

**SECTION 03 30 00**  
**CAST-IN-PLACE CONCRETE**

**PART 1      GENERAL**

**1.01      REFERENCES**

A.    The following is a list of standards that may be referenced in this section:

1.    American Concrete Institute (ACI):
  - a.    117, Specification for Tolerances for Concrete Construction and Materials.
  - b.    301, Specifications for Structural Concrete.
  - c.    305.1, Specification for Hot Weather Concreting.
  - d.    306.1, Standard Specification for Cold Weather Concreting.
  - e.    350.1, Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures.
  - f.    CP-1, Technical Workbook for ACI Certification of Concrete Field Testing Technician – Grade 1.
2.    ASTM International (ASTM):
  - a.    C31/C31M, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
  - b.    C33/C33M, Standard Specification for Concrete Aggregates.
  - c.    C39/C39M, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
  - d.    C94/C94M, Standard Specification for Ready-Mixed Concrete.
  - e.    C109/C109M, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens).
  - f.    C143/C143M, Standard Test Method for Slump of Hydraulic-Cement Concrete.
  - g.    C150/C150M, Standard Specification for Portland Cement.
  - h.    C157/C157M, Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete.
  - i.    C227, Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method).
  - j.    C231/C231M, Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
  - k.    C260/C260M, Standard Specification for Air-Entraining Admixtures for Concrete.
  - l.    C494/C494M, Standard Specification for Chemical Admixtures for Concrete.
  - m.    C595/C595M, Standard Specification for Blended Hydraulic Cements.

- n. C618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
  - o. C881/C881M, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
  - p. C979/C979M, Standard Specification for Pigments for Integrally Colored Concrete.
  - q. C989, Standard Specification for Slag Cement for Use in Concrete and Mortars.
  - r. C1012/C1012M, Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.
  - s. C1017/C1017M, Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete.
  - t. C1074, Standard Practice for Estimating Concrete Strength by the Maturity Method.
  - u. C1077, Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation.
  - v. C1218/C1218M, Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.
  - w. C1240, Standard Specification for Silica Fume Used in Cementitious Mixtures.
  - x. C1260, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method).
  - y. C1293, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction.
  - z. C1567, Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method).
  - aa. C1582/C1582M, Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete.
  - bb. C1602/C1602M, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.
  - cc. D4580, Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding.
  - dd. E329, Standard Specification for Agencies Engaged in Construction Inspection, Special Inspection, or Testing Materials Used in Construction.
  - ee. E1155, Standard Test Method for Determining  $F_F$  Floor Flatness and  $F_L$  Floor Levelness Numbers.
3. National Ready Mixed Concrete Association (NRMCA).

## 1.02 DEFINITIONS

- A. Cold Weather: When ambient temperature is below 40 degrees F or is approaching 40 degrees F and falling.
- B. Contractor's Licensed Design Engineer: Individual representing Contractor who is licensed to practice engineering as defined by statutory requirements of professional licensing laws in state or jurisdiction in which Project is to be constructed.
- C. Defective Area: Surface defects that include honeycomb, rock pockets, indentations, and surface voids greater than 3/16-inch deep, surface voids greater than 3/4 inch in diameter, cracks in liquid containment structures and below grade habitable spaces that are 0.005-inch wide and wider, and cracks in other structures that are 0.010-inch wide and wider, spalls, chips, embedded debris, sand streaks, mortar leakage from form joints, deviations in formed surface that exceed specified tolerances and include but are not limited to fins, form pop-outs, and other projections. At exposed concrete, defective areas also include texture irregularities, stains, and other color variations that cannot be removed by cleaning.
- D. Exposed Concrete: Concrete surface that can be seen inside or outside of structure regardless of whether concrete is above water, dry at all times, or can be seen when structure is drained.
- E. Hot Weather: As defined in ACI 305.1.
- F. Hydraulic Structure: Liquid containment structure.
- G. New Concrete: Less than 60 days old.
- H. Slurry Mixture: Mixture of sand, 3/8-inch maximum nominal aggregate size, cement, and water for wall construction joints with waterstop.

## 1.03 SUBMITTALS

- A. Action Submittals:
  - 1. Mix Designs:
    - a. Contain proportions of materials and admixtures to be used on Project, signed by mix designer.
    - b. Documentation of average strength for each proposed mix design in accordance with ACI 301.
    - c. Manufacturer's Certificate of Compliance, in accordance with Section 01 67 00, Product Requirements, for the following:
      - 1) Portland cement.
      - 2) Fly ash.

- 3) Slag cement.
- 4) Silica Fume.
- 5) Aggregates, including specified class designation for coarse aggregate.
- 6) Admixtures.
- 7) Concrete producer has verified compatibility of constituent materials in design mix.
- d. Test Reports:
  - 1) Water-Soluble Chloride-Ion Content in Hardened Concrete: Unless otherwise permitted, in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
  - 2) Shrinkage Test Results: In accordance with ASTM C157/C157M as modified herein.
- e. Aggregates:
  - 1) Coarse Aggregate Gradation: List gradings and percent passing through each sieve.
  - 2) Fine Aggregate Gradation: List gradings and percent passing through each sieve.
  - 3) Percent of fine aggregate weight to total aggregate weight.
  - 4) Deleterious substances in fine aggregate per ASTM C33/C33M, Table 2.
  - 5) Deleterious substances in coarse aggregate per ASTM C33/C33M, Table 4.
  - 6) Test Reports:
    - a) Alkali Aggregate Reactivity: Aggregate shall be classified as nonpotentially reactive in accordance with Article Concrete Mix Design. Include documentation of test results per applicable standards.
- f. Admixtures: Manufacturer's catalog cut sheets and product data sheets for each admixture used in proposed mix designs.
2. Product Data: Specified ancillary materials.
3. Detailed plan for curing and protection of concrete placed and cured in cold weather. Details shall include, but not be limited to, the following:
  - a. Procedures for protecting subgrade from frost and accumulation of ice or snow on reinforcement, other metallic embeds, and forms prior to placement.
  - b. Procedures for measuring and recording temperatures of reinforcement and other embedded items prior to concrete placement.
  - c. Methods for temperature protection during placement.
  - d. Types of covering, insulation, housing, or heating to be provided.
  - e. Curing methods to be used during and following protection period.
  - f. Use of strength accelerating admixtures.
  - g. Methods for verification of in-place strength.

- h. Procedures for measuring and recording concrete temperatures.
- i. Procedures for preventing drying during dry, windy conditions.
- 4. Detailed plan for hot weather placements including curing and protection for concrete placed in ambient temperatures over 80 degrees F. Plan shall include, but not be limited to, the following:
  - a. Procedures for measuring, and recording temperatures of reinforcement and other embedded items prior to concrete placement.
  - b. Use of retarding admixture.
  - c. Methods for controlling temperature of reinforcement and other embedded items and concrete materials before and during placement.
  - d. Types of shading and wind protection to be provided.
  - e. Curing methods, including use of evaporation retardant.
  - f. Procedures for measuring and recording concrete temperatures.
  - g. Procedures for preventing drying during dry, windy conditions.

