, use a two-component, mineral-filled, epoxy-resin grout meeting the requirements of **ASTM C881/C881M** for the type, grade, and class specified.

13.2.7 Insulated member components and accessories

13.2.7.1 General—If specified, provide insulated precast concrete members of the specified thickness and R -value. Use insulation material meeting the requirements of 13.2.7.2 through 13.2.7.4 at specified locations.

13.2.7.2 Molded-polystyrene board insulation—Rigid, cellular polystyrene thermal insulation complying with **ASTM C578**.

13.2.7.3 Extruded-polystyrene board insulation—Rigid, cellular polystyrene thermal insulation complying with **ASTM C578**.

13.2.7.4 Polyisocyanurate board insulation—Square-edged, rigid, cellular, polyisocyanurate thermal insulation complying with **ASTM C591** or **ASTM C1289**.

13.2.7.5 Wythe connectors—Provide wythe connectors manufactured to connect wythes of precast concrete members. Unless otherwise specified, wythe connectors shall be one of the following:

- (a) Glass-fiber and vinyl-ester polymer connectors
- (b) Polypropylene pin connectors
- (c) Stainless-steel pin connectors
- (d) Bent zinc-coated (galvanized) reinforcing bars
- (e) Zinc-coated (galvanized) welded wire trusses
- (f) Zinc-coated (galvanized) bent wire connectors
- (g) Epoxy-coated carbon fiber grid
- (h) Cylindrical corrosion-resistant steel sleeve anchors

13.2.8 Concrete mixtures

13.2.8.1 General—Prepare concrete mixtures for each type of concrete required.

13.2.8.2 Normalweight concrete mixtures—Proportion mixtures by laboratory trial mixture or field test data methods according to Section 4 with materials to be used on project to provide normalweight concrete with the following properties, unless otherwise specified:

- (a) Specified compressive strength at 28 days: at least 35 MPa
- (b) Maximum w/cm : 0.45
- (c) Air content as required by **4.2.2.6(c)**

13.2.8.3 Lightweight concrete mixtures—If lightweight concrete is specified, proportion mixtures by laboratory trial mixture or field test data methods according to Section 7, with materials to be used on project, to provide lightweight

concrete with the following properties, unless otherwise specified:

- (a) Specified compressive strength at 28 days: at least 35 MPa
- (b) Specified equilibrium density: 1840 kg/m³ measured in accordance with **ASTM C567/C567M**
- (c) Air content as required by **4.2.2.6(c)**

13.2.9 Form fabrication

13.2.9.1 Formwork shall comply with Section 2 except as modified in this Section.

13.2.9.2 Maintain forms to provide completed precast concrete members of specified shapes, lines, and dimensions within fabrication tolerances specified in **ACI ITG-7M**. Unless otherwise specified, edges and corners shall be chamfered.

13.2.10 Hardware

13.2.10.1 Steel connection materials—Provide steel connection materials of the grades, types, and surface finish indicated in Contract Documents. Weld headed concrete anchors and deformed bar anchors used for anchorage in accordance with **AWS D1.1/D1.1M**, **AWS D1.4/D1.4M**, and **AWS C5.4**.

13.2.10.1(a) Carbon steel shapes and plates shall conform to **ASTM A36/A36M**.

13.2.10.1(b) Carbon-steel headed studs shall conform to **ASTM A108** Grades 1010 through 1020, cold finished, **AWS D 1.1/D 1.1M** Type A or B, with arc shields and with minimum mechanical properties specified in **PCI MNL-116** Table 3.2.3.

13.2.10.1(c) Malleable iron castings shall conform to **ASTM A47/A47M** Grade 32510 or 35028.

13.2.10.1(d) High-strength, low-alloy structural steel shall conform to **ASTM A992/A992M** or **ASTM A572/A572M**.

13.2.10.1(e) Carbon-steel structural tubing shall conform to **ASTM A500/A500M** Grade B or C.


13.2.10.1(f) Wrought carbon-steel bars shall conform to **ASTM A675/A675M** Grade 65 (Grade 450).

13.2.10.1(g) Deformed-steel wire or bar anchors shall conform to **ASTM A1064/A1064M** or **ASTM A706/A706M**.

13.2.10.2 Hardware surface finish—Surface finish shall comply with 13.2.10.2(a) through 13.2.10.2(c) as indicated in Contract Documents.

13.2.10.2(a) Shop prime finish—If shop prime finish is specified, prepare surfaces in accordance with **SSPC-SP3**. Primer shall be lead- and chromate-free, rust-inhibitive primer, complying with performance requirements of **MPI #79**. Shop apply in accordance with **SSPC-PA1**.

13.2.10.2(b) Galvanized finish—If galvanized finish is specified, apply zinc coating by hot-dip process in accordance with **ASTM A123/A123M**, after fabrication, or **ASTM A153/A153M**, as applicable. For steel shapes, plates, and tubing to be galvanized, limit silicon content of steel to less than 0.03 percent or to between 0.15 and 0.25 percent or limit sum of silicon content and 2.5 times phosphorous content to 0.09 percent. Repair damaged galvanized areas with zinc paint with dry film containing not less than 94 percent zinc dust by mass and complying with **NAVY MIL DOD-P-21035A** or **SSPC-Paint 20**.

13.2.10.2(c) Galvanizing paint—If galvanizing paint finish is specified, apply zinc paint with dry film 

not less than 94 percent zinc dust by mass and complying with **NAVY MIL DOD-P-21035A** or **SSPC-Paint 20**. Comply with paint manufacturer's requirements for surface preparation.

13.2.10.3 Bolted connectors—If specified, provide bolted connectors of the grade and type indicated.

13.2.10.3(a) Carbon-steel bolts and studs shall conform to **ASTM A307** Grade A or **ASTM F1554** Grade 36. Carbon-steel nuts shall conform to **ASTM A563** Grade A. Flat unhardened steel washers shall conform to **ASTM F844**.

13.2.10.3(b) High-strength bolts and nuts shall conform to **ASTM A193/A193M** Grade B5 or B7, **ASTM A325**, or **ASTM A490** Type 1 heavy hex steel structural bolts. Heavy hex carbon-steel nuts shall conform to **ASTM A563**. Hardened carbon-steel washers shall conform to **ASTM F436/F436M**.

13.2.10.4 Stainless-steel connection materials—If specified, provide stainless-steel connection materials of the grades and types specified. Weld headed concrete anchors and deformed bar anchors used for anchorage in accordance with **AWS D1.6/D1.6M** and **AWS C5.4**.

13.2.10.4(a) Stainless-steel plate shall conform to **ASTM A666/C66M** Type 304, Type 316, or Type 201.

13.2.10.4(b) Stainless-steel bolts, hex cap screws, and studs shall conform to **ASTM F593** alloy 304 or 316. Stainless-steel nuts shall conform to **ASTM F594**. Nuts and washers shall conform to same alloy as bolts, screws, and studs.

13.2.10.4(c) Stainless-steel headed studs shall conform to **ASTM A276/A276M**, with minimum mechanical properties for studs specified in **PCI MNL-116** Table 3.2.3.

13.2.10.5 Cast-in anchors, inserts, plates, angles, and other anchorage hardware—Position embedded anchorage hardware for attachment of loose hardware and secure in place during precasting operations. Locate anchorage hardware as indicated on shop drawings. Fabricate anchorage hardware to comply with design requirements.

13.2.10.6 Furnish loose hardware items, including steel plates, clip angles, seat angles, anchors, dowels, cramps, hangers, and other hardware, for securing precast concrete members to supporting and adjacent construction. Provide locations, setting diagrams, templates, instructions, and installation directions for installation of each anchorage device.

13.2.11 Fabrication

13.2.11.1 Provide specified sizes and shapes of precast members as indicated in Contract Documents.

13.2.11.2 Provide specified cast-in reglets, slots, holes, and other accessories as indicated in Contract Documents.

13.2.11.3 Openings larger than 250 mm in any dimension shall be formed or saw cut. Do not drill or cut openings without obtaining acceptance from Architect/Engineer.

13.2.11.4 Reinforcement

13.2.11.4(a) Place nonprestressed reinforcement and prestressing steel within tolerances specified in **ACI ITG-7M**. Arrange, space, and tie bars and reinforcement supports to hold reinforcement in position during concrete placement

and consolidation operations. Position wire tie ends away from exposed concrete surfaces.

13.2.11.4(b) Install welded wire reinforcement in lengths as long as practicable. Unless otherwise specified, lap adjoining pieces at least one full wire spacing and use wire to tie laps. Offset laps of adjoining widths to prevent continuous laps in either direction.

13.2.11.5 Place concrete in a continuous operation.

13.2.11.6 Consolidate concrete by internal vibration, external vibration, or both, without dislocating or damaging reinforcement and embedments.

13.2.11.7 Identify pickup points of precast concrete members and orientation in structure with permanent markings, complying with markings indicated on shop drawings. Imprint or permanently mark casting date and member identification on each precast concrete member on a surface that will not show in completed structure.

13.2.11.8 Cure concrete by moisture retention or by accelerated heat curing using steam or radiant heat and moisture. Cure members until the concrete compressive strength exceeds the greater of release strength specified in Contract Documents or structural design submittal.

13.2.11.9 *Maximum concrete temperature during curing*—Unless otherwise specified, maximum concrete temperature during curing shall not exceed 70°C. Measure the temperature inside the portion of the member that is likely to experience the highest concrete temperature during curing.

13.2.11.10 Prestress the precast concrete members by pretensioning or post-tensioning methods if specified.

13.2.11.10(a) Delay detensioning or post-tensioning of precast prestressed concrete members until concrete reaches the compressive strength required for release or tensioning.

13.2.11.10(b) Detension pretensioned steel by gradually releasing tensioning jacks or by flame-cutting tendons, using a sequence and pattern to prevent shock or unbalanced loading.

13.2.11.10(c) If concrete was heat cured, detension while concrete is still warm and moist.

13.2.11.10(d) Where specified in Contract Documents, protect strand ends and anchorages with at least 25 mm thickness of nonmetallic, nonshrink mortar and sack rub surface. Before installing mortar, verify that inside surfaces of the pocket are clean, free of release agent and grease. Coat or spray the inside surfaces of the pocket with a latex or epoxy bonding agent before installing the pocket mortar.

13.2.11.10(e) For members assigned to Exposure Class C1 or C2, and 13.2.11.10(d) does not apply, protect strand ends and anchorages with bitumastic, zinc-rich, or epoxy paint.

13.2.11.11 If members are damaged, submit repair procedures before executing repair. Repair damaged precast concrete members in accordance with accepted repair procedures.

13.2.11.12 *Casting insulated members*

13.2.11.12(a) If insulated members are specified, cast and screed bottom wythe supported by form.

13.2.11.12(b) Place insulation boards so that sides and ends abut with adjacent boards. Insert wythe connectors through insulation into bottom wythe and consolidate

concrete around connectors according to connector manufacturer's written instructions.

13.2.11.12(c) Cast and screed top wythe to achieve finish specified in Contract Documents.

13.2.11.12(d) Maximum concrete temperature at the insulation board during curing shall not exceed the maximum temperature limit for the insulation board as recommended by insulation manufacturer.

13.2.12 *Fabrication tolerances*

13.2.12.1 Unless otherwise specified, fabricate precast concrete members in accordance with tolerances specified in **ACI ITG-7M**.

13.2.13 *Finishes*

13.2.13.1 *Formed surface finishes*—Provide finish in accordance with 13.2.13.1(a) to 13.2.13.1(d) for formed surfaces of precast members as indicated in Contract Documents.

13.2.13.1(a) *Commercial grade finish*—Remove fins and protrusions larger than 3 mm and fill holes with a diameter larger than 13 mm. Rub or grind ragged edges. Air holes, water marks, and color variations are acceptable. Allowable form joint offsets are limited to 5 mm.

13.2.13.1(b) *Standard grade finish surface*—Air holes smaller than 13 mm, color variations, form joint marks, chips, and spalls are acceptable. Fill air holes greater than 13 mm wide that occur more than once per 1300 mm². Allowable form joint offsets are limited to 3 mm.

13.2.13.1(c) *Grade B finish*—Fill air pockets and holes with a diameter larger than 6 mm with sand-cement grout matching color of adjacent surfaces. Fill air holes with a diameter greater than 3 mm that occur more than one per 1300 mm². Grind form offsets or fins larger than 3 mm. Repair surface defects due to dents in forms. Discoloration is acceptable at form joints.

13.2.13.1(d) *Grade A finish*—Repair surface defects with the exception of air holes with a diameter less than 1.5 mm and form marks where the surface deviation is less than 1.5 mm. Float-apply a neat cement-paste coating to exposed surfaces. Rub dried paste coat with burlap to remove loose particles. Discoloration is acceptable at form joints. Grind form offsets or fins larger than 1.5 mm.

