SECTION 03 05 15

PORTLAND CEMENT CONCRETE

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Portland cement.

B. Aggregates.

C. Drying shrinkage of concrete.

D. Concrete admixtures and cementitious materials.

E. Tests and analysis of materials.

F. Mix designs.

G. Batching, mixing, and transporting.

H. Inspection and Testing.

1.02 MEASUREMENT AND PAYMENT

A. Measurement: Portland cement concrete will not be measured separately for payment. It will be measured in accordance with the Sections specifying construction requiring concrete.

B. Payment: Portland cement concrete will be paid for as part of the indicated Contract unit prices or lump-sum prices for the associated concrete work as indicated in the Bid Schedule of the Bid Form.

1.03 CLASSES OF CONCRETE

A. Classes of concrete are designated by numerical symbol indicating the minimum 28-day compressive strength, in pounds per square inch as determined by ASTM C39, and the maximum permissible size of coarse aggregate.

B. Each class of concrete may consist of one or more mixes determined by the maximum size of aggregate, cement factor, and types of admixtures or special aggregates used.

C. Each mix within a Class shall be considered a specific type, requiring acceptance of the mix design.

D. The various classes of concrete are listed in Table 03 05 15-A at the end of this Section.

1.04 DEFINITIONS

A. The word "concrete" followed only by a class designation (that is, Concrete Class 3000-1-inch) indicates normal weight aggregate concrete, such as concrete having a 28-day compressive strength of 3,000 psi, a maximum coarse aggregate size of 1 inch, and a minimum unit weight of 145 pounds per cubic foot (without reinforcement) at 28 days.

B. The word “HVFAC” followed only by a class designation (that is, HVFAC 4000 – 1-inch) includes normal weight aggregate high volume fly ash concrete, such as HVFAC having a 56-day compressive strength of 4,000 psi, a maximum coarse aggregate size of 1 inch, with a minimum unit weight of 145 pounds per cubic foot (without reinforcement).

C. The term "lightweight concrete" indicates lightweight structural concrete which has a maximum unit weight of 115 pounds per cubic foot at 28 days.

D. The term "fill concrete" indicates a concrete containing sufficient cement to develop a 28-day compressive strength of 2500 psi.

E. The term "lean concrete" indicates a concrete containing the equivalent of two 94-pound sacks of cement per cubic yard.

F. The term “controlled density fill” indicates a flow-able mixture of aggregate and cementitious materials containing sufficient cement to develop a 28-day compressive strength of 50 to150 psi.

G. The term "mass concrete" indicates any volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat from hydration of the cement and attendant volume change in order to minimize shrinkage and cracking.

H. The term “high volume fly ash concrete” (HVFAC) indicates concrete using a mix that replaces 25 percent or more of weight of Portland cement with specified fly ash.

I. Except for the foregoing definitions, the words and terms used in these Specifications conform to the definitions given in ACI 116R.