B. Informational Submittals:

- 1. Preinstallation Conference minutes.
- 2. Manufacturer's application instructions for bonding agent and bond breaker.
- 3. Manufacturer's Certificate of Compliance to specified standards:
  - a. Bonding agent.
  - b. Bond breaker.
- 4. Statement of Qualification:
  - a. Batch Plant: Certification as specified herein.
  - b. Mix designer.
  - c. Installer.
  - d. Testing agency.
- 5. Field test reports.
- 6. Tightness test results.
- 7. Concrete Delivery Tickets:
  - a. For each batch of concrete before unloading at Site.
  - b. In accordance with ASTM C94/C94M, including requirements 14.2.1. through 14.2.10.
  - c. Indicate amount of mixing water withheld and maximum amount that may be permitted to be added at Site.

#### 1.04 QUALITY ASSURANCE

- A. Concrete construction shall conform to requirements of ACI 117 and ACI 301, except as modified herein.

B. Qualifications:

1. Batch Plant: NRMCA Program for Certification of Ready-Mixed Concrete Production Facilities or approved equivalent program.
2. Mix Designer: Person responsible for developing concrete mixture proportions certified as NRMCA Concrete Technologist Level 2 or DOT certified mix designer in jurisdiction of the Work. Requirement may be waived if individual is Contractor's Licensed Design Engineer.
3. Flatwork Finisher: Unless otherwise permitted, at least one person on finishing crew shall be certified as an ACI Flatwork Finisher, or equivalent.
4. Testing Agency: Unless otherwise permitted, an independent agency, acceptable to authorities having jurisdiction, qualified according to ASTM C1077 and ASTM E329 for testing indicated.
  - a. Where field testing is required of Contractor, personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-1 or an equivalent certification program.
  - b. Personnel performing laboratory tests shall be ACI-certified Concrete Strength Testing Technician and Concrete Laboratory Testing Technician - Grade I. Testing Agency laboratory supervisor shall be an ACI-certified Concrete Laboratory Testing Technician - Grade II.

C. Preinstallation Conference:

1. Required Meeting Attendees:
  - a. Contractor, including pumping, placing and finishing, and curing subcontractors.
  - b. Ready-mix producer.
  - c. Admixture representative.
  - d. Testing and sampling personnel.
  - e. Contracting Officer.
2. Schedule and conduct prior to incorporation of respective products into Project. Notify Contracting Officer of location and time.
3. Agenda shall include:
  - a. Admixture types, dosage, performance, and redosing at Site.
  - b. Mix designs, test of mixes, and Submittals.
  - c. Placement methods, techniques, equipment, consolidation, and form pressures.
  - d. Slump and placement time to maintain slump.
  - e. Finish, curing, and water retention.
  - f. Protection procedures for weather conditions.
  - g. Other specified requirements requiring coordination.
4. Conference minutes as specified in Section 01 31 00, Project Management and Coordination.

## **PART 2      PRODUCTS**

### **2.01      MATERIALS**

#### **A.      Cementitious Materials:**

1.    Cement:
  - a.    Portland Cement: Unless otherwise specified, conform to requirements of ASTM C150/C150M.
  - b.    Blended Hydraulic Cement:
    - 1)    Unless otherwise specified, conform to requirements of ASTM C595/C595M.
    - 2)    Portland cement used in blended hydraulic cement, conform to requirements of ASTM C150/C150M.
  - c.    Furnish from one source.
2.    Supplementary Cementitious Materials (SCM):
  - a.    Fly Ash (Pozzolan):
    - 1)    Class F and Class C fly ash in accordance with ASTM C618, except as modified herein:
      - a)    ASTM C618, Table 1, Loss on Ignition: Unless permitted otherwise, maximum 3 percent.
  - b.    Slag Cement: In accordance with ASTM C989, Grade 100 or Grade 120.

#### **B.      Aggregates: Furnish from one source for each aggregate type used in a mix design.**

1.    Normal-Weight Aggregates:
  - a.    In accordance with ASTM C33/C33M, except as modified herein.
    - 1)    Class Designation: 4S unless otherwise specified.
  - b.    Free of materials and aggregate types causing popouts, discoloration, staining, or other defects on surface of concrete.
  - c.    Alkali Silica Reactivity: See Article Concrete Mix Design.
2.    Fine Aggregates:
  - a.    Clean, sharp, natural sand.
  - b.    ASTM C33/C33M.
  - c.    Limit deleterious substances in accordance with ASTM C33/C33M, Table 2 and as follows:
    - 1)    Limit material finer than 75- $\mu$ m (No. 200) sieve to 5 percent mass of total sample.
    - 2)    Limit coal and lignite to 1 percent.

3. Coarse Aggregate:
    - a. Natural gravels, combination of gravels and crushed gravels, crushed stone, or combination of these materials containing no more than 15 percent flat or elongated particles (long dimension more than five times the short dimension).
    - b. Limit deleterious substances in accordance with ASTM C33/C33M, Table 4 for specified class designation.
- C. Admixtures: Unless otherwise permitted, furnish from one manufacturer.
1. Characteristics:
    - a. Compatible with other constituents in mix.
    - b. Contain at most, only trace amount chlorides in solution.
    - c. Furnish type of admixture as recommended by manufacturer for anticipated temperature ranges.
  2. Air-Entraining Admixture: ASTM C260/C260M.
  3. Water-Reducing Admixture: ASTM C494/C494M, Type A or Type D.
  4. Retarding Admixture: ASTM C494/C494M, Type B.
  5. Accelerating Admixture: ASTM C494/C494M, Type C.
  6. High-Range, Water-Reducing Admixture: ASTM C494/C494M, Type F or Type G.
- D. Water and Ice: Mixing water for concrete and water used to make ice shall be potable water, unless alternative sources of water are permitted.
1. Water from alternative sources shall comply with requirements of ASTM C1602/C1602M, and concentration of chemicals in combined mixing water shall be less than:
    - a. Chloride Content: 1,000 ppm.
    - b. Sulfate Content as SO<sub>4</sub>: 3,000 ppm.
    - c. Alkalis as (Na<sub>2</sub>O + 0.658 K<sub>2</sub>O): 600 ppm.
    - d. Total Solids by Mass: Less than 50,000 ppm.

## 2.02 ANCILLARY MATERIALS

- A. Bonding Agent:
1. Manufacturers and Products:
    - a. Sika Chemical Corp., Lyndhurst, NJ; Sikadur 32 Hi-Mod.
    - b. Or equal.
  2. Physical Characteristics: Two-component, moisture insensitive, 100 percent solids epoxy.
  3. Functional Characteristics: None.  
Performance Characteristics: Meets ASTM C881/C881M, Type V.

B. Repair Material:

1. In accordance with requirements of Section 03 01 32, Repair of Vertical and Overhead Concrete Surfaces.
2. In accordance with requirements of Section 03 01 33, Repair of Horizontal Concrete Surfaces.

C. Crack Repair: In accordance with requirements of Section 03 64 23, Epoxy Injection Grouting, and/or Section 03 64 24 Polyurethane Injection Grouting.