13.2.13.2 *Unformed surfaces finish*—Unless otherwise specified, screed or float finish unformed surfaces. If screed finish is specified, strike off and consolidate concrete with vibrating screeds to a uniform finish. Hand screed at projections. Color variations or defects are acceptable.

13.2.13.3 *Top surface of composite members*—Top surfaces of precast concrete members intended to act compositely with a concrete topping shall be intentionally roughened as indicated in Contract Documents.

13.2.14 *Rejection of precast members*—Precast concrete members will be considered deficient if concrete fails to comply with concrete strength, durability, or surface finish requirements.

13.2.15 *Defective Work*—If specified, repair chipped, spalled, or cracked members. Obtain acceptance from Architect/Engineer before making structural repairs. Replace

unacceptable members with precast concrete members that comply with requirements.

13.3—Execution

13.3.1 Preparation

13.3.1.1 Deliver anchorage devices to be embedded in or attached to the building structural frame or foundation.

13.3.2 Examination

13.3.2.1 Examine supporting structural frame or foundation for compliance with requirements for installation tolerances, bearing surface tolerances, and other conditions affecting performance. Notify Architect/Engineer of unsatisfactory conditions. Proceed with installation only after unsatisfactory conditions have been corrected.

13.3.2.2 As indicated in Contract Documents, do not install precast concrete members until supporting cast-in-place concrete foundation and building structural framing has attained required in-place compressive strength and supporting steel, precast concrete frames, or assemblies are structurally ready to support loads from precast concrete members.

13.3.3 Erection

13.3.3.1 Install loose clips, hangers, bearing pads, and other accessories required for connecting precast concrete members to supporting members and backup materials.

13.3.3.1(a) Install bearing pads to a maximum height of 40 mm. If the height required to achieve bearing is in excess of 40 mm, add steel shims below bottom bearing pad. Tack weld steel shims together.

13.3.3.2 Erect precast concrete members within tolerances specified in 13.3.4. Provide temporary structural framing, supports, and bracing to maintain position, stability, and alignment of members until permanent connections are completed.

13.3.3.2(a) Install temporary steel or plastic spacing shims or bearing pads as precast concrete members are being erected. Tack weld steel shims together to prevent them from separating.

13.3.3.2(b) Maintain horizontal and vertical joint alignment and uniform joint width within specified tolerances as erection progresses.

13.3.3.2(c) Remove projecting lifting devices and, if recess is exposed, use sand-cement grout to fill voids within recessed lifting devices flush with adjacent precast concrete surfaces.

13.3.3.2(d) Provide and install headers for openings larger than one slab width according to hollow-core slab unit fabricator's written instructions.

13.3.3.3 Connect precast concrete members in position by bolting, welding, or grouting as indicated on shop drawings. Remove temporary shims, wedges, and spacers after permanent connections and grouting are completed and grout has achieved specified strength.

13.3.3.4 *Welding*—Comply with **AWS D1.1/D1.1M** or **AWS D1.4/D1.4M** requirements for welding, welding electrodes, appearance, weld quality, and methods used in correcting welding work.

13.3.3.4(a) Protect precast concrete members and bearing pads from damage due to field welding or cutting.

13.3.3.4(b) Unless otherwise specified, welds shall be continuous fillet welds, using not less than the minimum fillet specified by **AWS D1.1/D1.1M** or **AWS D1.4/D1.4M**.

13.3.3.4(c) For galvanized metal, clean weld-affected metal surfaces with chipping hammer and follow with brushing or power tool cleaning. Inspect welds for defects. If welds satisfy **AWS D1.1/D1.1M**, apply at least a 0.10 mm-thick coat of galvanized repair paint to galvanized surfaces in accordance with **ASTM A780/A780M**.

13.3.3.4(d) Clean weld-affected metal surfaces with chipping hammer followed by brushing or power tool cleaning and prime damaged painted surfaces in accordance with paint manufacturer's recommendations.

13.3.3.5 *Bolted connections*—After final tightening, damage bolt threads, tack weld, or otherwise restrain nut so that nut cannot be loosened by hand.

13.3.3.5(a) Where slotted connections are used, verify bolt position and tightness at installation. For sliding connections, secure bolt but allow bolt to move within connection slot.

13.3.3.5(b) For slip-critical connection, apply bolt torque as specified in Contract Documents and check 25 percent of bolts at random by calibrated torque wrench. Test all bolts if insufficient bolt torque is found. Cost for this testing will be borne by Contractor.

13.3.3.6 *Grouting or dry packing connections and joints*—Joints and connections to be grouted and critical grouting sequences shall be as indicated on shop drawings. Ensure grout remains in place until it gains sufficient strength to support itself. Pack spaces with stiff grout material, tamping until voids are filled. Place grout and finish flush with adjacent concrete surfaces. Remove grout from exposed surface before it affects finishes or sets. Keep grouted joints damp for at least 24 hours.

13.3.3.6(a) Where specified, trowel top of grout joints on roofs to prevent unevenness that might interfere with placing of, or cause damage to, insulation and roofing. Finish transitions due to different surface levels at a slope not steeper than 1 to 12.

13.3.3.6(b) If grouting slab ends of hollow-core slabs, provide suitable end cap or dams in voids.

13.3.3.6(c) For areas where slab voids are to be used as electrical raceways or mechanical ducts, provide a taped butt joint at slab ends, making sure voids are aligned.

13.3.3.7 After installation, do not cut or core precast concrete members unless otherwise specified.

13.3.3.8 Unless otherwise specified, do not use drilled-in or powder-actuated fasteners for attaching accessory items to precast, prestressed concrete members. If drilled-in or powder-actuated fasteners are acceptable, do not allow fasteners to contact prestressing tendons.

13.3.4 *Erection tolerances*—Erect precast concrete members in accordance with noncumulative erection tolerances of **ACI ITG-7M**.

13.3.5 Repairs

13.3.5(a) Submit request and procedures to repair members. Repairs will be acceptable provided structural adequacy, serviceability, durability, and appearance are not impaired.

13.3.5(b) Repair damaged members to meet surface finish requirements of 13.2.13.

13.3.5(c) Mix patching materials and repair members so cured patches blend with color, texture, and uniformity of adjacent exposed surfaces and show no apparent line of demarcation between original and repaired work when viewed in daylight from 6 m.

13.3.5(d) Prepare and repair damaged galvanized coatings with galvanizing repair paint in accordance with ASTM A780/A780M.

13.3.5(e) Wire brush, clean, and paint damaged prime-painted steel hardware with same type of shop primer.

13.3.5(f) Remove and replace damaged precast concrete members if repairs are not acceptable.

13.3.6 Cleaning

13.3.6.1 Clean mortar, plaster, fireproofing, weld slag, and other deleterious material from concrete surfaces and adjacent materials without delay.

13.3.6.2 After completion of joint treatment, clean exposed surfaces of precast concrete members to remove weld marks, other markings, dirt, and stains.

13.3.6.2(a) Perform cleaning procedures according to precast concrete fabricator's recommendations. Protect other Work from staining or damage due to cleaning operations.

13.3.6.2(b) Do not use cleaning materials or processes that could change the appearance of exposed concrete finishes or damage adjacent materials.

SECTION 14—PRECAST ARCHITECTURAL CONCRETE

14.1—General

14.1.1 Scope—This Section covers construction requirements for members designated in Contract Documents as precast architectural concrete units and precast structural concrete members with commercial architectural (CA) finish.

14.1.2 General requirements—Unless otherwise specified in this Section or in Contract Documents, requirements of **Sections 1** through **5** and **Section 13** are applicable for precast architectural concrete units and precast structural concrete with an architectural finish.

14.1.3 Submittals

14.1.3.1 Water absorption testing—If specified, submit results of water absorption tests conducted in accordance with ASTM C642, using only immersion in water at laboratory temperature.

14.1.3.2 Design reference sample—Submit design reference sample for initial verification of design in accordance with 14.1.4.1.

14.1.3.3 Sample panels—Unless otherwise specified, submit sample panels in accordance with 14.1.4.2.

14.1.3.4 Range sample panels—If specified, submit range sample panels in accordance with 14.1.4.3.

14.1.3.5 Full-size mockup—If specified, provide in accordance with 14.1.4.4.

14.1.3.6 Submittals required before execution of Work are specified in 14.1.3.6(a) through 14.1.3.6(f).

14.1.3.6(a) Shop drawings—Submit shop drawings for erection of architectural precast concrete showing panel types, panel finishes, and connections. Shop drawings shall indicate structural design criteria. If specified, submit shop drawings for fabrication in accordance with Contract Documents.

14.1.3.6(b) Structural design calculations—If specified, submit structural calculations prepared, signed, and sealed by an engineer licensed in the jurisdiction of the project. Calculations shall include design of members and connections as required in 14.2.1 through 14.2.3. Submit location, type, magnitude, and direction of loads imposed on building structural frame.

If designs use a computer program, submitted calculations shall include design assumptions, input data, and computer-generated output.

14.1.3.6(c) Design modifications—If modifications to design in Contract Documents are proposed, submit drawings. If specified, submit design calculations in accordance with 14.1.3.6(b). Maintain specified design requirements if altering size of members or alignment.

14.1.3.6(d) Erector quality control—Unless otherwise specified, submit a current certificate furnished by Precast/Prestressed Concrete Institute (PCI) designating erector certification.

14.1.3.6(e) Plant quality control—Unless otherwise specified, submit current certificates furnished by Precast/Prestressed Concrete Institute (PCI) designating plant and personnel certification.

14.1.3.6(f) Material test reports—Submit material test reports from testing agency or material certificates signed by manufacturers certifying that each of the following items complies with reference specification requirements:

- (a) Clay product units
- (b) Stone and stone anchors

14.1.3.7 Fabricator qualifications—Unless otherwise specified, fabricator shall be certified in accordance with PCI Plant Certification program. Unless otherwise specified, fabricator shall be designated a PCI Certified plant for Group A, Category A1—Architectural Cladding and Load Bearing Units.

14.1.4 Design reference samples, sample panels, and mockup

14.1.4.1 Design reference samples—Design reference samples for initial verification of design intent shall be approximately 300 x 300 x 50 mm and be representative of finishes, color, and textures of precast concrete unit exposed surfaces. If back face of precast concrete unit is to be exposed, include reference samples illustrating workmanship, color, and texture of backup concrete and facing concrete. Design reference samples shall include brick units showing full range of color and texture expected including joint treatment. Provide drawing of each corner or special

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shape with dimensions if not included on design reference sample.

14.1.4.2 Sample panels—Unless otherwise specified, before fabricating CA members or architectural precast concrete units, produce and submit at least two sample panels each with an area of at least 1.5 m². Incorporate full-scale details of architectural features, finishes, textures, and transitions.

14.1.4.2(a) Locate sample panels where indicated in Contract Documents.

14.1.4.2(b) Damage part of an exposed-face surface on two sample panels for each finish, color, and texture, and demonstrate sufficiency of repair techniques proposed for repair of surface damage.

14.1.4.2(c) After acceptance of repair technique, maintain one sample panel at manufacturer's plant and submit one for project site in an undisturbed condition as a standard for visual evaluation of completed Work.

14.1.4.2(d) Demolish and remove sample panels if directed.

14.1.4.3 Range sample panels—After sample panel acceptance and before starting production of precast architectural concrete units, produce and submit, if specified, at least three samples each with an area of at least 1.5 m² representing anticipated range of each color and texture on project's units. After acceptance of range sample panels, maintain accepted range sample panels at manufacturer's plant as color and texture acceptability reference.

14.1.4.4 Mockups—If specified, construct mockups at location and of size indicated in Contract Documents. Construct mockup after acceptance of sample panels and range sample panels, but before production of precast structural members with an architectural finish or precast architectural concrete units. Mockup shall be representative of completed Work, including glass, aluminum framing, sealants, and precast concrete complete with anchors, connections, flashings, and joint fillers as accepted on final shop drawings. Build mockups to conform to 14.1.4.8.4(a) through 14.1.4.8.4(e), using materials indicated for completed Work.

14.1.4.4(a) Notify Architect/Engineer in advance of dates and times when mockups will be constructed.

14.1.4.4(b) Obtain Architect/Engineer's acceptance of mockups before fabrication.

14.1.4.4(c) Maintain mockups during construction in an undisturbed condition as a standard for visual evaluation of completed Work.

14.1.4.4(d) Demolish and remove mockups if directed. Unless otherwise specified, do not use mockup in part of completed Work.

14.1.4.4(e) If specified, provide a single, full-sized mockup for testing by others to the extent indicated in Contract Documents to simulate precast concrete and window wall assembly.

14.2—Products

14.2.1 Performance requirements

14.2.1.1 Structural design—Unless otherwise specified, design governing panels for required loads, handling, transportation, erection, and other specified design criteria.

14.2.2 Window washing system—If support of window washing system is specified, design precast concrete units supporting window washing system to resist specified loads transmitted from window washing equipment.

14.2.3 Stone to precast concrete anchorages—If specified, provide number and types of anchors required for stone veneer precast concrete units.