1.05 REFERENCES

A. American Concrete Institute (ACI):

1. ACI 116R Cement and Concrete Terminology

2. ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

3. ACI 211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete

4. ACI 301 Standard Specifications for Structural Concrete

5. ACI 304R Guide for Measuring, Mixing, Transporting, and Placing Concrete

6. ACI 304.2R Placing Concrete by Pumping Methods

7. ACI 305R Hot Weather Concreting

8. ACI 306.1 Standard Specification for Cold Weather Concreting

9. ACI 318 Building Code Requirements for Structural Concrete

B. American Society for Testing and Materials (ASTM):

1. ASTM C31 Standard Practice for Making and Curing Concrete Test Specimens in the Field

2. ASTM C33 Specification for Concrete Aggregates

3. ASTM C39 Test Method for Compressive Strength of Cylindrical Concrete Specimens

4. ASTM C40 Test Method for Organic Impurities in Fine Aggregates for Concrete

5. ASTM C42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

6. ASTM C88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

7. ASTM C94 Specification for Ready-Mixed Concrete

8. ASTM C114 Test Methods for Chemical Analysis of Hydraulic Cement

9. ASTM C117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

10. ASTM C123 Test Method for Lightweight Particles in Aggregate

11. ASTM C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

12. ASTM C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

13. ASTM C131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

14. ASTM C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

15. ASTM C142 Test Method for Clay Lumps and Friable Particles in Aggregates

16. ASTM C143 Test Method for Slump of Hydraulic Cement Concrete

17. ASTM C150 Specification for Portland Cement

18. ASTM C157 Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

19. ASTM C172 Standard Practice for Sampling Freshly Mixed Concrete

20. ASTM C289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

21. ASTM C330 Specification for Lightweight Aggregates for Structural Concrete

22. ASTM C470 Specification for Molds for Forming Concrete Test Cylinders Vertically

23. ASTM C490 Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

24. ASTM C494 Specification for Chemical Admixtures for Concrete

25. ASTM C535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

26. ASTM C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

27. ASTM C979 Specification for Pigments for Integrally Colored Concrete

28. ASTM C1017 Specification for Chemical Admixtures for Use in Producing Flowing Concrete

29. ASTM E329 Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

1.06 DESCRIPTION

A. Portland cement concrete shall be composed of portland cement, fine aggregate, coarse aggregate, and water, with or without admixtures as approved by the Engineer, proportioned and mixed as specified herein.

1.07 SUBMITTALS

A. General: Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.

B. Concrete Mix Designs: Submit mix designs as herein specified in Article 2.03. Include laboratory test reports of trial strength and shrinkage tests.

1. Submit HVFAC concrete mix designs and laboratory test reports of trial strength and shrinkage tests, including data at 56 days, at least 10 working days before placing concrete.

C. Product Data: Submit manufacturer's product data for proposed concrete admixtures.

D. Samples: Furnish and deliver samples of cement and aggregates as selected by the Engineer for testing and analysis, and additional samples to the District for information. This requirement may be waived if certificates of compliance are furnished as specified in following Article 1.05E. and Article 2.02.

E. Affidavits/Certificates: For each shipment of materials, submit evidence of compliance with Specification requirements for cement, aggregate, and admixtures. Mill tests and manufacturers' certification of compliance with ASTM Specifications will be accepted in lieu of testing of cement and analysis of aggregates. Certificates of Compliance shall be signed by the materials manufacturer and the Contractor.

F. Batch Tickets: Submit a delivery ticket with each batch of concrete delivered to the site in accordance with the requirements of ASTM C94.

G. Quality Control Program: Submit quality program meeting requirements of Article 1.06C. herein.

H. Submit for the Engineer’s approval the name, address, and telephone number of the laboratory, agency, mill, or ready-mix plant which the Contractor intends to engage to design the concrete mixes.

I. Submit for the Engineer's approval the name and qualifications of the proposed concrete technologist.

1.08 QUALITY ASSURANCE AND CONTROL

A. The Contractor shall select a qualified concrete supplier capable of meeting project requirements and the requirements of these Specifications.

B. The concrete supplier shall be certified by the National Ready Mix Concrete Association and shall hold a valid certificate of conformance for concrete production facilities.

C. In conformance with applicable requirements of Section 01 45 00, Quality Control, the Contractor shall provide a quality control plan to assure control and uniformity of materials, conformance with accepted mix designs, and prompt and proper delivery of concrete to the jobsite in accordance with applicable requirements of ASTM C94. Include in the plan all tests the Contractor will perform to verify compliance with Specification requirements, and the independent laboratory the Contractor intends to engage to perform the tests.

1.09 ENVIRONMENTAL REQUIREMENTS

A. Hot Weather Concreting:

1. Batching, mixing, and delivering of concrete in hot weather shall conform to the applicable requirements of ACI 305R.

2. Maximum ambient temperature for placing concrete shall be 90 degrees F. If the ambient temperature exceeds 90 degrees F, the mix shall be cooled by an appropriate method approved by the Engineer, such as icing the mixing water. Maintain uniform concrete temperature of succeeding batches placed.