2.03 CONCRETE MIX DESIGN

A. General:

1. See Supplement at the end of this section for mix design requirements for each class of concrete used on Project.
2. Prepare design mixtures for each type and strength of concrete, selecting and proportioning ingredients in accordance with requirements of ACI 301, unless otherwise specified.
3. Selection of constituent materials and products in mix design are optional, unless specified otherwise.
4. Unless otherwise permitted, use water-reducing admixture or water-reducing admixture and high-range, water-reducing admixture in pumped concrete, in concrete with a water-cementitious materials ratio below 0.50, and in concrete that is part of a liquid-containment structure.
5. Unless otherwise permitted, use water-reducing admixture and high-range, water-reducing admixture in columns, piers, pilasters, and walls.
6. Use water-reducing admixture or high-range, water-reducing admixture to achieve fresh properties that facilitate handling, placing, and consolidating of concrete, and specified hardened properties.
7. Use water-reducing and retarding admixture when anticipated high temperatures, low humidity, or other adverse placement conditions can adversely affect fresh properties of concrete.
8. Unless otherwise specified, desired fresh properties of concrete shall be determined by Contractor, and coordinated with concrete producer. Fresh properties of concrete shall remain stable to satisfaction of Contractor, for duration of placement and consolidation, and shall remain in conformance with requirements of Contract Documents.
9. Contractor is encouraged to consider using environmentally sustainable concrete mix design technologies such as use of supplementary cementitious materials and aggregate packing.

B. Potential Alkali-aggregate Reactivity of Concrete:

1. Do not use aggregates known to be susceptible to alkali-carbonate reaction (ACR).
2. Aggregates shall have been tested to determine potential alkali-aggregate reactivity in concrete in accordance with ASTM C1260 or ASTM C1567.
  - a. Aggregates that indicate expansion greater than 0.10 percent at 16 days after casting shall not be used unless they have been shown to be nondeleteriously reactive in accordance with ASTM C227 or ASTM C1293, with less than 0.04 percent expansion at 1 year for cement-aggregate combinations or less than 0.04 percent expansion at 2 years for combinations with pozzolan or slag.
  - b. Alkali content of cement used in proposed concrete mixture shall not be greater than alkali content of cement used in test for potential alkali-aggregate reactivity.
  - c. Use low-alkali cement or incorporate pozzolans into concrete mixture as necessary to satisfy testing for potential alkali reactivity.

C. Proportions:

1. Design mix to meet aesthetic, durability, and strength requirements.
2. Where fly ash is included in mix, minimum fly ash content shall be a minimum of 15 percent of weight of total cementitious materials.

D. Slump Range at Site:

1. Prior to submitting mix design, consult with concrete producer and select a target slump value at point of delivery, for each application of each design mix. Unless otherwise permitted, target slump value will then be enforced for duration of Project.
2. Design mixes that include a high-range, water-reducing admixture shall have a minimum slump of 2 inches prior to addition of admixture. Unless otherwise permitted, slump shall be 8 inches maximum at point of delivery, for concrete with a high-range, water-reducing admixture.
3. Slump tolerance shall meet requirements of ACI 117.

E. Combined Aggregate Gradation:

1. Combined Gradation Limits: Fine aggregate shall be in range of 36 percent to 40 percent of total aggregate weight.

## 2.04 CONCRETE MIXING

- A. General: In accordance with ACI 301, except as modified herein.
- B. Truck Mixers:
  - 1. For every truck, test slump of samples taken per ASTM C94/C94M, paragraph 12.5.1.
  - 2. Where specified slump is more than 4 inches, and if slump tests differ by more than 2 inches, discontinue use of truck mixer, unless causing condition is corrected and satisfactory performance is verified by additional slump tests.

## 2.05 SOURCE QUALITY CONTROL

- A. Source Quality Control Inspection: Contracting Officer shall have access to and have right to inspect batch plants, cement mills, and supply facilities of suppliers, manufacturers, and Subcontractors, providing products included in this section.

# **PART 3 EXECUTION**

## 3.01 PLACING CONCRETE

- A. Preparation: Meet requirements ACI 301, except as modified herein.
- B. Inspection: Notify Contracting Officer and Special Inspector at least 1 full working day in advance before starting to place concrete.
- C. Placement into Formwork:
  - 1. Where vapor retarder or barrier is required, coordinate subgrade preparation with requirements in Division 07, Thermal and Moisture Protection of these Specifications.
  - 2. Reinforcement: Secure in position before placing concrete.
  - 3. Place concrete as soon as possible after leaving mixer, without segregation or loss of ingredients, without splashing forms or steel above, and in layers not over 1.5 feet deep, except for slabs which shall be placed full depth. Place and consolidate successive layers prior to initial set of first layer to prevent cold joints.
  - 4. Placement frequency shall be such that lift lines will not be visible in exposed concrete finishes.
  - 5. Use placement devices, for example chutes, pouring spouts, and pumps as required to prevent segregation.
  - 6. Vertical Free Fall Drop to Final Placement:
    - a. Forms 8 Inches or Less Wide: 5 feet.
    - b. Forms Wider than 8 Inches: 8 feet, except as specified.

7. For placements where drops are greater than specified, use placement device such that free fall below placement device conforms to required value.
  - a. Limit free fall to prevent segregation caused by aggregates hitting steel reinforcement.
8. Do not use aluminum conveying devices.
9. Provide sufficient illumination in the interior of forms so concrete deposition is visible, permitting confirmation of consolidation quality.
10. Joints in Footings and Slabs:
  - a. Ensure space beneath plastic waterstop completely fills with concrete.
  - b. During concrete placement, make visual inspection of entire waterstop area.
  - c. Limit concrete placement to elevation of waterstop in first pass, vibrate concrete under waterstop, lift waterstop to confirm full consolidation without voids, and place remaining concrete to full height of slab.
  - d. Apply procedure to full length of waterstop.
11. Trowel and round off top exposed edges of walls with 1/4-inch radius steel edging tool.
12. Cure concrete as specified in Section 03 39 00, Concrete Curing.

D. Conveyor Belts and Chutes:

1. Design and arrange ends of chutes, hopper gates, and other points of concrete discharge throughout conveying, hoisting, and placing system for concrete to pass without becoming segregated.
2. Do not use chutes longer than 50 feet.
3. Minimum Slopes of Chutes: Angled to allow concrete to readily flow without segregation.
4. Conveyor Belts:
  - a. Approved by Contracting Officer.
  - b. Wipe clean with device that does not allow mortar to adhere to belt.
  - c. Cover conveyor belts and chutes.

E. Retempering: Not permitted for concrete where cement has partially hydrated.

F. Pumping of Concrete:

1. Provide standby pump, conveyor system, crane and concrete bucket, or other system onsite during pumping, for adequate redundancy to ensure completion of concrete placement without cold joints in case of primary placing equipment breakdown.

2. Minimum Pump Hose (Conduit) Diameter: 4 inches.
3. Replace pumping equipment and hoses (conduits) that are not functioning properly.

G. Maximum Size of Concrete Placements:

1. Limit size of each placement to allow for strength gain and volume change as a result of shrinkage.
2. Locate expansion, control, and contraction joints where shown on the Drawings.
3. Construction Joints:
  - a. Unless otherwise shown or permitted, locate construction joints as follows:
    - 1) Locate construction joints as shown on the Drawings or where approved in joint location submittal required in Section 03 15 00, Concrete Joints and Accessories.
    - 2) Provide vertical construction joints in walls and slabs at maximum spacing of 40 feet, unless shown or approved otherwise.
    - 3) When vertical expansion, contraction, or control joint spacing does not exceed 60 feet, intermediate construction joints are not required.
    - 4) Uniformly space vertical construction joints within straight sections of walls and slabs, avoiding penetrations.
4. Consider beams, girders, brackets, column capitals, and haunches as part of floor or roof system and place monolithically with floor or roof system.
5. Should placement sequence result in cold joint located below finished water surface, install waterstop in joint.