14.2.4 Form liners—If specified, form liners shall match the design, texture, arrangement, and configuration of those used for precast concrete design reference sample. Provide solid backing and form supports to ensure that form liners remain in place during concrete casting. Use with manufacturer's recommended form-release agent. The release agent shall not bond with, stain, or adversely affect hardening of precast concrete surfaces and shall not impair subsequent surface or joint treatments of precast concrete.

14.2.5 Surface retarder—If specified, use chemical surface retarder to delay setting of freshly placed concrete to depth accepted by Architect/Engineer from design reference sample.

14.2.6 Thin and half-brick units and accessories

14.2.6.1 If specified, half-brick units shall comply with ASTM C216 and meet the type, grade, face size, and dimensional tolerances.

14.2.6.2 Unless otherwise specified, provide thin brick units meeting the requirements given in 14.2.6.2(a) to 14.2.6.2(k).

14.2.6.2(a) Thickness and tolerances—Thickness not less than 13 mm nor more than 25 mm with an overall tolerance of +0 mm, −1.5 mm for any unit dimension 200 mm or less and an overall tolerance of +0 mm, −2.5 mm for any unit dimension greater than 200 mm measured in accordance with **ASTM C67/C67M**.

14.2.6.2(b) Cold water absorption at 24 hours—Maximum 6 percent when tested in accordance with ASTM C67/C67M.

14.2.6.2(c) Efflorescence—Provide brick that has been tested in accordance with ASTM C67/C67M and rated not effloresced.

14.2.6.2(d) Out of square—±1.5 mm measured in accordance with ASTM C67/C67M.

14.2.6.2(e) Warpage—+0, −1.5 mm when tested in accordance with ASTM C67/C67M.

14.2.6.2(f) Deviation from specified angle—±1 degree.

14.2.6.2(g) Tensile bond strength and resistance to freezing and thawing—Tensile bond strength in accordance with **ASTM E488/E488M**, as modified in the following two paragraphs, shall not be less than 1.0 MPa before and after freezing-and-thawing testing. Freezing-and-thawing testing in accordance with Method B of **ASTM C666/C666M** shall show no detectable deterioration after 300 cycles on assembled specimens.

Prepare 10 test specimens measuring 200 x 400 mm with brick embedded into a concrete substrate (assembled system) for tensile bond strength and resistance to freezing-

and-thawing testing. Divide test specimens with five designated as Sample A assemblies and five designated as Sample B assemblies. Specimen shall have a thickness of at least 65 mm plus brick thickness. Concrete shall have a compressive strength of at least 35 MPa and 4 to 6 percent entrained air. Embedded brick coursing pattern for test specimens shall be modular size brick 57 x 194 mm on a half running bond pattern with a formed raked joint geometry not less than 10 mm wide and a depth not greater than 6 mm from the exterior face of brick.

One brick from the center of each Sample A assembly shall be tested for tensile bond strength. In place of anchor specified in ASTM E488/E488M, use steel plate at least 6 mm thick and of same size as single brick face bonded with epoxy to a single brick face for each tensile bond strength test. The steel plate shall have a centrally located pull-rod welded to the plate. Each Sample B assembly shall first be tested for freezing-and-thawing resistance in accordance with ASTM C666/C666M Method B. After freezing-and-thawing resistance testing, one brick from the center of each Sample B assembly shall be tested for tensile bond strength.

14.2.6.2(h) Modulus of rupture—Not less than 1.7 MPa when tested in accordance with ASTM C67.

14.2.6.2(i) Chemical resistance—Rated “not affected” when tested in accordance with **ASTM C650**.

14.2.6.2(j) Surface coloring—Brick specified with surface coloring, other than flashed or sand-finished brick, shall withstand 50 cycles of freezing and thawing in accordance with ASTM C67 with no observable difference in applied finish if viewed in daylight from 6 m.

14.2.6.2(k) If specified, face color and texture shall match accepted design reference sample.

14.2.7 Glazed and unglazed ceramic tile units—Unless otherwise specified, unit properties shall comply with the following:

- (a) Thickness of units shall not be less than 10 mm.
- (b) Body of glazed tile shall have water absorption of less than 3 percent measured in accordance with **ASTM C373**.
- (c) Manufacturer shall warrant materials as frost-resistant.
- (d) Glazed units shall conform to **ASTM C126**.

14.2.8 Architectural terra cotta units—If specified, terra cotta units shall comply with requirements of architectural terra cotta manufacturer’s recommendations for application indicated.

14.2.9 Setting mortar—Unless otherwise specified, mortar for setting thin or half-brick, ceramic tile, or terra cotta unit joints before placing precast concrete shall use backup concrete or portland cement, **ASTM C150/C150M** Type I, and **ASTM C144** natural sand. Mix at a ratio of 1 part portland cement to 4 parts sand, by bulk volume, with minimum water required for casting.

14.2.10 Latex portland-cement pointing grout—Unless otherwise specified, fill brick joints after precast concrete panel production. Unless otherwise specified, use pointing grout conforming to **ANSI A118.6** and meeting 14.2.10.1 or 14.2.10.2.

14.2.10.1 Dry-grout mixture, factory prepared, of portland cement, graded aggregate, and dry, redispersible, ethylene-vinyl-acetate additive for mixing with water.

14.2.10.2 Commercial portland cement grout, factory prepared, with liquid styrene-butadiene rubber or acrylic-resin latex additive.

14.2.10.3 Unless otherwise specified, color of pointing grout shall match design reference sample.

14.2.11 Setting systems for brick and ceramic tile—Unless otherwise specified, setting systems with thin and full brick or ceramic tile laid after casting precast concrete units shall conform to 14.2.11.1 or 14.2.11.2.

14.2.11.1 Thin brick and ceramic tile units shall be set using dry-set mortar conforming to **ANSI A118.1** or latex-portland cement mortar conforming to **ANSI A118.4**.

14.2.11.2 For full brick units, use galvanized or stainless-steel dovetail slots in precast concrete, not less than 0.5 mm thick. Felt or fiber fill or cover face opening of dovetail slots.

14.2.12 Stone facing—If specified, provide stone facing for precast concrete meeting requirements of 14.2.12.1 to 14.2.12.5.

14.2.12.1 Tolerance of length and width of +0, –3 mm.

14.2.12.2 Anchors shall be stainless steel; **ASTM A666** Type 304; and of temper, diameter, and embedment required to support loads without exceeding allowable design stresses.

14.2.12.3 If a flexible sealant material is specified for filling anchor holes, use a low-modulus sealant that is nonstaining to stone substrate and that complies with **ASTM C920**.

14.2.12.4 If rigid filler is specified for filling anchor holes, use epoxy conforming to **ASTM C881/C881M**, 100 percent solids, sand-filled with a sand-to-binder ratio between 6 and 9, nonshrinking, nonstaining of a type, class, and grade to suit application. Fit each anchor leg with 60 Durometer neoprene grommet collar, having a width at least twice the diameter and length at least five times the anchor diameter.

14.2.12.5 Unless otherwise specified, bond breaker between stone and precast concrete shall be polyethylene sheet, **ASTM D4397**, 0.15 to 0.25 mm thick.

14.2.13 Form fabrication

14.2.13.1 General—Construct mortar-tight forms of sufficient strength to withstand pressures due to concrete placement, vibration operations, and temperature changes. Coat contact surfaces of molds with release agent before reinforcement is placed.

Maintain forms to provide completed precast concrete units of shapes, lines, and dimensions within **ACI ITG-7M** fabrication tolerances. Unless otherwise specified, visible form joints are prohibited on faces exposed to view in finished Work.

14.2.13.2 Thin and half-brick facing—If thin or half-brick facings are specified, place form liner templates accurately to provide grid for brick facings. Provide solid backing and supports to maintain liner stability while placing bricks and during concrete casting. Securely place brick units face down into form liner pockets and place precast concrete backing mixtures. Clean faces and joints of brick facing.

14.2.13.3 Form liners—Place form liners to provide surface appearance specified in Contract Documents. Provide solid backing and supports to maintain liner stability during concrete placement. Coat form liner with form-release agent that will not affect form liner material.

14.2.14 Stone facing installation—If specified, stone facings are to be positioned in locations specified in Contract Documents. Install spring clips, anchors, supports, and other attachments indicated or necessary to secure stone in place. Maintain minimum embedment depth requirements of stone anchors into concrete substrates. Orient stone veining in direction indicated in Contract Documents. Space anchors at least 150 mm from an edge and provide no less than two anchors per stone unit of less than 0.2 m² in area and four anchors per unit of less than 1.1 m² in area. For units larger than 1.1 m² in area, provide anchors spaced no more than 750 mm on center, depending on provisions in local building code and lateral load requirements. Use continuous spacers to obtain uniform joints of specified widths and with edges and faces aligned according to specified pattern. Ensure no passage of concrete matrix to stone surface or joints between stones.

14.2.14.1 Furnish and install sealant backings and sealant into stone-to-stone joints and stone-to-concrete joints on each unit. Apply a continuous sealant bead along both sides and top of precast concrete units at stone/precast concrete interface. Do not seal bottom edge of unit.

14.2.14.2 Stone anchor shear and tensile testing—Engage testing agency acceptable to Architect/Engineer to evaluate and test proposed stone anchorage system. Submit qualifications of selected testing agency. Provide two sets of six stone samples 300 x 300 mm with stone of proposed thickness. Test for shear and tensile strength of proposed stone anchorage system in accordance with **ASTM E488/E488M** modified as follows:

- (a) Before testing, submit a description of test assembly, pertinent data on materials, test apparatus, and procedures.
- (b) Test stone anchors of sizes and shapes proposed for installation.
- (c) Test the assembly to failure and record test load at failure. Record the type of failure, anchor pullout, stone breakage, and other pertinent information in accordance with requirements of **ASTM E488/E488M**. In addition, submit load-deflection curves of each test assembly.

14.2.15 Face and backup concrete mixtures—If only one face of unit is exposed, use either of the techniques in 14.2.15.1 or 14.2.15.2 unless otherwise specified.

14.2.15.1 The same concrete mixture throughout panel thickness.

14.2.15.2 Different concrete mixtures for face and backup.

14.2.15.3 Place face concrete to a thickness after consolidation that equals or exceeds the largest of the following:

- (a) 40 mm
- (b) One and one-half times the nominal maximum aggregate size
- (c) Required concrete cover

14.2.16 Precast architectural concrete unit finishes

14.2.16.1 General—Exposed faces shall be free of joint marks, grain, or defects not accepted in accepted sample or mockup units. Corners, including false joints, shall match accepted sample or mockup units. Finish exposed-face surfaces of precast concrete units to match accepted sample or mockup units.

14.2.16.2 Provide one of the finishes described in 14.2.16.2(a) through 14.2.16.2(i) as specified in Contract Documents.

14.2.16.2(a) As-cast surface finish—Provide surfaces to match accepted sample panels or mockups for acceptable surface air voids and sand streaks of as-cast surface finishes.

14.2.16.2(b) Textured-surface finish—Provide surfaces to match accepted sample panels or mockups for acceptable surface air voids, sand streaks, and uniformity of color for textured-surface finishes.

14.2.16.2(c) Bush-hammer finish—Use power or hand tools to remove matrix and fracture coarse aggregates to match accepted sample panels or mockups.

14.2.16.2(d) Exposed-aggregate finish—Use chemical retarding agents applied to molds and washing and brushing procedures to expose aggregate and surrounding matrix surfaces after form removal to match accepted sample or mockup units.

14.2.16.2(e) Abrasive-blast finish—Use abrasive grit, equipment, application techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces to match accepted sample panels or mockups.

14.2.16.2(f) Acid-etched finish—Use acid and hot-water solution, application equipment and techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces to match accepted sample panels or mockups. Protect hardware, connections, and insulation from acid attack.

14.2.16.2(g) Honed finish—Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures to match accepted sample panels or mockups.

14.2.16.2(h) Polished finish—Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures to match accepted sample panels or mockups.

14.2.16.2(i) Sand-embedment finish—Use selected stones placed in a sand bed in bottom of mold, with sand removed after curing to match accepted sample panels or mockups. Sand depth shall keep backup concrete 25 to 35 percent of stone's nominal diameter from face.

14.2.16.3 Unless otherwise specified, float finish unexposed surfaces of architectural concrete units.

14.2.16.4 Defective Work—Precast concrete units that do not comply with requirements including concrete strength, manufacturing tolerances, and color and texture range are unacceptable. Chipped, spalled, or cracked units may be repaired if repaired units match accepted sample panels and mockups. Architect/Engineer maintains the right to reject any unit if it does not match accepted sample panels and mockups. Replace unacceptable units with precast concrete units that comply with requirements.

14.2.16.5 Cleaning—Unless otherwise specified, fabricator shall clean surfaces of precast concrete units with mild soap and high-pressure water before shipping.

14.2.16.6 Protection—Protect architectural face of precast unit from contamination and damage during transportation and handling.