B. Cold Weather Concreting:

1. Batching, mixing, and delivering of concrete in cold weather shall conform to the applicable requirements of ACI 306.1.

2. When the ambient temperature drops below 35 degrees F, or is expected to drop below 35 degrees F during placement, the temperature of the mix shall be heated by adding hot water, not exceeding 120 degrees F, or by steam heating the aggregates, or both. Other methods of heating aggregates will not be permitted. Steam heating the aggregates may require an adjustment in the mixing water.

3. All concrete shall be protected against freezing for at least 36 hours after placing.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Portland Cement: ASTM C150, Type II, low alkali. Type III portland cement may be used where high early strength concrete is a requirement as approved by the Engineer.

B. Aggregates:

1. Coarse Aggregate: ASTM C33, clean and uniformly graded from 3/8 inch to maximum size indicated or specified. When not specified, provide 1 inch maximum size (ASTM C33, Size No. 57). Deleterious materials in aggregates shall not exceed the limits specified in ASTM C33.

2. Fine Aggregate: ASTM C33, uniformly graded from 3/8-inch to fines, washed clean. Deleterious materials in fine aggregates shall not exceed the limits specified in ASTM C33.

3. Lightweight Aggregates: ASTM C330, uniformly graded to maximum size indicated or specified. When not specified, provide 3/4-inch to No. 4 coarse aggregate combined with ASTM C33 graded fine aggregate.

4. Aggregate for Exposed Concrete: Aggregate for concrete which will be exposed to the public shall be obtained from one source for each type of aggregate required in order to produce a uniform color.

C. Special Aggregates for Reducing Shrinkage and Creep: Cast-in-place reinforced concrete used for underground structures critical to continued main line track operations,concrete for post-tensioned cast-in-place concrete and for precast, prestressed concrete, and for topping slabs shall be produced with special aggregates conforming to the following requirements:

1. Source of Aggregates: Aggregates shall be obtained from a selected aggregate source, known to produce aggregates complying with the specified requirements, as approved by the Engineer.
2. Coarse Aggregate:

a. Coarse aggregate shall consist of hard, dense, durable crushed or uncrushed gravel or crushed aggregate conforming to ASTM C33 and the herein specified requirements. Deleterious substances in aggregates shall not exceed the following limits:

Deleterious Material	Percent By Weight
1) Material Passing No. 200 Sieve (ASTM C117):	
a) Nominal size range No. 4 to 3/4 inch:	0.5

b) Nominal size range 3/4 inch to 1-1/2 inch: 0.4

2) Shale (ASTM C123, specific gravity of heavy liquid 1.95): 1.0

3) Clay lumps (ASTM C142): 0.5

4) Other deleterious substances: 1.0

5) Total of all deleterious substances: 3.0

b. Coarse aggregate shall conform to the following requirements when tested in accordance with the specified ASTM Test Methods:

1) Resistance to Abrasion (ASTM C131): The loss for aggregate size range 3/4 inch to 3/16 inch after 100 revolutions and 500 revolutions shall not exceed 10 percent and 40 percent, respectively. The test sample shall consist of 7 parts of grading B and 3 parts of grading C.

2) Resistance to Abrasion (ASTM C535): The loss for aggregate size range 1-1/2 inch to 3/4 inch (grading 3) after 200 revolutions and 1000 revolutions shall not exceed 10 percent and 40 percent, respectively.

3) Soundness (ASTM C88): Weighted average loss after 5 cycles shall not exceed 12 percent when tested with sodium sulfate.

4) Specific Gravity (ASTM C127): Bulk specific gravity on the basis of saturated surface-dry aggregate shall be not less than 2.60.