H. Minimum Time between Adjacent Placements:

1. Construction or Control Joints: 7 days unless otherwise specified.
2. Construction Joint between Top of Footing or Slab, and Column or Wall: As soon as can safely be done without damaging previously cast concrete or interrupting curing thereof, but not less than 24 hours.
3. Expansion or Contraction Joints: 1 day.
4. For columns and walls with a height in excess of 10 feet, wait at least 2 hours before depositing concrete in beams, girders, or slabs supported thereon.
5. For columns and walls 10 feet in height or less, wait at least 1 hour prior to depositing concrete in beams, girders, brackets, column capitals, or slabs supported thereon.

I. Consolidation and Visual Observation:

1. Consolidation Equipment and Methods: ACI 301.
2. Provide at least one standby vibrator in operable condition at Site prior to placing concrete.
3. Provide sufficient windows in forms or limit form height to allow for concrete placement through windows and for visual observation of concrete.
4. Vibrate concrete in vicinity of joints to obtain impervious concrete.

J. Hot Weather:

1. Prepare ingredients, mix, place, cure, and protect in accordance with ACI 301, ACI 305.1, and as follows:
  - a. Maintain concrete temperature below 90 degrees F at time of placement, or furnish test data or other proof that admixtures and mix ingredients do not produce flash set plastic shrinkage, or cracking as a result of heat of hydration. Cool ingredients before mixing to maintain fresh concrete temperatures as specified or less.
  - b. Provide for windbreaks, shading, fog spraying, sprinkling, ice, wet cover, or other means as necessary to maintain concrete at or below specified temperature.
2. Concrete Curing: As specified in Section 03 39 00, Concrete Curing.

K. Cold Weather Placement:

1. Unless otherwise permitted, shall be in accordance with requirements of ACI 306.1 and as follows:
  - a. Cold weather requirements shall apply when ambient temperature is below 40 degrees F or approaching 40 degrees F and falling.
  - b. Do not place concrete over frozen earth or against surfaces with frost or ice present. Frozen earth shall be thawed to acceptance of Contracting Officer.
  - c. Unless otherwise permitted, do not place concrete in contact with surfaces less than 35 degrees F; requirement is applicable to all surfaces including reinforcement and other embedded items.
  - d. Provide supplemental external heat as needed when other means of thermal protection are unable to maintain minimum surface temperature of concrete as specified in ACI 306.1.
  - e. Maintain minimum surface temperature of concrete as specified in ACI 306.1 for no less than 3 days during cold weather conditions.

- f. Cure concrete as specified in Section 03 39 00, Concrete Curing.
  - 1) Protect concrete from freezing until end of curing period and until concrete has attained a compressive strength of 3,500 psi or design compressive strength if less than 3,500 psi.
- 2. Provide maximum and minimum temperature sensors placed on concrete surfaces spaced throughout Work to allow monitoring of concrete surface temperatures representative of Work. Unless otherwise permitted, record surface temperature of concrete at least once every 12 hours during specified curing period.
- 3. External Heating Units: Do not exhaust heater flue gases directly into enclosed area as it causes concrete carbonation as a result of concentrated carbon dioxide.
- 4. Maintain curing conditions as specified in Section 03 39 00, Concrete Curing.

### 3.02 CONCRETE BONDING

#### A. Construction Joints in New Concrete Members:

- 1. Prepare surface of construction joint as specified in Section 03 15 00, Concrete Joints and Accessories.
- 2. Horizontal Construction Joints Containing Waterstop in New Concrete Walls:
  - a. Unless otherwise permitted, place slurry mixture 4-inch maximum thickness, 2-inch minimum thickness in horizontal construction joints containing waterstops.
  - b. Use positive measuring device such as bucket or other device that will contain only enough slurry mixture for depositing in visually measurable area of wall to ensure that portion of form receives appropriate amount of slurry mixture to satisfy placement thickness requirements.
  - c. Do not deposit slurry mixture from pump hoses or large concrete buckets, unless specified placement thickness can be maintained and verified through inspection windows close to joint, or by other means.
  - d. Limit concrete placed immediately on top of slurry mixture to 12 inches thick. Thoroughly vibrate to mix concrete and slurry mixture together.

#### B. Construction Joints at Existing Concrete:

- 1. Thoroughly clean and mechanically roughen existing concrete surfaces to roughness profile of 1/4 inch.
- 2. Saturate surface with water for 24 hours prior to placing new concrete.

### 3.03 REPAIRING CONCRETE

#### A. General:

1. Inject cracks that leak with crack repair epoxy as specified in Section 03 64 23, Epoxy Repair Injection Grouting.
2. Repair defective areas of concrete.
3. Repair horizontal concrete surfaces in accordance with Section 03 01 33, Repair of Horizontal Concrete Surfaces.
4. Repair vertical and overhead concrete surfaces in accordance with Section 03 01 32, Repair of Vertical and Overhead Concrete Surfaces.
5. Develop repair techniques with material manufacturer on surface that will not be visible in final construction or on mockup panels prior to starting actual repair work and show how finish color will blend with adjacent surfaces. Obtain approval from Contracting Officer.
6. Obtain quantities of repair material and manufacturer's detailed instructions for use to provide repair with finish to match adjacent surface or apply sufficient repair material adjacent to repair to blend finish appearance.
7. Repair of concrete shall provide structurally sound surface finish, uniform in appearance or upgrade finish by other means until acceptable to Contracting Officer.

#### B. Tie Holes:

1. Unless otherwise specified, fill with specified repair material.
  - a. Prepare substrate and mix, place, and cure repair material per manufacturer's written recommendations.

#### C. Alternate Form Ties, Through-Bolts:

1. Mechanically roughen entire interior surface of through hole.
2. Apply bonding agent to roughened surface and drive elastic vinyl plug to half depth.
3. Dry pack entire hole from both sides of plug with nonshrink grout, as specified in Section 03 62 00, Grouting.
4. Use only enough water to dry pack grout.
5. Dry pack while bonding agent is still tacky.
6. If bonding agent has dried, remove bonding agent by mechanical means and reapply new coat of bonding agent.
7. Compact grout using steel hammer and steel tool to drive grout to high density.
8. Cure grout with water.

D. Exposed Metal Objects:

1. Remove metal objects not intended to be exposed in as-built condition of structure including wire, nails, and bolts, by chipping back concrete to depth of 1 inch and then cutting or removing metal object.
2. Repair area of chipped-out concrete as specified for defective areas.

E. Blockouts at Pipes or Other Penetrations: Where shown install in accordance with requirements of the Drawings.

3.04 CONCRETE WALL FINISHES

A. Type W-1 (Ordinary Wall Finish):

1. Patch tie holes.
2. Knock off projections.
3. Repair defective areas.
4. Inject cracks in accordance with requirements of Section 03 64 23, Epoxy Repair Injection Grouting.

B. Type W-2 (Smooth Wall Finish):

1. Patch tie holes.
2. Grind off fins and other projections.
3. Repair defective areas to provide smooth uniform appearance.
4. Inject cracks in accordance with requirements of Section 03 64 23, Epoxy Repair Injection Grouting.