14.3—Execution

14.3.1 Erection

14.3.1.1 Unless otherwise specified, provide for joint widths of 20 mm.

14.3.1.2 Disruption of roof flashing continuity by connections is prohibited; concealment within roof insulation is acceptable.

(Nonmandatory information follows)

NOTES TO SPECIFIER

General notes

G1. ACI Specification 301M-20 is to be used by reference in the Project Specification. Do not copy individual sections, parts, articles, or paragraphs into the Project Specification because taking them out of context may change their meaning.

G2. If sections or parts of ACI Specification 301M-20 are copied into the Project Specification or any other document, do not refer to them as an ACI specification.

G3. A statement such as the following will serve to make ACI Specification 301M-20 a part of the Project Specification:

“Work on (Project Title) shall conform to all requirements of ACI 301M-20 ‘Specifications for Concrete Construction’ published by the American Concrete Institute, Farmington Hills, Michigan, except as modified by these Contract Documents.”

G4. Each technical Section of ACI Specification 301M-20 is written in the three-part section format of the Construction Specifications Institute, as adapted for ACI requirements. The language is imperative and terse.

G5. If ACI Specification 301M-20 is referenced in Contract Documents along with another ACI specification that contains overlapping provisions, identify which requirements are in conflict and state in Contract Documents which requirements govern.

Foreword to checklists

F1. This foreword is included for explanatory purposes only; it is not a part of ACI Specification 301M-20.

F2. ACI Specification 301M-20 may be referenced by the Specifier in the Project Specification for any building project, together with supplementary requirements for the specific project. Responsibilities for project participants must be defined in the Project Specification. ACI Specification 301M-20 cannot and does not address responsibilities for any project participant other than Contractor.

F3. Checklists do not form a part of ACI Specification 301M-20. Checklists assist the Specifier in selecting and specifying project requirements in the Project Specification.

F4. The Mandatory Requirements Checklist indicates Work requirements regarding specific qualities, procedures, materials, and performance criteria that are not defined in ACI Specification 301M-20. The Specifier must include these requirements in the Project Specification.

F5. The Optional Requirements Checklist identifies Specifier alternatives or additions. The Checklist identifies the Sections, Parts, and Articles of the ACI Reference Specification 301M-20, and the action required or available to the Specifier. The Specifier should review each of the items in the Checklist and make adjustments to the needs of a particular project by including those selected alternatives or additions as mandatory requirements in the Project Specification.

F6. Cited references—Documents and publications that are referenced in the Checklists of ACI Specification 301M-20 are listed below. These references provide guidance to the Specifier and are not considered to be part of ACI Specification 301M-20.

American Concrete Institute (ACI)

ACI 117M-10(15)—Specifications for Tolerances for Concrete Construction

ACI 201.2R-16—Guide to Durable Concrete

ACI 207.1R-05(12)—Guide to Mass Concrete

ACI 207.2R-07—Report on Thermal and Volume Change Effects on Cracking of Mass Concrete

ACI 209R-92(08)—Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures

ACI 213R-14: Guide for Structural Lightweight-Aggregate Concrete

ACI 222R-19—Guide to Protection of Reinforcing Steel in Concrete against Corrosion

ACI 223R-10—Guide for the Use of Shrinkage-Compensating Concrete

ACI 225R-19—Guide to the Selection and Use of Hydraulic Cements

ACI 228.1R-19—Report on Methods for Estimating In-Place Concrete Strength

ACI 237R-07—Self-Consolidating Concrete

ACI 302.1R-15—Guide for Concrete Floor and Slab Construction

ACI 302.2R-06—Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials

ACI 305R-20—Guide to Hot Weather Concreting

ACI 306.1-90(02)—Standard Specification for Cold Weather Concreting

ACI 306R-16—Guide to Cold Weather Concreting

ACI 308R-16—Guide to Curing Concrete

ACI 311.1R-07—ACI Manual of Concrete Inspection (SP-2)

ACI 311.4R-05—Guide for Concrete Inspection

ACI 318M-19—Building Code Requirements for Structural Concrete and Commentary

ACI 347R-14—Guide to Formwork for Concrete

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ACI 347.2R-17—Guide for Shoring/Reshoring of Concrete Multistory Buildings
 ACI 360R-10—Guide to Design of Slabs-on-Ground
 ACI 423.7-14—Specification for Unbonded Single-Strand Tendon Materials and Commentary
 ACI 506R-16—Guide to Shotcrete
 ACI 506.2-13(18)—Specification for Shotcrete
 ACI 551.1R-14—Guide to Tilt-Up Concrete Construction
 ACI CP-10—Craftsman Workbook for ACI Certification of Concrete Flatwork Technician/Finisher
 ACI ITG-7M-09—Specification for Tolerances for Precast Concrete
 ACI SP-4(14)—Formwork for Concrete

American National Standards Institute (ANSI)

ANSI A118.6-10—Specification for Standard Cement Grout for Tile
 ANSI A137.1-12—Specifications for Ceramic Tile

ASTM International

ASTM A615/A615M-16—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
 ASTM A706/A706M-16—Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement
 ASTM A767/A767M-09(2015)—Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
 ASTM A1094/A1094M-18—Standard Specification for Continuous Hot-Dip Galvanized Steel Bars for Concrete Reinforcement
 ASTM C31/C31M-15—Standard Practice for Making and Curing Concrete Test Specimens in the Field
 ASTM C33/C33M-13—Standard Specification for Concrete Aggregates
 ASTM C42/C42M-13—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C78/C78M-15—Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

ASTM C94/C94M-15—Standard Specification for Ready-Mixed Concrete

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

ASTM C173/C173M-14—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C231/C231M-14—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

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

ASTM C845/C845M-12—Standard Specification for Expansive Hydraulic Cement

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

ASTM C1602/C1602M-12—Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

ASTM D1557-12e1—Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

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

American Welding Society (AWS)

AWS D1.4/1.4M:2018—Structural Welding Code—Reinforcing Steel

Concrete Reinforcing Steel Institute (CRSI)

CRSI MSP 2-01—Manual of Standard Practice

Post-Tensioning Institute (PTI)

PTI/ASBI M50.3-19—Specification for Multistrand and Grouted Post-Tensioning
PTI M55.1-19—Specification for Grouting of Post-Tensioned Structures
PTI TAB.1-06—Post-Tensioning Manual, sixth edition

Precast/Prestressed Concrete Institute (PCI)

MNL-116-99—Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, fourth edition
MNL-117-13—Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products
MNL-120-17—PCI Design Handbook, eighth edition
MNL-122-07—Architectural Precast Concrete, third edition
MNL-123-88—Connections Manual: Design and Typical Details of Connections for Precast and Prestressed Concrete

Authored references

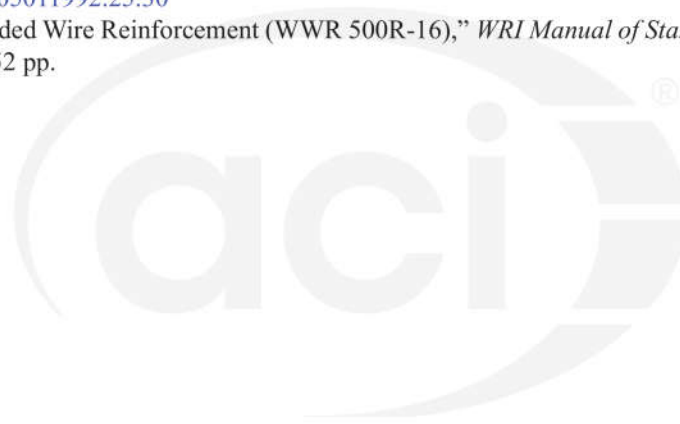
Gajda, J.; Feld, J.; and Ferraro, C. C., 2018, “Proposed Mass Concrete Definition Based on Concrete Constituents and Minimum Dimension,” *Mass Concrete and Thermal Cracking—A Joint ACI-JCI Seminar*, SP-325, American Concrete Institute, Farmington Hills, MI.

Kosmatka, S. H., and Wilson, M. L., 2016, *Design and Control of Concrete Mixtures*, 16th edition, EB001, Portland Cement Association, Skokie, IL, 632 pp.

NRMCA, 2015, “Section 3—Certification of Ready Mixed Concrete Production Facilities,” *Quality Control Manual*, National Ready Mixed Concrete Association, Silver Spring, MD, 8 pp.

Sason, A. S., 1992, “Evaluation of Degree of Rusting on Prestressed Concrete Strand,” *PCI Journal*, V. 37, No. 3, May-June, pp. 25-30. doi: [10.15554/pcij.05011992.25.30](https://doi.org/10.15554/pcij.05011992.25.30)

WRI, 2016, “Structural Welded Wire Reinforcement (WWR 500R-16),” *WRI Manual of Standard Practice*, Wire Reinforcement Institute, Hartford, CT, 52 pp.



MANDATORY REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
<i>General requirements</i>	
1.1.5	Designate portions of Work to be constructed of shotcrete. Concrete sections not initially designated as shotcrete may be subsequently considered for shotcrete placement after Contractor submittal for consideration. Refer to ACI 506R for guidance on shotcrete. Review ACI 506.2 and ACI 318M and specify requirements for shotcrete. (Refer to Table R4.2.1.1 of ACI 318M-19 for list of provisions applicable to shotcrete.)
<i>Formwork and formwork accessories</i>	
2.2.1.2	Indicate areas where walls require form ties with a positive water barrier. Indicate areas where coated or corrosion-resistant ties are required.
2.2.1.5	Specify materials and design for waterstops, sleeves, inserts, anchors, and other embedded items as required for Work.
2.2.2.5(b)	Indicate in Contract Documents the locations of required movement joints.
2.2.2.5(c)	Indicate in Contract Documents where keyways are required.
2.2.2.5(d)	Indicate in Contract Documents the locations where waterstops are required in joints.
<i>Reinforcement and reinforcement supports</i>	
3.1.2.1(f)	Specify locations where field bending or straightening of reinforcing bars is permitted.
3.2.1.1	Specify required grades, types of steel, and sizes of reinforcing bars.
3.2.1.2(a)	For zinc-coated (galvanized) reinforcing bars conforming to ASTM A767/A767M, specify coating class, whether galvanizing is to be performed before or after fabrication, and indicate which bars require special finished bend diameters.
3.2.1.2(b)	Specify ASTM specification to which epoxy-coated reinforcing bars are to conform.
3.2.1.5	Specify the following for wire reinforcement: (a) Material specification (b) Wire size (c) Minimum yield strength or grade (d) Additional specification for galvanizing or epoxy coating
3.2.1.6	Specify the following for welded wire reinforcement: (a) Material specification (b) Sheets or rolls (c) Wire size and spacing (longitudinal and transverse) (d) Minimum yield strength or grade (e) Additional specification for galvanizing or epoxy coating
3.2.1.8	Specify types of reinforcement supports and location used within structure. Refer to Chapter 3 in CRSI MSP 2.
3.3.2.5(a)	Specify location and tolerance for placement of welded wire reinforcement.
3.3.2.5(b)	Specify method of lapping at edges and ends of wire reinforcement.
3.3.2.7	Indicate splices in Contract Documents.
<i>Concrete mixtures</i>	
4.2.2.6(b)	Designate in Contract Documents the exposure class or specify requirements for concrete mixtures for portions of the structure requiring concrete resistant to sulfate attack. Refer to ACI 318M.
4.2.2.6(c)	Designate in Contract Documents the exposure class or specify requirements for concrete mixtures for portions of the structure requiring resistance to freezing and thawing. For Exposure Class F3, indicate if it is plain concrete. Refer to ACI 318M.
4.2.2.6(d)	Designate in Contract Documents the exposure class or specify requirements for concrete mixtures for portions of the structure in contact with water. Refer to ACI 318M.
4.2.2.6(e)	Designate in Contract Documents the exposure class or specify requirements for concrete mixtures for portions of the structure requiring corrosion protection of reinforcement. Refer to ACI 318M. Refer to ACI 201.2R and ACI 222R for additional information on the effects of chlorides on corrosion of reinforcement.
4.2.2.7	Indicate the specified compressive strength of concrete, f'_c , for various portions of Work. For most structural members, the requirements of the design will dictate the required strength. A higher compressive strength may be required for durability considerations. For floors, the specified compressive strength f'_c will generally depend upon the intended use and expected wear unless durability considerations dictate higher strengths. If the floor will be exposed to abrasive wear from early construction traffic, consider requiring a minimum compressive strength at 3 days of 13 MPa or higher. Refer to ACI 302.1R for guidance on compressive strengths to specify for various classes of floors. Concrete assigned to Exposure Class S1, S2, S3, F1, F2, F3, C2, or W2 as defined in ACI 318M, is required to meet the maximum w/cm limits given in Table 4.2.2.6(b), Table 4.2.2.6(c), Table 4.2.2.6(d), and Table 4.2.2.6(e).
<i>Handling, placing, and constructing</i>	
5.3.1.4	Specify requirements of base and subgrade preparation for slab-on-ground.