5) Absorption (ASTM C127): Absorption shall not exceed 3 percent.

6) Potential Reactivity (ASTM C33): Only aggregates considered innocuous in accordance with Appendix XI shall be used in the work.

3. Fine Aggregate:

a. Fine aggregate shall consist of hard, dense, durable, stone or rock fragments conforming to ASTM C33 and the herein specified requirements. Deleterious substances in aggregate shall not exceed the following:

Deleterious Material	Percent By Weight
1) Material passing No. 200 sieve (ASTM C117):	3.0
2) Shale (ASTM C123, specific gravity of heavy liquid 1.95):	1.0

3) Clay lumps (ASTM C142): 1.0

4) Total of other deleterious substances, (such as alkali, mica, coated grains, soft flaky particles, and loam): 2.0

5) Total of all deleterious substances: 5.0

b. Fine aggregate shall conform to the following requirements when tested in accordance with the specified ASTM Test Methods:

1) Specific Gravity (ASTM C128): Not less than 2.60 on a saturated surface-dry basis.

2) Organic Impurities (ASTM C40): Supernatant liquid must be lighter in color than the reference standard color solution.

3) Soundness (ASTM C88): Loss in 5 cycles of sodium sulfate test shall not exceed 12 percent.

4) Potential Reactivity (ASTM C289): Only fine aggregate considered innocuous shall be used in the work.

5) Fineness Modulus (ASTM C33): Fineness modulus shall be in the range of 2.30 to 3.00, however, the variation of the fineness modulus shall not exceed 0.20.

4. Drying Shrinkage of Concrete:

a. A trial batch of the proposed (mix design) concrete shall be prepared using the aggregates, cement, and admixture proposed for this work. From the trial batch, three specimens (4 inches by 4 inches by 11 inches) for determining "Drying Shrinkage" shall be prepared, cured, dried, and measured as specified in ASTM C157 and ASTM C490, with the following modifications:

1) Cast-in-place concrete shall be moist cured for 10 days.

2) Precast, prestressed concrete shall be steam cured for 1 day.

3) Measurements shall be made and reported for 7, 14, 21, and 28 days of drying after 9 days of moist curing and 1 day of steam curing. Measurements for HFVAC shall also be made and reported for 56 days of drying.

b. Shrinkage of specimens for cast-in-place concrete shall not exceed 0.040 percent when measured in accordance with ASTM C157 and ASTM C490 after 21 days of drying.

c. Shrinkage of specimens for prestressed concrete shall not exceed 0.035 percent when measured in accordance with ASTM C157 and ASTM C490 after 21 days of drying.

d. Shrinkage of HVFAC specimens shall not exceed 0.055 percent when measured in accordance with ASTM C157 after 28 days drying including minimum 7 days moist cure.

D. Concrete Admixtures and Cementitious Materials: The Contractor may include accepted concrete admixtures and cementitious materials in the mix to improve the water-cement ratio or water-cementitious ratio or workability of the concrete, providing the strengths specified and other desirable characteristics of the concrete can be achieved and maintained. Admixtures require the Engineer's acceptance before they may be used, and shall be included in the design mix, introduced in solution form. Admixtures shall be added at the batch plant, except as otherwise noted herein.

1. Chemical Admixtures, Water-Reducing: ASTM C494, Type A.

2. Pozzolanic Admixtures: ASTM C618, Class N or F.

3. Fly Ash: ASTM C618, Class F, with a maximum of 25 percent retained on the No. 325 mesh sieve and a loss on ignition of 1.0 percent maximum.

4. Pigments for integrally colored concrete: ASTM C979, for synthetic or natural iron oxides (red).

5. Chemical Admixtures, Plasticizing: ASTM C1017, or ASTM C494 Type F or Type G, high-range water-reducing admixtures.

6. Prohibited Admixtures: Admixtures containing chlorides or sulfides are not acceptable.

E. Water: Water for concrete mixes, curing, and cleaning shall be clean and potable, free of impurities detrimental to concrete.