C. Type W-4 (Finish for Cementitious Coatings): Not used.

D. Type W-5 (Finish for Painting):

1. In accordance with requirements for Type W-2 except as follows:
  - a. Leave surface ready for painting as specified in Section 09 90 00, Painting and Coating.

3.05 CONCRETE SLAB FINISHES

A. General:

1. Use manual screeds, vibrating screeds, or roller compacting screeds to place concrete level and smooth.
2. Do not use "jitterbugs" or other special tools designed for purpose of forcing coarse aggregate away from surface and allowing layer of mortar, which will be weak and cause surface cracks or delamination, to accumulate.
3. Finish slab in accordance with specified slab finish.

4. Do not dust surfaces with dry materials nor add water to surfaces.
5. Cure concrete as specified in Section 03 39 00, Concrete Curing.

B. Type S-1 (Steel Troweled Finish):

1. Finish by screeding and floating with straightedges to bring surfaces to required finish elevation.
2. Wood float to true, even plane with no coarse aggregate visible.
3. Use sufficient pressure on wood floats to bring moisture to surface.
4. After surface moisture has disappeared, hand steel trowel concrete to produce smooth, smooth dense surface, free from trowel marks.
5. Provide light steel-troweled finish (two trowelings) at air-entrained slabs. Provide hard steel-troweled finish (ringing sound from the trowel) for nonair-entrained slabs.
6. Do not use dry cement or additional water during troweling, nor will excessive troweling be permitted.
7. Power Finishing:
  - a. Approved power machine may be used in lieu of or in addition to hand finishing in accordance with directions of machine manufacturer.
  - b. Do not use power machine when concrete has not attained necessary set to allow finishing without introducing high and low spots in slab.
  - c. Do first steel troweling for slab S-1 finish by hand.

C. Type S-2 (Wood Float Finish):

1. Finish slab to receive fill and mortar setting bed by screeding with straightedges to bring surface to required finish plane.
2. Wood float finish to compact and seal surface.
3. Remove laitance and leave surface clean.
4. Coordinate with other finish procedures.

D. Type S-3 (Underside Elevated Slab Finish):

1. When forming is removed, grind off projections on underside of slab and repair defective areas, including small shallow air pockets where schedule of concrete finishes requires:
  - a. Prepare surfaces to match Type W-2 (Smooth Wall Finish) unless noted otherwise.
  - b. Prepare surfaces to match Type W-5 (Finish for Painting). Where indicated on the Drawings.

E. Type S-5 (Broomed Finish):

1. Finish as specified for Type S-1 floor finish, except use only a light-steel troweled finish, and then finish surface by drawing fine-hair broom lightly across surface.
2. Broom in same direction and parallel to expansion joints, or, in case of inclined slabs, perpendicular to slope, except for round roof slab, broom surface in radial direction.

F. Type S-6 (Sidewalk Finish):

1. Slope walks down 1/4 inch per foot away from structures, unless otherwise shown.
2. Strike off surface by means of strike board and float with wood or cork float to true plane, then flat steel trowel before brooming.
3. Broom surface at right angles to direction of traffic or as shown.
4. Lay out sidewalk surfaces in blocks, as shown or as directed by Contracting Officer, with grooving tool.

G. Concrete Curbs:

1. Float top surface of curb smooth, and finish all discontinuous edges with steel edger.
2. After concrete has taken its initial set, remove front form and give exposed vertical surface an ordinary wall finish, Type W-1.

3.06 CONCRETE SLAB TOLERANCES

A. Slab Flatness and Levelness:

1. Floor finish tolerances shall meet requirements specified herein, and as measured in accordance with ASTM E1155.
2. Levelness tolerance, FL, shall not apply to slabs placed on unshored form surfaces or shored form surfaces after removal of shores.
3. Levelness tolerances, FL, shall not apply to cambered or inclined surfaces, and shall be measured within 72 hours after slab concrete placement.

| Slab Type S-A             |               |                         |               |
|---------------------------|---------------|-------------------------|---------------|
| Minimum Overall F Numbers |               | Minimum Local F Numbers |               |
| Flatness, FF              | Levelness, FL | Flatness, FF            | Levelness, FL |
| 20                        | 15            | 15                      | 10            |

| Slab Type S-B             |               |                         |               |
|---------------------------|---------------|-------------------------|---------------|
| Minimum Overall F Numbers |               | Minimum Local F Numbers |               |
| Flatness, FF              | Levelness, FL | Flatness, FF            | Levelness, FL |
| 30                        | 20            | 15                      | 10            |

| Slab Type S-C             |               |                         |               |
|---------------------------|---------------|-------------------------|---------------|
| Minimum Overall F Numbers |               | Minimum Local F Numbers |               |
| Flatness, FF              | Levelness, FL | Flatness, FF            | Levelness, FL |
| 50                        | 30            | 25                      | 15            |

B. Slab Elevation and Thickness:

1. Finish Slab Elevation: Slope slabs to floor drains and gutter. Slabs shall adequately drain regardless of tolerances.
2. Thickness: Maximum 1/4 inch minus or 1/2 inch plus from thickness shown. Where thickness tolerance will not affect slope, drainage, or slab elevation, thickness tolerance may exceed 1/2 inch plus.

3.07 BEAM AND COLUMN FINISHES

- A. Type B-1: Match wall Type W-1.
- B. Type B-2: Match wall Type W-2.
- C. Type B-3:
  1. Repair rock pockets.
  2. Fill air voids.
  3. Match wall Type W-3 W-4 W-5.
- D. Type C-1: Match wall Type W-1.
- E. Type C-2: Match wall Type W-2.
- F. Type C-3:
  1. Fill air pockets.
  2. Match wall Type W-3 W-4 W-5.

### 3.08 BACKFILL AGAINST STRUCTURES

- A. Do not backfill against walls until concrete has obtained specified 28-day compressive strength.
- B. Refer to General Structural Notes on the Drawings for additional requirements, including elevated slab and diaphragm completion prior to backfill.
- C. Unless otherwise permitted, place backfill simultaneously on both sides of structure, where such fill is required, to prevent differential pressures.

### 3.09 FIELD QUALITY CONTROL

- A. General:
  - 1. Provide adequate facilities for safe storage and proper curing of concrete test specimens onsite for first 24 hours, and for additional time as may be required before transporting to test lab.
  - 2. Unless otherwise specified, sample concrete for testing for making test specimens, from point of delivery.
  - 3. When concrete is pumped, sample and test air content at point of delivery and at point of placement.
    - a. For Each Concrete Mixture: Provided results of air content tests for first load of the day are within specified limits, testing need only be performed at point of delivery for subsequent loads of that concrete mixture except that testing should be performed at point of placement every 4 hours.
  - 4. Evaluation will be in accordance with ACI 301 and Specifications.
  - 5. Test specimens shall be made, cured, and tested in accordance with ASTM C31/C31M and ASTM C39/C39M.
  - 6. Frequency of testing may be changed at discretion of Contracting Officer.
  - 7. Pumped Concrete: Take concrete samples for slump, ASTM C143/C143M, and test specimens, ASTM C31/C31M and ASTM C39/C39M.
  - 8. If measured air content at delivery is greater than specified limit, check test of air content will be performed immediately on a new sample from delivery unit. If check test fails, concrete has failed to meet requirements of Contract Documents. If measured air content is less than lower specified limit, adjustments will be permitted in accordance with ASTM C94/C94M, unless otherwise specified. If check test of adjusted mixture fails, concrete has failed to meet requirements of Contract Documents. Concrete that has failed to meet requirements of Contract Documents shall be rejected.