MANDATORY REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
5.3.2.4(i)	Indicate where higher-strength concrete for columns and walls is required to be integrated with floor systems.
5.3.3.2	Specify required as-cast finish.
5.3.4.2(f)	Specify base slab preparation, bonding and topping materials, type of surface finish, curing method, and jointing requirements.
5.3.5	Designate locations for saw-cut joints and any requirements or restrictions for cutting reinforcement at joints.
5.3.8.2	Designate adhesive anchors that will support sustained tension that are installed into holes that are horizontally or upwardly inclined.
<i>Architectural concrete</i>	
6.1.1	Designate portions of Work to be constructed of architectural concrete. Specify requirements for each designated area. Refer to ACI 303R for additional information on architectural concrete.
6.2.1.8(a)	Specify cone diameter for form ties.
6.3.9	Specify which of the finishes listed under 6.3.9 are required. Specify other finishes required.
<i>Lightweight concrete</i>	
7.1.1	Designate portions of Work to be constructed of lightweight concrete. Refer to ACI 213R for guidance on lightweight concrete.
7.2.2.1	Specify equilibrium density for lightweight concrete.
<i>Mass concrete</i>	
8.1.1	Designate portions of Work to be constructed as mass concrete. Concrete placements where maximum temperatures and temperature differences must be controlled due to factors including the content and type of cementitious materials, environment surrounding placement, and minimum dimension of placement should be designated as mass concrete. Evaluate the requirements for each portion of project. In general, a placement of concrete with a minimum dimension equal to or greater than 1.2 m should be considered mass concrete. Similar considerations should be given to other concrete placements that do not meet this minimum dimension but generate high heat at early ages such as concretes that contain Type III cement, accelerating admixtures, or have high cementitious materials contents. Consideration should also be given to placements that trap heat such as where heat in soil does not allow placement to cool or in stacked placements with too little time provided for adequate heat dissipation. Refer to ACI 207.1R for further guidance on mass concrete construction, and Gajda et al. (2018) for information regarding mass concrete behavior based on member thickness and concrete mixture proportions.
<i>Post-tensioned concrete</i>	
9.1.1	Designate those portions of Work to be constructed as post-tensioned concrete. Refer to PTI TAB.1 for guidance on design and construction of post-tensioned structures.
9.2.1.1	Specify post-tensioning system tendon protection level (PL) in accordance with nomenclature in PTI/ASBI M50.3.
9.2.1.3	Specify type and minimum tensile strength of prestressing steel.
9.2.2.1	Specify class of grout to be used for bonded tendons. PTI M55.1 provides added detail on materials and proportions for grout classes.
9.2.2.1(d)	Specify materials, admixtures, and properties for Class D grout.
9.3.6.1	Specify stressing sequence, minimum in-place concrete compressive strength, and stages at which tendons are to be stressed.
<i>Shrinkage-compensating concrete for interior slabs</i>	
10.1.1	Designate interior slabs to be constructed of shrinkage-compensating concrete. Refer to ACI 223R for guidance on shrinkage-compensating concrete.
10.2.4	Specify the reinforcement required. Shrinkage-compensating concrete must always be reinforced. Refer to ACI 223R for additional guidance.
10.3.3	Specify the required location of isolation joints.
<i>Industrial floor slabs</i>	
11.1.1	Designate portions of Work to be constructed as industrial floor slabs. Refer to ACI 302.1R for guidance on concrete floor slab construction.
11.3.1	Specify proof-rolling procedure, method of acceptance, and corrective requirements if unacceptable material is identified. Refer to ACI 302.1R and 360R for guidance.
11.3.6	Specify movement joint layout. Refer to ACI 360R for guidance on design of joints that accommodate movement.
<i>Tilt-up construction</i>	
12.1.1	Designate portion of Work to be constructed using tilt-up concrete panels. Refer to ACI 551.1R for guidance on tilt-up concrete construction.
12.1.3.5	Specify if field mockup panels are required. Specify if mockup comprises other than two panels.
12.3.8	Specify type, location, and extent of each seismic isolation

MANDATORY REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
<i>Precast structural concrete</i>	
13.1.1	Designate portions of Work to be constructed using precast structural concrete members. Refer to PCI MNL-120 and PCI MNL-123 for guidance on precast concrete.
13.1.4.1	Specify category for erector certification: <ul style="list-style-type: none"> (a) Category A (Architectural Systems) for non-load-bearing members (b) Category S1 (Simple Structural Systems) for horizontal decking members and single-lift wall panels (c) Category S2 (Complex Structural Systems) for load-bearing members
13.1.4.2	Specify group and category for the fabricator: <ul style="list-style-type: none"> (a) Group A <ul style="list-style-type: none"> Category A1—Architectural Precast Products (b) Group C or CA <ul style="list-style-type: none"> i. Category C1—Precast Concrete Products (no prestressed reinforcement) ii. Category C2—Prestressed Hollow-Core and Repetitive Products iii. Category C3—Prestressed Straight-Strand Structural Members iv. Category C4—Prestressed Deflected-Strand Structural Members
13.2.1.1	For precast members to be designed by Contractor, specify design criteria and applicable codes and standards. Design criteria shall include (as applicable): <ul style="list-style-type: none"> (a) Superimposed gravity loads (b) Lateral load provisions (c) Wind, seismic, and other vertical loads (d) Topping slab thickness (e) Design temperature range (f) Lateral drift limits (g) Deflection requirements other than those required by specified codes
13.2.1.2	Specify required fire rating in hours of precast concrete members.
13.2.3(a)	Specify type and minimum tensile strength of prestressing steel.
13.2.6.1	Specify strength of grout. A specified strength of at least 14 MPa is recommended.
13.2.10.1	Specify the grade, type, and surface finish required for connection material.
13.2.10.2	Specify surfaces to receive specific types of surface finish.
13.2.11.1	Specify precast concrete member sizes and shapes.
13.2.11.2	Specify cast-in reglets, slots, holes, and accessories.
13.2.11.10(d)	Specify where strand ends and anchorages are to be covered, typically where appearance is critical.
13.2.11.12(c)	Specify finish for top wythe of insulated members.
13.2.13.1	Specify finish. If more than one finish is required, create a finish schedule in Contract Documents. Finishes are in ascending order of finish quality and price. Specify other specific finish requirements to suit Work. Specify the minimum finish grade consistent with a member's application and the intended use of the structure. Consult fabricators regarding the finishes appropriate for various members and cost effectiveness. Coordinate precast concrete finishes with required floor, ceiling, roof, deck finishes, or toppings. <p>Specify commercial grade finish if the member will not be visible in the completed structure, or if the function of the structure does not require an enhanced surface. This is essentially an as-cast finish.</p> <p>Specify standard grade finish if members are exposed to view but the function of the structure does not require a special finish. The surface is suitable for an applied textured coating but not necessarily suitable for painting. This is the typical finish grade for structural members.</p> <p>Specify Grade B finish on visually exposed structural members such as columns or walls. Grade B finish is primarily focused on surface finish. Color variations are acceptable.</p> <p>Specify Grade A finish if surface will be painted (especially with a textured or sand paint); however, some surface defects will be visible. If a surface with fewer imperfections than allowed for Grade A finish is needed, specify the requirements as a special finish. Requirements for Grade A finish are not applicable to extruded members manufactured with zero-slump concrete.</p>
13.2.13.3	Specify surface preparation, if required, to adequately transfer horizontal shear for composite action.
13.3.2.2	Specify in-place strength of supporting cast-in-place foundation and building structural framing concrete required before installation of precast concrete members.
13.3.3.5(b)	Specify bolt torque for slip-critical connections.
<i>Precast architectural concrete</i>	
14.1.1	Designate portions of Work to be constructed using precast architectural units and precast structural concrete members with CA finish. Refer to PCI MNL-122 for guidance on architectural precast concrete.
14.1.4.2(a)	Specify in Contract Documents where sample panels are to be located.