F. Reinforcement Fibers: Chopped strands of alkali-resistant polypropylene fibers added to the concrete mix for protection against shrinkage cracks where indicated or required.

2.02 TESTS AND ANALYSES OF MATERIALS

A. Tests and Sample Analyses: Testing of cement and analysis of aggregates shall be performed by the Contractor as specified herein. Mill tests and supplier's certification of

compliance with ASTM Specifications will be accepted in lieu of testing of cement and analysis of aggregates. Tests and services shall consist of the following:

1. Testing of portland cement in accordance with ASTM C150 and ASTM C114.

2. Analysis of aggregates in accordance with ASTM C33, and sieve analysis of fine and coarse aggregates in accordance with ASTM C136.

3. Tests of special aggregates for reducing shrinkage and creep shall conform to the requirements herein specified under Article 2.01C.

B. Samples: Furnish and deliver identified samples of materials required for tests and analysis in the amounts required by the Contractor's employed independent testing laboratory without charge. Samples shall be selected at random by the testing laboratory. Deliver samples of cement and aggregates at least 30 days prior to use on the project.

2.03 MIX DESIGNS

A. Design of concrete mixes, including recommended amounts of admixture and water to be used in the mixes, shall be obtained by the Contractor from a qualified independent testing laboratory or agency, or from a mill or ready-mix plant, properly equipped to design concrete mixes. The design shall be performed and certified by a professional engineer currently registered as a civil or structural engineer in the State of California. The laboratory, agency, mill, or ready-mix plant shall meet applicable requirements of ASTM E329, and shall be approved by the Engineer. Costs of obtaining the mix designs shall be paid by the Contractor.

1. In addition to the requirements specified above, concrete mix designs for HVFAC shall be performed by a concrete technologist with documented experience in the design of HVFAC.

B. Selection of mix proportions shall conform to the applicable requirements of ACI 211.1 and ACI 211.2. Concrete shall comply with ACI 301 and ACI 318, as applicable. Ensure that mix designs will produce concrete suited for proper placement and finishing.

C. Mix design for HVFAC shall include replacement of 25 to 50 percent of Portland cement by weight with fly ash.

D. Mix design for subway structures and below-grade retaining walls for stations and other facilities shall include 15 percent replacement of the cement with fly ash, along with a plasticizing admixture conforming with ASTM C1017, to provide a dense and plastic concrete with low shrinkage and permeability characteristics.

E. Mix design for architectural concrete and formed concrete which will be exposed to the public in the finished work shall include 10 percent replacement of the cement with fly ash along with a plasticizing admixture, conforming with ASTM C1017, to provide a dense and plastic concrete mix which completely fills out the forms and form detail without air holes and rock pockets.

F. Mix designs shall indicate brands, types, and quantities of admixtures included. If fly ash is proposed, it shall be identified as such (for example, "fly ash"), and the mix design shall identify the percentage of cement replacement and the locations in the structures where such mixes are proposed for use.

G. Mix designs for integrally colored concrete shall indicate brand type of natural or synthetic metallic oxide or pigment, and quantity used, all prepared as specified in ASTM C979. Compensate for fly ash with additional pigment as applicable. Concrete encasements of below-grade electrical conduits and ductbanks containing circuits over 600 Volts shall be integrally colored red concrete.

H. Mix design for mass concrete shall have a percentage of fly ash replacement of cement by weight to reduce the amount of heat generated during heat of hydration. Amount of fly ash to be introduced into the mix shall be approved by the Engineer. ASTM C494 Type F or Type G high-range water-reducing admixture may also be used to reduce heat of hydration.

I. If concrete is to be placed by pumping, concrete mixes shall be designed in accordance with the applicable requirements of ACI 304R and ACI 304.2R, and shall include strengths and slumps.