B. Concrete Strength Test:

1. Unless otherwise specified, one specimen at age of 7 days for information, and two 6-inch diameter or when permitted three 4-inch diameter test specimens at age of 28 days for acceptance.
2. Concrete with specified 56-day strength, test one specimen at age of 7 days for information, two 6-inch diameter or when permitted three 4-inch diameter test specimens at age of 28 days for acceptance, and two 6-inch diameter or when permitted three 4-inch diameter test specimens at age of 56 days for acceptance. Should results of 28-day tests meet specified requirement for 56-day strength, 56-day tests will not be required.
3. If result of 7-day concrete strength test is less than 50 percent of specified 28-day strength, extend period of moist curing specified in Section 03 39 00, Concrete Curing, by 7 additional days.
4. Provide a minimum of one spare test specimen per sample. Test spare cylinder as directed by Contracting Officer.

C. High-Range, Water-Reducer (Superplasticizer) Admixture Segregation Test:  
Test each truck prior to use on Project.

1. Segregation Test Objective: Concrete with 4-inch to 8-inch slump shall stay together when slumped. Segregation is assumed to cause mortar to flow out of mix even though aggregate may stay piled enough to meet slump test.
2. Test Procedure: Make slump test and check for excessive slump and observe to see if mortar or moisture flows from slumped concrete.
3. Reject concrete if mortar or moisture separates and flows out of mix.

D. Cold Weather Placement Tests:

1. During cold weather concreting, cast cylinders for field curing as follows. Use method that will produce greater number of specimens:
  - a. Six extra test cylinders from last 100 cubic yards of concrete.
  - b. Minimum three specimens for each 2 hours of placing time or for each 100 cubic yards.
2. These specimens shall be in addition to those cast for lab testing.
3. Protect test cylinders from weather until they can be placed under same protection provided for concrete of structure that they represent.
4. Keep field test cylinders in same protective environment as parts of structure they represent to determine if specified strength has been obtained.
5. Test cylinders in accordance with applicable sections of ASTM C31/C31M and ASTM C39/C39M.
6. Use test results to determine specified strength gain prior to falsework removal or for prestressing.

E. Tolerances:

1. Walls: Measure and inspect walls for compliance with tolerances specified in Section 03 10 00, Concrete Forming and Accessories.
2. Slab Finish Tolerances and Slope Tolerances:
  - a. Slab Flatness and Levelness: Make measurements within 72 hours of concrete placement.
    - 1) Flatness measurements are not applicable to unshored form surfaces or shored form surfaces after removal of shores.
    - 2) Levelness measurements are not applicable to cambered or sloped surfaces.
  - b. Slab flatness and levelness shall be determined in accordance with ASTM E1155.

F. Liquid Tightness Tests:

1. Purpose: To determine integrity and liquid-tightness of finished exterior and interior concrete surfaces of liquid containment structures.
2. Test the following structures for liquid-tightness:
  - a. Facility 20 – Headworks.
  - b. Facility 25 – Process Tanks.
  - c. Facility 80 – Digester Facility.
3. Water for initial tightness test will be provided by Contracting Officer.
4. Water source shall be coordinated with Contracting Officer.
  - a. Provide means to transport water to structure to be tested.
  - b. If additional tightness tests are required because of failure to meet criteria, provide water for subsequent tests.
5. After testing has been completed, dispose of test water in a manner approved by Contracting Officer.
6. Liquid-Tightness Test Requirement:
  - a. Perform tightness tests in accordance with ACI 350.1 and as specified herein.
  - b. Do not place backfill or install brick facing, grout topping slab, coatings, or other work that will cover concrete surfaces until tightness testing has been completed and approved.
  - c. Measure evaporation, precipitation, and temperature as specified.
7. Measure water surface at two points 180 degrees apart when possible where attachments, such as ladders exist, at 24-hour intervals.
8. Acceptance Criteria:
  - a. Volume loss shall not exceed 0.050 percent of contained liquid volume per 24-hour period, adjusted for evaporation, precipitation, and temperature.
  - b. Acceptance that structure has passed tightness test shall be based on total volume loss at end of specified test period.

9. Repairs When Test Fails:
  - a. Dewater structure; fill leaking cracks with crack repair epoxy as specified in Section 03 64 23, Epoxy Injection Grouting or Section 03 64 24, Polyurethane Injection Grouting. Coordinate with Contracting Officer regarding with section applies based on crack size and location.
  - b. Patch areas of damp spots previously recorded, and repeat water leakage test in its entirety until structure successfully passes test.

### 3.10 MANUFACTURER'S SERVICES

- A. Provide representative at Site in accordance with Section 01 43 33, Manufacturers' Field Services, for installation assistance, inspection, and certification of proper installation for concrete ingredients, mix design, mixing, and placement.
  1. Concrete Producer Representative:
    - a. Observe how concrete mixes are performing.
    - b. Be present during first placement of each type of concrete mix.
    - c. Assist with concrete mix design, performance, placement, weather problems, and problems as may occur with concrete mix throughout Project, including instructions for redosing.
    - d. Establish control limits on concrete mix designs.
    - e. Provide equipment for control of concrete redosing for air entrainment or high-range, water-reducing admixture, superplasticizers, at Site to maintain proper slump and air content if needed.
  2. Admixture Manufacturer's Representative: Available for consultations as required to ensure proper installation and performance of specified products.
  3. Bonding Agent Manufacturer's Representative: Available for consultations as required to ensure proper installation and performance of specified products.

### 3.11 PROTECTION OF INSTALLED WORK

- A. After curing as specified in Section 03 39 00, Concrete Curing, and after applying final floor finish, cover slabs with plywood or particle board or plastic sheeting or other material to keep floor clean and protect it from material and damage as a result of other construction work.
- B. Repair areas damaged by construction, using specified repair materials and approved repair methods.

### 3.12 SCHEDULE OF CONCRETE FINISHES

A. Form Tolerances: As specified in Section 03 10 00, Concrete Forming and Accessories.

B. Provide concrete finishes as scheduled:

| Area                                                                 | Type of Finish | Required Form Tolerances |
|----------------------------------------------------------------------|----------------|--------------------------|
| <b>Exterior Wall Surfaces</b>                                        |                |                          |
| Abovegrade/exposed (above point 6" below finish grade)               | W-2            | W-B                      |
| Backfilled/waterproofed (below point 6" below finish grade)          | W-1            | W-A                      |
| Backfilled/not waterproofed (below point 6" below final grade)       | W-1            | W-A                      |
| <b>Interior Wall Surfaces</b>                                        |                |                          |
| Open top water-holding tanks and basins/not painted or coated        | W-2            | W-A                      |
| Covered water-holding tanks and basins/not painted or coated         | W-1            | W-A                      |
| Water-holding tanks, channels, and basins/painted or coated          | W-5            | W-A                      |
| Buildings, pipe galleries, and other dry areas/not painted or coated | W-2            | W-A                      |
| Buildings, pipe galleries, and other dry areas/painted or coated     | W-5            | W-A                      |
| <b>Exterior Slabs</b>                                                |                |                          |
| Roof slab/exposed                                                    | S-5            | S-B                      |
| Roof slab/covered with roofing material                              | S-1            | S-A                      |
| Water-holding tanks and basins/top of wall                           | S-5            | S-B                      |
| Top of footing                                                       | S-2            | S-A                      |
| Other water-holding tanks and basins                                 | S-1            | S-A                      |
| Stairs and landings                                                  | S-5            | S-B                      |