MANDATORY REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
14.2.1.1	Specify design criteria, and applicable codes and standards. Design criteria shall include (as applicable): (a) Superimposed gravity loads (b) Lateral load provisions (c) Wind, seismic, and other vertical loads (d) Design temperature range (e) Lateral drift limits (f) Deflection requirements other than those required by specified codes
14.2.13.3	Specify required surface appearance.
14.2.16.2	Specify required finish for exposed faces. Specify which structural precast concrete members require an architectural finish (CA category). If more than one finish is required, add locations to finish descriptions or indicate in Contract Documents. Specify more detailed descriptions of finishes if greater definition is required, such as light, medium, or deep.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
<i>General requirements</i>	
1.1.2	Designate Work not subject to Sections 1 through 5 of this Specification.
1.5.3	Specify if Contractor is required to submit a quality-control plan.
1.6	Specify if a preconstruction conference is required, and if so, who should be notified, and length of notice required before conference.
1.7.2.2	Specify if other testing duties and responsibilities are required of Contractor.
1.7.3.2	Specify if other testing services will be provided.
1.7.3.3(d)	Specify if more frequent sampling and testing will be required. More frequent sampling is typical with high-strength concrete, especially for columns and shearwalls, or if control of air content is critical.
1.7.3.3(e)	Specify if strength test specimens are to be tested at ages other than at 28 days.
1.7.3.4	Specify additional testing and inspection services desired for the Work, if applicable. Refer to ACI 311.1R and ACI 311.4R for specific inspection items that may be appropriate. If it is necessary or desirable to know properties of concrete at locations other than the point of delivery, specify that concrete is to be sampled at these other locations for testing. Refer to the discussion under Optional Requirements Checklist in 4.2.2.3.
1.7.4.2	Specify if rebound hammer or pulse velocity testing will be permitted to evaluate uniformity of in-place concrete. Refer to ACI 228.1R for guidance on these test methods.
1.7.4.3(a)	Specify if cores are required other than if concrete strength is in doubt. Specify alternative moisture conditioning procedures and duration to those defined in ASTM C42/C42M. The core conditioning procedures defined in ASTM C42/C42M are intended to minimize the effects of moisture gradients on the measured strengths of cores. Specify if cores may be tested before 5 days or after 7 days from time of drilling.
1.7.4.3(c)	Specify alternative repair, curing requirements, or both for repairs to core holes.
1.7.4.4	Specify if other methods are acceptable to determine floor flatness and levelness. Refer to ACI 117M and ACI 302.1R.
1.7.6.4	Specify requirements for use of in-place tests; for example, pullout testing or penetration resistance (probe) testing, in the event standard-cured specimens fail to meet the strength criteria. Include procedures to develop strength correlations. Refer to ACI 228.1R for guidance on required correlation data and acceptable data analysis methods.
1.7.7	Specify alternative acceptance requirements for steel-fiber reinforced concrete to provide shear resistance. The stated criteria are based on ACI 318M.
1.7.8.1	Specify if on-site addition of air-entraining agent is not permitted if air content as delivered is less than required.
1.7.8.2	Specify if project site adjustments to slump in accordance with ASTM C94/C94M are not permitted.
1.7.8.3	Specify if maximum and minimum temperatures other than those given in 4.2.2.4 are permitted. Architect/Engineer will need to decide if other limits are acceptable without affecting performance.
1.8.2.1	Specify tolerances different from those in ACI 117M.
<i>Formwork and formwork accessories</i>	
2.1.2.1	Review items listed in 2.1.2.1(a) through 2.1.2.1(e) and specify in Contract Documents the items that are not required to be submitted.
2.1.2.2	Review items listed and specify the items to be submitted.
2.1.2.2(a)	Specify if shop drawings are required to be signed and sealed.
2.1.2.2(b)	Specify if design calculations for formwork, shoring, reshoring, and backshoring are required to be signed and sealed by a licensed design engineer.
2.2.1.1	Specify form-facing materials to be used.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
2.2.1.2	Specify alternative break-back distance for ferrous ties.
2.2.1.6	Specify alternative materials or size, or both, for chamfer strips.
2.2.2.3	Specify if earth cuts are permitted as forms.
2.2.2.4	Specify more stringent limitations on deflection of facing materials if needed.
2.2.2.5(a)	Specify locations or allowable spacings for construction joints. Specify or allow alternative locations for formed construction joints, if necessary, to facilitate formwork removal or accelerate construction, provided that the alternative joint locations do not adversely affect the strength of the structure.
2.2.2.5(c)	Specify keyway depths other than 40 mm if required.
2.3.1.2	Specify if chamfer strips are not required on exterior corners of permanently exposed surfaces. Specify if bevels are required on reentrant corners of concrete or on edges of formed concrete joints.
2.3.1.5	Specify tolerance limits different from requirements of ACI 117M. Specify if a more or less restrictive tolerance for abrupt offset is required. Refer to ACI 347R and ACI 117M for further guidance.
2.3.2.4	Specify the minimum in-place compressive strength for removal of forms supporting the weight of concrete and construction loads if different from f'_c . Refer to ACI 347R and ACI 347.2R for guidance on items to consider.
2.3.2.5	Specify if form-facing material and horizontal facing support members are not permitted to be removed at an earlier age than the vertical support members. Refer to ACI SP-4 for a discussion of drophead shore systems that allow removal of form-facing materials without removing vertical supports.
2.3.2.6	Specify if Architect/Engineer acceptance of post-tensioned reinforcing stressing records is not required before formwork removal provided elongations are in accordance with 9.3.6.3.
2.3.4.2	Specify if the alternative methods for evaluating in-place concrete strength for formwork removal are permitted.
2.3.5.2	Specify if notification of formwork inspection is to be provided to Special Inspector or Owner's testing agency.
<i>Reinforcement and reinforcement supports</i>	
3.1.2.1	Specify if any submittals listed in 3.1.2.1(a) through 3.1.2.1(j) are not required.
3.2.1.2	Specify if coated reinforcing bars are required and, if so, whether coating is to be zinc (galvanized), epoxy, or zinc and epoxy dual-coated. Avoid mixing galvanized and nongalvanized reinforcement or other embedded steel that could result in galvanic cells.
3.2.1.2(a)	ACI 318M requires zinc-coated (galvanized) reinforcing bars to conform to ASTM A767/A767M. For other applications, specify use of alternative zinc-coated reinforcing bars. Reinforcing bars coated to ASTM A767/A767M have a zinc coating thickness of 0.13 or 0.15 mm (Class 1, based on bar size) or 0.09 mm (Class 2). Reinforcing bars conforming to ASTM A1094/A1094M have a zinc or zinc-aluminum alloy coating thickness of 0.05 mm.
3.2.1.3	Specify use of bar mats.
3.2.1.4	Specify alternative type and grade of steel for headed reinforcing bars: (a) Carbon-steel (ASTM A615/A615M) (b) Low-alloy steel (ASTM A706/A706M)
3.2.2.2(a)	If welding steel reinforcing bars is specified, specify requirements for welding preparation (such as removal of zinc or epoxy coating) more stringent than those in AWS D1.4/D1.4M. Specify desired requirements for chemical composition of reinforcing bars more stringent than ASTM specifications. Specify special heat treatment of welded assemblies, if required. Specify supplementary requirements for welding of wire to wire, and welding of wire or welded wire reinforcement to reinforcing bars or structural steel element.
3.3.2.3	Specify increased cover requirements for corrosive environments, other severe exposure conditions, or fire protection. Refer to ACI 318M.
3.3.2.5(a)	Specify where welded wire reinforcement may extend through movement joints, including saw-cut joints. Specify alternative method of lapping at edges and ends of welded wire reinforcement. Refer to <i>WRI Manual of Standard Practice</i> (WRI 2016) for additional guidance.
3.3.2.8	Specify if field bending of partially embedded bars is permitted. If field bending is permitted, specify alternative method of bending or straightening of partially embedded reinforcing bars.
3.3.2.10	Specify dowels that are to be unbonded on one side of expansion joint.
<i>Concrete mixtures</i>	
4.1.2.3(b)	Specify alternative requirements for evaluating potential alkali-silica reactivity of aggregates. Refer to ASTM C1778.
4.1.2.3(g)	Specify if documentation on compliance with the optional requirements of ASTM C1602/C1602M is required if nonpotable water is proposed for use. Optional requirements in ASTM C1602/C1602M establish limits on soluble chlorides, sulfates and alkalis, and total solids in mixing water. These limits may be individually specified if applicable to the Work.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
4.2.1.1	Specify if specific cementitious materials are required or prohibited. If one or combinations of cementitious materials given in 4.2.1.1(a) through 4.2.1.1(f) are used in structures that will be assigned Exposure Class F3, verify compliance of the concrete with 4.2.2.6(e). Use ACI 318M and ACI 225R to determine what will be acceptable for the project conditions. Refer to Kosmatka and Wilson (2016) for additional guidance.
4.2.1.2	<p>If aggregates are to conform to a specification other than ASTM C33/C33M for grading, deleterious substances, or soundness, specify the other requirements.</p> <p>If desired, specify the test for determining conformance to requirements for cleanliness, and specify grading be determined on samples obtained from the aggregates at the point of batching.</p> <p>If desired, specify additional requirements for aggregate such as hardness, color, mineralogical composition, texture, or shape (crushed or gravel).</p>
4.2.1.2(a)	<p>Specify if aggregate derived from crushed hydraulic cement concrete or other recycled aggregate is not permitted.</p> <p>If acceptable for Work, state the required documentation for use of these aggregates in concrete as required by design and in accordance with Chapter 26 of ACI 318M-19. Documentation should include:</p> <ol style="list-style-type: none"> (1) Data showing that concrete mixtures incorporating such aggregate comply with mechanical properties and durability required by design (2) Quality control plan that includes tests to verify consistency of aggregate and properties of concrete for the duration of the Work. <p>Use of recycled aggregate requires approval by the building official.</p>
4.2.1.4	Specify if potable water is required for mixing water.
4.2.1.5	<p>If mineral fillers are to conform to a specification other than ASTM C1797, specify the other requirements.</p> <p>Specify if mineral filler derived from carbonate sources is permitted in concrete for members assigned to Exposure Classes S1, S2, or S3. If the quantity of mineral filler derived from carbonate sources is such that the total calcium carbonate content from cement and mineral filler is less than 15 percent by mass of cementitious materials, sulfate resistance can be evaluated by ASTM C1012/C1012M to demonstrate compliance with the expansion criteria in Table 4.2.2.6(b)1. These criteria are used to permit the use of blended cements conforming to ASTM C595/C595M that contain up to 15 percent limestone in concrete exposed to sulfates.</p>
4.2.1.6	Specify if specific admixtures are required or prohibited.
4.2.1.7	For other applications of fiber-reinforced concrete, specify requirements for steel fibers.
4.2.2.1	Specify slump if it is not permissible for Contractor to select this value.
4.2.2.2	<p>Specify slump flow if it is not permissible for Contractor to select this value. Specify if passing ability of proposed mixture should be evaluated and the acceptance criteria. This may be specified for placement in congested reinforcement.</p> <p>Specify if proposed mixture should be evaluated for static segregation and provide the acceptance criteria. Guidance is provided in ACI 237R.</p>
4.2.2.3	If desired aggregate size limit requirement differs from that specified by 4.2.2.3 (for example, smaller size in floor toppings), specify limit for nominal maximum size of aggregate.
4.2.2.4(a)	Specify if the air content should be different from 4.2.2.6(c).
4.2.2.4(b)	Specify if a particular ASTM test method (ASTM C231/C231M or C173/C173M) is required for measuring air content or if an alternative method is required.
4.2.2.4(c)	<p>If concrete is to be sampled other than at the point of delivery, specify where the concrete is to be sampled and describe the method to obtain samples.</p> <p>It may be necessary to specify that air content be measured at the point of placement to account for loss of air content during pumping. Once the loss of air content during pumping is established, acceptance limits at the point of delivery can be determined.</p>
4.2.2.5(a)	Specify alternative minimum concrete temperature requirements. The default requirements are from ACI 306.1. For projects in cold climates, such as in northern winters, or in situations where it is prudent to require Contractor to follow specific procedures to achieve the limits of 4.2.2.5(a), the temperature limits for cold weather may be deleted and ACI 306.1 can be referred to in its entirety. Options provided in ACI 306.1 must then be exercised.
4.2.2.5(b)	Specify alternative maximum concrete temperature. If concrete delivered in hot weather with a temperature higher than 35°C has been used successfully in given climates or situations, the higher temperature may be specified in place of the 35°C limit. Review ACI 305R for guidance on specifying a higher temperature limit.
4.2.2.6(a)	<p>Specify alternative requirements for evaluating the potential reactivity of aggregates or for mitigating alkali-silica reaction (ASR). Refer to ASTM C1778 for more details on evaluating mitigating strategies.</p> <p>In using ASTM C1567 to demonstrate the effectiveness of combinations of cementitious materials in mitigating ASR, (b) requires submittal of data showing the aggregate expansion is greater than 0.10 percent at 16 days age when tested in accordance with ASTM C1260.</p>
4.2.2.6(b)	Specify alternative requirements to those in Table 4.2.2.6(b) for sulfate resistance.

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OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
4.2.2.6(c)	Specify alternative requirements to those in Table 4.2.2.6(c) for freezing-and-thawing resistance.
4.2.2.6(d)	Specify alternative requirements to those in Table 4.2.2.6(d) for concrete in contact with water.
4.2.2.6(e)	Specify alternative requirements to those in Table 4.2.2.6(e) for corrosion protection of reinforcement.
4.2.2.6(f)	Specify if water-soluble chloride limits for concrete cast on stay-in-place galvanized forms should be less than 0.30 percent.
4.2.2.7(a)	Specify if test age is to be other than 28 days.
4.2.2.8	Specify if modulus of elasticity results are required for specific concrete mixtures, along with the required elastic modulus value. Specify the test age for modulus of elasticity tests if different from 28 days. Specify alternative requirements for modulus of elasticity. There may be design situations where the modulus of elasticity should not exceed a maximum value. This evaluation is based on concrete mixtures and specimens prepared in a laboratory.
4.2.2.9	Indicate in Contract Documents where steel fiber-reinforced concrete is required to provide shear resistance. The stated requirements for concrete mixtures are in accordance with ACI 318M. Specify alternative requirements for steel fiber-reinforced concrete to provide shear resistance. For other applications of fiber-reinforced concrete, specify the requirements for the concrete mixture. The high dosage of steel fibers needed for providing shear resistance may not be appropriate for other applications and can impact the construction of concrete members.
4.2.3.5	Specify if field verification of concrete mixtures is required.
4.3.1.1	If concrete materials are to be measured, batched, or mixed other than in conformance to ASTM C94/C94M, specify how these procedures are to be accomplished. Specify if the ready mixed concrete production facility does not need to be certified by the NRMCA Program for Certification of Ready Mixed Concrete Production Facilities approved by state highway agency or certified by an equivalent program. NRMCA's Certification Program is in accordance with NRMCA (2015). Equivalent approval or audit should include: (a) Documentation that storage of concrete ingredient materials is such as to minimize segregation, breakage, and contamination (b) Verification of the accuracy of measuring devices (c) Verification that batching meets accuracy requirements of ASTM C94/C94M (d) Delivery ticket that includes mandatory reporting fields of ASTM C94/C94M (e) Verification of central mixer ability to mix concrete (f) Delivery vehicles are of such condition, verified visually, to ensure ability to mix concrete (g) Availability of functioning revolution counters (h) Defined rated capacity of mixers and verification of accuracy of measuring devices of truck-mounted water tanks The audit should be performed by a licensed engineer or third party.
4.3.2.1	Specify if adjustments to delivered concrete at the project site are not permitted.
4.3.2.2	Specify limits on time to discharge or number of revolutions if they are to be different than specified in ASTM C94/C94M.
<i>Handling, placing, and constructing</i>	
5.1.2.2	Specify the information in 5.1.2.2(a) to 5.1.2.2(m) that is to be submitted.
5.2.1.1	Specify if alternative sources of curing water are permitted. Water may be used if it can be demonstrated to cause no harm to concrete by meeting the requirements of ASTM C1602/C1602M.
5.2.1.2	Where concrete surface is exposed to view and appearance is a factor, specify curing materials that will not stain or discolor concrete. If flooring materials or surface densifiers are to be used, specify compatible curing materials and procedures. Refer to ACI 302.2R.
5.2.1.3	Where concrete surface is exposed to view and appearance is a factor, specify curing sheet materials that will not stain or discolor concrete.
5.2.1.4	Specify alternative absorbent materials for curing. Where concrete surface is exposed to view and appearance is a factor, specify absorbent materials that will not stain or discolor concrete.
5.2.1.6	Specify alternative repair materials.
5.3.2.1(b)	Specify alternative minimum temperature of metallic embedments and contact surfaces before placing concrete. Refer to ACI 306R for additional guidance.
5.3.2.1(c)	If a concrete temperature limit higher or lower than 35°C for concrete members is required or acceptable, based on member being cast, location, relative humidity, and past experience, specify a lower or higher limit for concrete temperature in hot weather. Review ACI 305R for guidance on specifying a higher temperature limit.
5.3.2.4(f)	Specify alternative requirements for placing beams, girders, or slabs monolithically with columns or walls.
5.3.2.5	Specify if consolidating of concrete by methods other than vibration will be permitted.
5.3.2.6	Specify if bond is required at construction joints.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
5.3.3.1	Specify alternative finish or finish as defined in 5.3.3.2, 5.3.3.3, or 5.3.3.4 if the default finish in 5.3.3.1(a) or 5.3.3.1(b) is not desired for specific areas of Work.
5.3.3.3	Specify where rubbed finish is required.
5.3.3.4	Designate those portions of the structure to receive special finish. Specify requirements such as color, texture, limited surface voids, or other features. Specify acceptance criteria. If field mockup is required, specify requirements. Alternatively, review Section 6, Architectural Concrete, and determine if members should be designated as architectural concrete.
5.3.4.1	Specify alternative requirements for concrete flatwork finishers. More stringent qualifications for finishing contractor and finishers may be appropriate if floor serviceability is significant to Owner and for large floor projects with specific requirements for flatness, heavy loading, frequent lift truck traffic, or automated warehouse truck traffic. For such projects, specify that the finishing contractors use qualified flatwork finishers skilled in the specific Work required. Flatwork finishers should be certified on the basis of documented work experience or successful completion of a certification program that includes written and performance examinations as described in ACI CP-10.
5.3.4.2	Specify locations and required finish for unformed surfaces if different than 5.3.4.2(h).
5.3.4.2(b)	If applicable, specify tolerances that are more restrictive. The ACI 117M tolerance for conventional surfaces applies to most general floor construction. For floors requiring tighter tolerances, specify moderately flat, flat, very flat, or super flat floor tolerances from ACI 117M. Refer to ACI 302.1R and ACI 117M and its Commentary for more guidance.
5.3.4.2(c)	Specify alternative tolerances for concrete floors. For floors requiring tolerances other than flat surface, refer to ACI 117M and its Commentary and ACI 302.1R for guidance.
5.3.4.2(e)	For dry-shake finishes, specify metallic or mineral aggregate. Specify if bagged, premixed materials are to be used.
5.3.4.2(f)	Specify if special wear-resistant aggregate or other materials are required.
5.3.4.2(g)	If a nonslip finish using dry-shake materials is desired, specify the abrasive particles and the rate of application.
5.3.4.3	Specify if slab surface measurement is required and specify measurement methods for slab elevation.
5.3.5.1	Specify alternative saw-cut depths for saw cutting requirements for specific applications, such as with the use of early-entry saws.
5.3.6.1	Specify curing methods other than 5.3.6.2, 5.3.6.3, and 5.3.6.4.
5.3.6.3	The methods specified in 5.3.6.5 are for final curing of unformed concrete surfaces and are intended to provide protection against moisture loss beginning immediately after final finishing. Specify if a curing method from 5.3.6.5 that supplies additional water is required. Specify if supplying additional water is required for the entire curing period. Specify locations requiring specific curing methods. Refer to ACI 308R for recommendations on specific curing methods.
5.3.6.4	Specify the duration that forms are to be left in place or alternative curing requirements. For interior nonaggressive exposure conditions, leaving forms in place may be acceptable. Additional curing may be needed after removal of forms when durability requirements mandate. Specify if forms are to be loosened on one or both sides so that curing water can penetrate the gap between the concrete and the face of form, uniformly wetting the concrete surface. For concrete exposed to view, architectural finishes, or if coverings are required, specify compatible curing materials and procedures.
5.3.6.5	Specify if a specific curing method is to be used or if a specific curing method is not permitted.
5.3.6.6(a)	Specify alternative minimum curing period. For concrete surfaces that require enhanced durability, such as high wear resistance, low permeability, or minimal cracking, a longer curing duration could be needed than is required to meet compressive strength criteria alone. If such enhanced properties are required, minimum curing periods of 7 days for high-early-strength concrete, 14 days for concrete incorporating Type I or Type II cements, and 14 to 21 days for concrete incorporating pozzolan as one of the cementitious materials are recommended. Specify a longer curing duration as appropriate to the performance requirements of the concrete. Refer to ACI 308R for additional guidance.
5.3.6.6(b)	Specify the criterion for termination of curing if the three criteria are not applicable.
5.3.6.6(c)	Specify if curing method is not allowed to change for entire duration of curing period.
5.3.6.7(a)	Specify alternative requirements for duration of thermal protection. Refer to ACI 306R.
5.3.6.7(b)	Specify alternative requirements for permitted rate of surface temperature decrease at removal of thermal protection. Requirements for maximum rate of surface temperature change have been adapted from ACI 306.1.
5.3.7.1	Specify alternative requirements for surface repairs than in 5.3.3.
5.3.7.2	Specify locations where tie holes do have to be patched.
5.3.7.3	Specify alternative method to repair surface defects other than tie holes.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
5.3.7.6	Specify where stains, rust, efflorescence, and surface deposits require removal.
<i>Architectural concrete</i>	
6.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for architectural concrete.
6.1.3.2	Specify if submittal in 6.1.3.2(a) to 6.1.3.2(e) is not required.
6.1.3.4	Specify if Contractor is required to submit a disposal plan for wastewater resulting from surface washing operations.
6.1.3.5	Specify if submittal of record of previous experience is required and define experience requirements.
6.1.4.1	Specify which systems or products require manufacturer's on-site technical specialist. Specify if and for how long a technical specialist approved by the specialty item manufacturer should be on site to provide technical assistance.
6.1.4.3	Specify if mockup of architectural concrete is to match an architectural concrete reference sample or a specific location(s) in a designated existing structure.
6.1.4.4(b)	Specify if and where sealers and coatings are to be used on the mockup.
6.2.1.1	Specify if specific cementitious materials are to be used for architectural concrete.
6.2.1.3	Specify if aggregate for architectural concrete must meet additional requirements such as specific color, shape, size, or gradation.
6.2.1.7	Specify alternative formwork facing requirements.
6.2.1.9	Specify location, size, and spacing of required rustications and reveals.
6.2.2.1(d)	Specify location of ties if different than in recessed or emphasized joints.
6.3.9.3	If abrasive blasting is specified, specify degree of abrasive blasting using the description brush, light, medium, or heavy.
<i>Lightweight concrete</i>	
7.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for lightweight concrete.
7.2.2.1	Specify alternative method of determining equilibrium density if other than calculated method in ASTM C567/C567M.
7.3.1.1	Specify density tolerance if other than $\pm 65 \text{ kg/m}^3$. Note that some UL assembly ratings only permit $\pm 50 \text{ kg/m}^3$ of the equilibrium density.
<i>Mass concrete</i>	
8.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for mass concrete in Work.
8.1.3	Specify alternative maximum temperature limit. Maximum temperature is limited to minimize future durability concerns due to delayed ettringite formation (DEF), restraint cracking, and potential reductions in ultimate strength. ACI 201.2R suggests that the potential for DEF in concrete at temperatures between 70 and 85°C may be reduced by using cementitious materials that consist of at least one of the following: <ul style="list-style-type: none"> (a) 25 percent Class F fly ash (b) 35 percent slag cement (c) 35 percent Class C fly ash (d) 5 percent silica fume with either 20 percent Class F fly ash or 30 percent slag cement (e) 10 percent metakaolin Specify if maximum temperature difference limit in concrete after placement can be other than 20°C. The purpose of limiting the temperature difference is to minimize thermal cracking. A higher temperature difference limit may be acceptable depending on concrete properties, placement dimensions, and reinforcement configuration. The temperature difference limit for a specific concrete mixture and placement conditions can be determined through numerical simulations and comparing calculated thermally induced tensile stresses with the developing tensile strength at the surface of the concrete placement. Refer to ACI 207.2R for additional guidance.
8.1.4	Specify if thermal control plan is not required. Specify which of the items (a) through (n) are not required in the thermal control plan. A thermal control plan may address a single placement or a series of similar placements that use same concrete mixture.
8.2.1.1	Specify alternative requirements for cementitious materials to those listed in Section 4 In many mass concrete placements, Class F fly ash often makes up 40 to 50 percent of cementitious materials, or slag cement often makes up 65 to 80 percent of cementitious materials. Ternary mixtures are also sometimes used. Reduced replacement levels are sometimes required as addressed in Section 4. Because concretes at low temperatures or with a low temperature rise generally have longer setting times and lower early strengths, consider implications on form pressures, finishing, formwork removal, cylinder handling, curing duration, and post-tensioning. If slag cement is used as a portion of the cementitious material, at least 65 percent slag cement is often required to effectively reduce the temperature rise of mass concrete.
8.3.1.1(b)	For formed surfaces, specify acceptable methods of preserving moisture, other than maintaining forms in place. Specify if methods in 5.3.6.5(a) through 5.3.6.5(d) are permissible if thermal control plan demonstrates specified maximum temperature and temperature rise limitations will not be exceeded.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
8.3.1.2(a)	Specify alternative requirements for the minimum number of temperature sensors and where they should be located. Additional sensors are recommended for placements over 750 m ³ of concrete. Specify alternative requirements for how frequently temperature sensors should be monitored. Specify frequency of temperature data submittal, if other than on a daily basis.
<i>Post-tensioned concrete</i>	
9.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for post-tensioned concrete.
9.1.3.1(a)	Specify if shop drawings are to be signed and sealed by a licensed design engineer.
9.1.3.1(c)	Specify if submittal of any of the listed test reports is not required.
9.1.3.2	Specify required submittals.
9.1.4.1	Specify alternative qualifications for installers.
9.1.4.2	Specify alternative qualifications for tensioning personnel.
9.1.4.3	Specify alternative qualifications for grouting personnel. Specify alternative qualifications for grouting supervisor. Specify if name and proof of experience of supervisor has to be submitted.
9.1.4.4	Specify alternative certification requirements for inspectors.
9.2.1.2	Specify if test data are to be submitted to demonstrate compliance of encapsulated anchors with watertightness requirements of ACI 423.7. Indicate areas in slabs-on-ground where non-encapsulated tendons are allowed.
9.2.2	Specify alternative grout materials, admixtures, and testing.
9.2.2.2(a)	Specify if field trial tests of grout are required. Refer to PTI M55.1. Specify an alternative time when to conduct field trial tests.
9.2.2.2(b)	Specify if field mockup tests of grouting are required.
9.3.2.3	Specify other parts of tendon that require additional corrosion protection.
9.3.2.5(b)	Specify air pressure and acceptance criteria for pressure testing of ducts, if required.
9.3.3.3	Specify if longer exposure is allowed before applying protection.
9.3.3.5(c)	Specify alternative cover requirements.
9.3.3.5(f)	Specify alternative cover requirements.
9.3.3.6(a)	Specify if watertight joints are not required.
9.3.4.1	Specify alternative tolerances if required.
9.3.4.2(a)	Specify alternative tolerances.
9.3.7.4	Specify grout injection rate(s) that is not between 5 and 15 m of duct per minute.
9.3.8.1	Specify alternative strand removal techniques or limit allowable removal techniques. Specify if permanent grout caps are required.
<i>Shrinkage-compensating concrete for interior slabs</i>	
10.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for shrinkage-compensating concrete used for interior slabs.
10.2.1.1	Specify requirements if expansive cementitious material, other than materials conforming to ASTM C845/C845M, is acceptable or required. Refer to ACI 223R for further information about types of expansive cements and components.
10.2.1.2	Specify if accelerating admixtures or admixtures containing calcium chloride are permitted. Accelerating admixtures, specifically ones that contain calcium chloride, may reduce concrete expansion and should not be permitted for use in shrinkage-compensating concrete unless test results show that they do not affect expansion.
10.2.2.2	If different expansion limits are desired, specify the required limits. The minimum required expansion is based on the projected shrinkage for the particular concrete mixture and the amount of reinforcement used. Consult ACI 223R for guidance.
10.2.2.3	Specify if slump at point of placement is permitted to exceed 150 mm. Expansive cement or expansive component manufacturers' slump requirements may vary and should be considered.
10.2.3.1	If the concrete mixture used in Work will have a delivery time longer than 20 minutes, specify a longer hold time to be used in the trial mixture proportioning procedure. Due to the initial slump loss of shrinkage-compensating concrete, it is necessary to proportion the concrete mixture to consider initial slump loss. Consult ACI 223R for guidance.
10.2.5	Specify alternative compressible isolation-joint filler material if desired.
10.3.1.1	Specify reinforcement cover from top surface in reinforced slabs-on-ground if different from 40 mm.
10.3.2.2	If a different expansion between casting adjoining sections is needed, specify the required expansion. Refer to ACI 223R.
10.3.4	Specify if water curing is to be continued for more than 7 days.
<i>Industrial floor slabs</i>	
11.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for industrial floor slabs.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
11.1.3.2(c)	Specify if curing compound can be used where subsequent finish flooring is to be installed. Specify acceptable curing compound or require curing compound removal by acceptable method before installing floor finish.
11.1.3.3	Specify if any of the submittals in 11.1.3.3(a) through 11.1.3.3(g) are required.
11.1.3.3(a)	Specify if shrinkage test results are to be submitted and specify required length change criteria. Typical length change criteria used are 0.04 to 0.05 percent determined by ASTM C157/C157M at 28 days with the stated curing and drying period. If desired, specify alternative shrinkage test requirements. The length change criteria should change if drying period is changed. Ultimate concrete shrinkage may be estimated from early-age test results in accordance with ACI 209R. According to ACI 360R, the ultimate (long-term) shrinkage for typical concrete mixtures ranges from 0.052 to 0.078 percent. The ultimate shrinkage can be used to establish required joint spacing.
11.2.1.2(a)	Specify aggregate requirements if ASTM C33/C33M requirements are insufficient or if alternative nominal maximum size is desired. More restrictive gradation or limitations of lignite, coal, or other deleterious substances may be required. Refer to ACI 302.1R for further guidance.
11.2.1.2(b)	Specify if alternative aggregate is acceptable for use as a base course material.
11.2.1.3(a)	Specify if admixtures containing chloride ions are acceptable and maximum dosage based on use of steel reinforcement and ultimate shrinkage submittal.
11.2.2	If desired, specify alternative or additional mixture requirements. Specify shrinkage limit, if desired, as a calculated ultimate value or as a measured value after a specified drying period.
11.2.2.2	If desired, specify an alternative maximum concrete temperature as delivered. Refer to ACI 360R and ACI 305R for guidance and consider a lower alternative temperature limit to decrease risk of cracking due to thermal contraction.
11.2.3	Specify if field verification is required.
11.2.4	Specify alternative vapor retarder material and required thickness if less than 0.25 mm.
11.2.5	If required, specify the type(s), amounts, and locations of slab reinforcement.
11.2.6	If required, specify the type(s) and amount(s) of fibers to be included in concrete mixture.
11.2.7	Specify joints to receive load-transfer devices and indicate acceptable types of devices. Acceptable mechanical load-transfer devices may be smooth dowel bars (round or square) or dowel plates (available in a variety of shapes and installation systems). Steel load-transfer devices require a method to prevent bonding with concrete.
11.2.8	Specify alternative joint filler material. For smaller, harder wheels, the minimum Shore A hardness may need to be increased to 90 or greater. Refer to ACI 302.1R and ACI 360R for further guidance.
11.2.9	Specify additional requirements for isolation-joint filler materials, if required.
11.2.11	Specify if liquid surface densifier is required and specify where densifier is to be used.
11.2.12	Specify if metallic shake hardener is required and specify where dry-shake hardener is to be used.
11.3.1	Specify compaction in accordance with ASTM D1557 instead of ASTM D698 if a higher base density is required. Specify if vapor retarder is required and specify where a vapor retarder is required directly beneath slab.
11.3.5	Specify if alternative finish is desired. Refer to ACI 302.1R for guidance. Consider requiring the use of a highway straightedge to improve flatness. In addition, if aggregate shadowing should appear while finishing concrete that has been optimized for shrinkage performance, consider requiring walk-behind power trowels equipped with float shoes as first pass instead of pan floats.
11.3.5.1	If required, specify alternative surface flatness and levelness values.
11.3.6.2	Specify doweled construction joints that do not have to be saw cut or if depth of saw-cut can be other than one-fourth the slab thickness or 50 mm. Joints trafficked by hard-wheeled vehicles should be saw cut.
11.3.6.3	Specify alternative requirements for contraction joints if required.
11.3.7	Specify if a curing period other than 7 days is required.
11.3.8	Specify if a liquid surface densifier is required.
11.3.9	Specify joints not to receive semi-rigid filler. Specify if joint filling should be performed at a time earlier than that recommended by the manufacturer. According to ACI 209R, 90 percent of the shrinkage can be expected during the first 12 to 18 months under sustained drying. As concrete shrinks, joints widen. Joint widening causes filler separation that requires correction.
<i>Tilt-up construction</i>	
12.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for tilt-up construction.
12.1.3	Specify which submittal items are not required.
12.1.3.4(a)	Specify if signed and sealed design calculations are to be submitted.
12.2.1	Specify if special aggregates are required.
12.2.2	Specify alternative bearing shims.
12.2.9	Specify if wythe connectors do not have to maintain acceptable <i>R</i> -value specified in ASHRAE 90.1 if applicable.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
12.3.1	Specify if waste slab is to be used as a casting bed.
12.3.9	Specify the type of smooth panel finish other than SPF-2 based on normal intended service. Finish SPF-2 should be specified for projects where people will be at a distance greater than 3 m from visible panel surfaces. Finish SPF-3 should be specified if people will be at or less than 3 m from visible panel surfaces. Finish SPF-1 should be specified if people will not see panel surface during normal intended service. For SPF-1, define expectations for appearance of panel surfaces. For any SPF classification, specify if panel cracking needs to be repaired. If crack repair is required, specify scope of Work by crack width and repair methods.
12.3.9(c)	Specify additional requirements for panels with finish SPF-1.
12.3.12.1	Specify if aggregate exposure other than 10 mm is required.
12.3.15	Specify if aggregate reveal other than 3 mm is required.
12.3.16.1	Specify if bond breaker needs to be omitted for facing materials such as limestone or sandstone.
12.3.17.3	If needed, provide a more prescriptive description of period that panels must remain braced.
12.3.19.1	Specify if alternative strength testing is required such as beams made in accordance with ASTM C31/C31M and tested in accordance with ASTM C78/C78M.
<i>Precast structural concrete</i>	
13.1.2	Review Sections 1 through 5 and specify requirements to be omitted or made mandatory for precast structural concrete.
13.1.2.1	Specify if members are to be constructed with lightweight concrete.
13.1.3.1(a)	Specify if shop drawings for fabrication are to be submitted.
13.1.3.1(b)	Specify if structural design calculations are to be submitted.
13.1.3.1(c)	Specify if an erection plan is to be submitted.
13.1.3.1(d)	Specify if calculations for modifications to design are to be submitted.
13.1.3.1(e)	Specify if an erector certification certificate is not to be submitted.
13.1.3.1(f)	Specify if plant and personnel certification certificates are not to be submitted.
13.1.3.2	Specify if test reports or material certifications are to be submitted and signed by authorized manufacturer's or supplier's representative.
13.1.4.1	If applicable, specify that erector is not required to be qualified by PCI. Contact PCI for current listing of PCI Qualified Erectors.
13.1.4.2	Specify if different fabricator qualifications are allowed. The National Precast Concrete Association (NPCA) may provide an alternative certification program applicable to some structural precast concrete products, except those which are prestressed. PCI MNL-116 and MNL-117 mandate source testing requirements and a plant Quality Systems Manual. PCI certification also ensures periodic auditing of plants for compliance with requirements in PCI MNL-116 and MNL-117. Specify alternative personnel certification requirements for testing and inspection. Specify if 5 years of work experience is not required.
13.1.4.5	Specify if certified welders are not required.
13.1.4.6	Specify if preconstruction conference is not required.
13.1.4.7	Specify retention period of quality-control records and compliance certificates if longer than 6 years is desired or required by the local building code.
13.2.1.1	Specify members not required to be designed by Contractor.
13.2.3(a)	Specify requirements differing from Section 3 or those specified in this Section. Guidance for evaluating the degree of rusting on strand is given in Sason (1992).
13.2.4.1	Specify requirements differing from Section 4 or those specified in this Section.
13.2.4.2	Specify if lightweight aggregates are required. Review Section 7 and modify requirements to suit project.
13.2.5.1	Specify if a particular bearing pad is required.
13.2.5.2(a)	Specify requirements of reglets.
13.2.6.1	Specify alternative materials, if desired. Add other proprietary grout systems to suit project. Specify locations of each grout if more than one type is required.
13.2.6.2	Specify if nonshrink grout is required. Specify if ferrous grouts can be used. Specify if field installation procedures are required to be submitted.
13.2.6.3	Specify if epoxy grout is required and specify type, grade, and class.
13.2.7.1	Specify if insulated members are required. Specify insulation type, thickness, <i>R</i> -value, and location for each member type used in Work.
13.2.7.5	Specify if a specific type of wythe construction is required.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
13.2.8.2	Specify if a different specified compressive strength is required. Higher-strength mixtures may be available; verify availability with fabricators. Specify if a lower maximum w/cm is required to suit project. Specify air content if different from 4.2.2.6(c).
13.2.8.3	Specify if lightweight concrete is required. Specify if a different specified compressive strength is required. Coordinate with lightweight aggregate supplier and precast concrete fabricator. Specify equilibrium density if other than 1840 kg/m ³ . Specify air content if different from 4.2.2.6(c).
13.2.9.2	Specify different edge or corner treatment if required.
13.2.10.3	Specify if bolted connections are required. Specify the grade and type of bolted connectors.
13.2.10.4	Specify if stainless-steel connection material is required. Specify the grade and type required for connection material.
13.2.11.4(b)	Specify if different lap length is required for welded wire reinforcement.
13.2.11.9	Specify alternative temperature limit. Refer to PCI MNL-117 for guidance.
13.2.11.10	Specify if pretensioning or post-tensioning is required.
13.2.11.12(a)	Specify if insulated members are required.
13.2.12.1	Specify tolerances different than those specified in ACI ITG-7M.
13.2.13.2	Specify if screed finish, float finish, or other finish is desired.
13.2.15	Specify if repair of chipped, spalled, or cracked members is permitted.
13.3.3.4(b)	Specify alternative weld requirements.
13.3.3.6(a)	Specify where troweling of grout joints is required. This should only be specified for specialty roof coverings that require a trowel finish.
13.3.3.7	Specify if cutting or coring of precast members is allowed after installation.
13.3.3.8	Specify if drilled or powder-actuated fasteners may be used.
<i>Precast architectural concrete</i>	
14.1.2	Review Sections 1 through 5 and Section 13 and specify requirements to be omitted or made mandatory for precast architectural concrete.
14.1.3.1	Specify if water absorption test results are to be submitted.
14.1.3.3	Specify if sample panels are not required.
14.1.3.4	Specify if range sample panels are to be submitted.
14.1.3.5	Specify if full-size mockup will be required.
14.1.3.6(a)	Specify if shop drawings for fabrication are to be submitted.
14.1.3.6(b)	Specify if structural design calculations are to be submitted.
14.1.3.6(c)	Specify if calculations for modifications to design are to be submitted.
14.1.3.6(d)	Specify if an erector certification certificate is not to be submitted.
14.1.3.6(e)	Specify if plant and personnel certification certificates are not to be submitted.
14.1.3.7	Specify alternative acceptable fabricator qualifications. The National Precast Concrete Association (NPCA) may provide an alternative certification program applicable to some structural precast concrete products, except those which are prestressed. Specify if alternative PCI category and group is required.
14.1.4.2	Revise size and number of sample panels to suit project.
14.1.4.4	If mockups are required, specify number, location, size, and other details in Contract Documents.
14.1.4.4(d)	Specify if mockups can be used in part of completed Work.
14.1.4.4(e)	Specify if separate mockup is required for testing by others. Specify required testing.
14.2.1.1	Specify members not required to be designed by Contractor.
14.2.2	Specify if precast concrete is to support all or any part of window washing system, and specify design loads and equipment to be used.
14.2.3	Specify if stone veneer precast units are required and specify number and types of anchors.
14.2.4	Specify if form liner is required and add description of the particular form liner selected.
14.2.5	Specify if surface retarder is required.
14.2.6.1	Specify if half-brick, veneer-faced, precast concrete units are required, and specify ASTM standard type and grade, face size, and dimensional tolerances.
14.2.6.2	Specify if different properties are required.
14.2.6.2(k)	Specify face color and texture to match design reference sample, if required. Specify if surface-colored brick, other than flashed or sand-finished, is to be used.