| <b>Area</b>                                    | <b>Type of Finish</b> | <b>Required Form Tolerances</b> |
|------------------------------------------------|-----------------------|---------------------------------|
| Sidewalks                                      | S-6                   | S-B                             |
| Other exterior slabs                           | S-5                   | S-A                             |
| <b>Interior Slabs</b>                          |                       |                                 |
| Buildings, pipe galleries, and other dry areas | S-1                   | S-B                             |
| Slabs to receive mortar setting bed for tile   | S-2                   | S-A                             |
| Slabs to receive resilient flooring or carpet  | S-1                   | S-A                             |
| Hydraulic channels                             | S-1                   | S-A                             |
| Underside of elevated slabs                    | S-3                   | S-A                             |
| <b>Beams and Columns</b>                       |                       |                                 |
| Beams/coated                                   | B-3                   | B-A                             |
| Beams/not coated                               | B-2                   | B-A                             |
| Columns/coated                                 | C-3                   | C-A                             |
| Columns/not coated                             | C-2                   | C-A                             |

### 3.13 SUPPLEMENTS

A. Requirements of concrete mix designs following “End of Section,” are a part of this specification and supplement requirements of Part 1 through Part 3 of this section:

1. Concrete Mix Design, Class A (5000F3S1P2C2).
2. Concrete Mix Design, Class B (4500F2S1P1C1).
3. Concrete Mix Design, Class C (SM00F2S1P2C1).
4. Concrete Mix Design, Class D (4500F1S1P0C1).
5. Concrete Mix Design, Class E (CF00F1S1P0C1).
6. Concrete Mix Design, Class F (4500F3S1P1C2).

**END OF SECTION**

## CONCRETE MIX DESIGN, CLASS A (5000F3S1P2C2)

- A. Mix Locations: All water-holding (hydraulic) structures.
- B. Exposure Categories and Classifications: F3S1P2C2.
- C. Mix Properties:
  - 1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.40.
  - 2. Minimum concrete compressive strength ( $f'_c$ ) shall be 4,000 psi at 28 days and 5,000 psi at 56 days.
  - 3. Designed to conform to shrinkage limits.
  - 4. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
    - a. Slabs to receive hard-troweled finish.
    - b. Slabs to receive dry shake floor hardener.
    - c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
  - 5. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

| Nominal Maximum Aggregate Size<br>in.‡ | Air Content<br>(%)* |
|----------------------------------------|---------------------|
| 3/8                                    | 7.5                 |
| 1/2                                    | 7.0                 |
| 3/4                                    | 6.0                 |
| 1                                      | 6.0                 |
| 1-1/2                                  | 5.5                 |
| 2§                                     | 5.0                 |
| 3§                                     | 4.5                 |

‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.

\*Tolerance of air content is  $\pm 1\frac{1}{2}$  percent.

§Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.

6. Limit supplementary cementitious materials measured as a percent of weight of total cementitious materials in mix design, as follows:
  - a. Fly Ash and other Pozzolans: 25 percent.
  - b. Slag Cement: 50 percent.
  - c. Combined Fly Ash and other Pozzolans and Slag Cement: 50 percent, with fly ash and other pozzolans not exceeding 25 percent.
  - d. Total cementitious materials include ASTM C150/C150M and ASTM C595/C595M cement.
    - 1) Fly ash and other pozzolans in Type IP, blended cement, ASTM C595/C595M.
    - 2) Slag used in the manufacture of an IS blended cement, ASTM C595/C595M.
    - 3) Silica fume, ASTM C1240, present in blended cement.
7. Provide cementitious materials in accordance with one of the following:
  - a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
  - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
    - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
    - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
  - c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
    - 1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
8. Unless otherwise permitted, minimum cementitious materials content in mix design shall be as follows:
  - a. 515 pounds per cubic yard for concrete with 1-1/2-inch nominal maximum size aggregate.
  - b. 535 pounds per cubic yard for 1-inch nominal maximum size aggregate.
  - c. 560 pounds per cubic yard for 3/4-inch nominal maximum size aggregate.
  - d. 580 pounds per cubic yard for 1/2-inch nominal maximum size aggregate.
  - e. 600 pounds per cubic yard for 3/8-inch nominal maximum size aggregate.
  - f. Unless otherwise permitted, limit cementitious materials content to 100 pounds per cubic yard greater than specified minimum cementitious materials content in mix design.

9. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
    - a. Limits are stated in terms of chloride ions in percent by weight of cement.
    - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
- D. Refer to Part 1 through Part 3 of this section for additional requirements.



## CONCRETE MIX DESIGN, CLASS B (4500F2S1P1C1)

- A. Mix Locations: Non-water-holding structures and buildings.
- B. Exposure Categories and Classifications: F2S1P1C1.
- C. Mix Properties:
  - 1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
  - 2. Minimum concrete compressive strength ( $f'_c$ ) shall be 4,000 psi at 28 days and 4,500 psi at 56 days.
    - a. Designed to conform to shrinkage limits.
    - b. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
      - 1) Slabs to receive a hard-troweled finish.
      - 2) Slabs to receive a dry shake floor hardener.
      - 3) Slabs to receive a topping placed monolithically as a two-course floor on top of plastic concrete.
    - c. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

| Nominal Maximum Aggregate Size<br>in. $\frac{1}{4}$ | Air Content<br>(%)* |
|-----------------------------------------------------|---------------------|
| 3/8                                                 | 7.5                 |
| 1/2                                                 | 7.0                 |
| 3/4                                                 | 6.0                 |
| 1                                                   | 6.0                 |
| 1-1/2                                               | 5.5                 |

| Nominal Maximum Aggregate Size<br>in. ‡                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Air Content<br>(%)* |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 2§                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 5.0                 |
| 3§                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4.5                 |
| ‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.<br>*Tolerance of air content is $\pm 1\frac{1}{2}$ percent.<br>§Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on sieved fraction passing 1-1/2-inch sieve in accordance with ASTM C231/C231M. |                     |

3. Provide cementitious materials in accordance with one of the following:
  - a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
  - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
    - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
    - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    - 3) ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
4. Limit water-soluble, chloride-ion content in hardened concrete to 0.30 percent, unless otherwise specified.
  - a. Limits are stated in terms of chloride ions in percent by weight of cement.
  - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to Part 1 through Part 3 of this section for additional requirements.

## CONCRETE MIX DESIGN, CLASS C (SM00F2S1P2C1)

- A. Mix Locations: Slurry mixture at horizontal construction joints with waterstop in wall.
- B. Exposure Categories and Classifications: F2S1P2C1.
- C. Mix Properties:
  - 1. Limit water to cementitious materials ratio (W/C<sub>m</sub>) in mix design to maximum value of 0.42.
  - 2. Minimum concrete compressive strength (f'<sub>c</sub>) shall be same as concrete mix for wall.
  - 3. Maximum Nominal Aggregate: 3/8 inch.
  - 4. Unless otherwise specified, provide 7.5 percent air content.
    - a. See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.
    - b. Tolerance of air content is plus or minus 1.5 percent.
  - 5. Provide cementitious materials in accordance with one of the following:
    - a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
    - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
      - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    - c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
      - 1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
  - 6. Unless otherwise permitted, minimum cementitious materials content in mix design shall be 600 pounds per cubic yard for 3/8-inch nominal maximum size aggregate.

7. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
    - a. Limits are stated in terms of chloride ions in percent by weight of cement.
    - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
- D. Refer to Part 1 through Part 3 of this section for additional requirements.

## CONCRETE MIX DESIGN, CLASS D (4500F1S1P0C1)

### A. Mix Locations:

1. Electrical duct banks.
2. Pipe encasements that are not cast monolithically with concrete base mats or slabs.
3. Where specified in Contract Documents.

### B. Exposure Categories and Classifications: F1S1P0C1.

### C. Mix Properties:

1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
2. Minimum concrete compressive strength ( $f'_c$ ) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
3. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
  - a. Slabs to receive hard-troweled finish.
  - b. Slabs to receive dry shake floor hardener.
  - c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
4. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

| Nominal Maximum Aggregate<br>Size<br>in. $\ddagger$ | Air Content<br>(%)* |
|-----------------------------------------------------|---------------------|
| 3/8                                                 | 6.0                 |
| 1/2                                                 | 5.5                 |
| 3/4                                                 | 5.0                 |
| 1                                                   | 4.5                 |
| 1-1/2                                               | 4.5                 |

| Nominal Maximum Aggregate<br>Size<br>in. ‡                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Air Content<br>(%)* |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 2§                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4.0                 |
| 3§                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3.5                 |
| <p>‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.</p> <p>*Tolerance of air content is <math>\pm 1\frac{1}{2}</math> percent.</p> <p>§Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.</p> |                     |

5. Provide cementitious materials in accordance with one of the following:
  - a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
  - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
    - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
    - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    - 3) ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
      - a) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
6. Limit water-soluble, chloride-ion content in hardened concrete to 0.30 percent, unless otherwise specified.
  - a. Limits are stated in terms of chloride ions in percent by weight of cement.
  - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to Part 1 through Part 3 of this section for additional requirements.

## CONCRETE MIX DESIGN, CLASS E (CF00F1S1P0C1)

- A. Mix Locations: Where Concete Fill is specified in the Contract Documents.
- B. Exposure Categories and Classifications: F1S1P0C1.
- C. Mix Properties:
  - 1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.45.
  - 2. Minimum concrete compressive strength (f'c) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
  - 3. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
    - a. Slabs to receive hard-troweled finish.
    - b. Slabs to receive dry shake floor hardener.
    - c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
  - 4. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

| Nominal Maximum Aggregate Size<br>in. ‡ | Air Content<br>(%)* |
|-----------------------------------------|---------------------|
| 3/8                                     | 6.0                 |
| 1/2                                     | 5.5                 |
| 3/4                                     | 5.0                 |
| 1                                       | 4.5                 |
| 1-1/2                                   | 4.5                 |
| 2§                                      | 4.0                 |
| 3§                                      | 3.5                 |

‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.

\*Tolerance of air content is  $\pm 1\frac{1}{2}$  percent.

§Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.

5. Provide cementitious materials in accordance with one of the following:
    - a. ASTM C150/C150M Type II; inclusion of supplementary cementitious materials in design mix is optional.
    - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
      - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
      - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
    - c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
      - 1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
  6. Limit water-soluble, chloride-ion content in hardened concrete to 0.10 percent, unless otherwise specified.
    - a. Limits are stated in terms of chloride ions in percent by weight of cement.
    - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.
  7. Fiber Reinforcement:
    - a. Where required, provide polypropylene micro-fibers in design mix in accordance with Section 03 24 00, Fibrous Reinforcing.
    - b. Add fiber-reinforcement to mix in concrete plant.
- D. Refer to Part 1 through Part 3 of this section for additional requirements.

## CONCRETE MIX DESIGN, CLASS F (4500F3S1P1C2)

- A. Mix Locations: Concrete curbs and sidewalks.
- B. Exposure Categories and Classifications: F3S1P1C2.
- C. Mix Properties:
  - 1. Limit water to cementitious materials ratio (W/Cm) in mix design to maximum value of 0.42.
  - 2. Minimum concrete compressive strength ( $f'_c$ ) shall be 3,500 psi at 28 days and 4,500 psi at 56 days.
  - 3. Air-entraining admixtures are prohibited in concrete mixtures and total air content shall not be greater than 3 percent, for the following:
    - a. Slabs to receive hard-troweled finish.
    - b. Slabs to receive dry shake floor hardener.
    - c. Slabs to receive topping placed monolithically as two-course floor on top of plastic concrete.
  - 4. Unless otherwise specified, provide air content based on nominal maximum size of aggregate as follows:

| Nominal Maximum Aggregate Size<br>in. ‡ | Air Content<br>(%)* |
|-----------------------------------------|---------------------|
| 3/8                                     | 7.5                 |
| 1/2                                     | 7.0                 |
| 3/4                                     | 6.0                 |
| 1                                       | 6.0                 |
| 1-1/2                                   | 5.5                 |
| 2§                                      | 5.0                 |
| 3§                                      | 4.5                 |

‡See ASTM C33/C33M for tolerance on oversize for various nominal maximum size designations.

\*Tolerance of air content is  $\pm 1\frac{1}{2}$  percent.

§Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 inches are to be removed by sieving and air content will be measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2-inch sieve in accordance with ASTM C231/C231M.

5. Limit supplementary cementitious materials measured as a percent of weight of total cementitious materials in a mix design, as follows:
  - a. Fly Ash and other Pozzolans: 25 percent.
  - b. Slag Cement: 50 percent.
  - c. Combined Fly Ash and other Pozzolans and Slag Cement: 50 percent, with fly ash and other pozzolans not exceeding 25 percent and silica fume not exceeding 10 percent.
  - d. Total cementitious materials include ASTM C150/C150M and ASTM C595/C595M cement.
    - 1) Fly ash and other pozzolans in Type IP, blended cement, ASTM C595/C595M.
    - 2) Slag used in the manufacture of an IS blended cement, ASTM C595/C595M.
6. Provide cementitious materials in accordance with one of the following:
  - a. ASTM C150/C150M Type II.
  - b. ASTM C150/C150M types other than Type II, plus supplementary cementitious materials in accordance with one of the following:
    - 1) Tricalcium Aluminate Content of Total Cementitious Materials: Maximum 8 percent by weight.
    - 2) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
  - c. ASTM C595/C595M Type IP or Type IS (less than 70), tested to comply with moderate sulfate resistance option (MS).
    - 1) Provide documentation of test results in accordance with ASTM C1012/C1012M, for combinations of cementitious materials providing sulfate resistance with expansion less than 0.10 percent at 6 months.
7. Limit water-soluble, chloride-ion content in hardened concrete to 0.15 percent, unless otherwise specified.
  - a. Limits are stated in terms of chloride ions in percent by weight of cement.
  - b. Unless otherwise permitted, provide documentation from concrete tested in accordance with ASTM C1218/C1218M at an age between 28 days and 42 days.

D. Refer to Part 1 through Part 3 of this section for additional requirements.