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/ Article	Notes to Specifier
14.2.7	Specify properties if different than noted or as required for particular project. Refer to ANSI A137.1 for commonly available sizes, shapes, physical properties, basis for acceptance, and testing methods.
14.2.8	Specify applications where terra cotta units are required.
14.2.9	Specify alternative mortar for joints.
14.2.10	Specify if brick unit joints are to be filled after precast concrete panel production. Specify if a particular grout type is required. Refer to ANSI A118.6 for additional recommendations.
14.2.10.3	Specify pointing grout color if reference sample panel not used or required.
14.2.11	Specify alternative setting systems for thin and full brick or ceramic tile.
14.2.12	Specify if stone facing is required. Specify location of stone facings and anchorage requirements if different from minimum specified, embedment depth of anchors into concrete, supports, and attachments. Indicate stone veining direction on drawings.
14.2.12.3	Specify if flexible sealant is required in anchor holes to prevent water intrusion into stone and future discoloration at anchor locations.
14.2.12.4	Specify if rigid filler is required in anchor holes to prevent water intrusion into stone and future discoloration at anchor locations.
14.2.12.5	Specify other types of bond breaker if desired such as preformed, compressible, resilient, nonstaining, nonwaxing, closed-cell polyethylene foam pad, nonabsorbent to liquid and gas, 3 mm thick.
14.2.13.1	Specify whether exposed form joints are permitted.
14.2.13.2	Specify if thin or half-brick facings are required.
14.2.14	Specify if stone facing is required. Specify alternative anchorage requirements. Specify joint pattern and joint width. Specify veining direction.
14.2.15	Specify if a particular face technique is required.
14.2.16.3	Specify surface finish if other than a float finish is required for unexposed surfaces.
14.2.16.5	Specify if cleaning is not necessary.
14.3.1.1	Specify different joint width.



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