J. Mix design for controlled density fill (controlled low strength material) to be used for structural backfill for utility trenches and pipe culverts shall contain approximately 20 to 30 pounds of cement per cubic yard along with fly ash in amount required to provide a workable mixture. The 28-day compressive strength shall be not less that 50 psi or more than 150 psi. Soil or aggregate component shall be an inert material without organic matter, all passing a 1-inch sieve.

K. Mix designs shall indicate location of each mix within the structure. Mix designs shall specify both coarse and fine aggregate sources.

L. Upon receipt of acceptable mix designs from the prequalified testing laboratory or agency or concrete supplier, conforming with specified requirements, the Contractor shall submit these accepted mix designs to the Engineer for review, 10 days prior to batching or delivering any concrete.

M. Concrete mixes shall contain the minimum number of 94-pound sacks of cement per cubic yard specified in Table 03305-A, regardless of the fact that the strengths specified may be obtained with lesser amounts of cement. Exception will be made only for mass concrete to reduce heat of hydration as hereinbefore specified.

N. The water-to-cement ratio shall not exceed 0.40 for concrete which may be exposed to underground water, such as subway and station structures and for concrete in structures critical to continued main line track operations. Conversion to equivalent water-to-cementitious ratio shall be performed in accordance with applicable requirements of ACI 211.1.

O. Concrete for duct banks shall have a 28-day compressive strength of 3,000 psi, minimum.

2.04 BATCHING, MIXING, AND TRANSPORTING

A. Batching, mixing, and transporting portland-cement concrete shall conform to the applicable requirements of ACI 301 and ACI 304R.

B. Concrete shall be central-mixed concrete from a central batch plant, to be transported to the jobsite in a truck mixer, in accordance with the requirements of ASTM C94. Equipment used in the manufacture of concrete shall be kept clean at all times.

C. Mixers shall be equipped with automatic device for recording number of revolutions of drum prior to completion of mixing operation. Each transit mixer shall also be equipped with water measuring devices consisting of either accurately calibrated water tanks or water meters.

D. Concrete in truck mixer shall be mixed continuously until discharged. The discharge time for concrete after the introduction of mixing water shall not exceed 60 minutes. The discharge time for concrete after cement has been mixed with aggregate shall not exceed 90 minutes. Delivery tickets shall show departure time from plants.

E. Ready-mixed concrete shall be mixed for a period of not less than 10 minutes and at least 3 minutes of the mixing period shall be immediately prior to discharging at the job. The introduction of additional water into transit type mixers after leaving the plant will not be permitted.

1. If adjustment of HVFAC slump in field is necessary, it may be made by addition of high range water reducing admixture within the limitations prescribed by the concrete technologist.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Inspection and Testing Services:

1. Visual inspections and acceptance of concrete mix designs will be by the Engineer. The Engineer will observe concrete batching, mixing, and placing

operations, and the Contractor shall keep records of all concrete placed. Copies of such records shall be submitted to the Engineer for record purposes.

2. Testing services for the Contractor's quality control program, including concrete strength tests, shall be provided by an independent testing laboratory or agency, employed by the Contractor and approved by the Engineer, and shall be performed in accordance with the applicable requirements of ACI 301. If, as a result of these tests, it is determined that the specified concrete properties are not being obtained, the Engineer will order such changes in proportions or materials, or both, as may be necessary to secure the specified properties.

   a. Field tests shall be performed by personnel having ACI Level 1 Field Technician Certification.

3. Failure of the Engineer to detect defective work or material shall not prevent later rejection when such defect is discovered, nor shall it obligate the Engineer for final acceptance.

4. Additional inspection and testing services required by the Engineer because of changes in materials, sources, or proportions; or occasioned by failure of inspections and tests to meet specification requirements, shall be paid for by the Contractor.

5. Provide materials, labor, and services for sampling and testing of concrete, including the following facilities and services:

   a. Preparation, handling, storage, and delivery of concrete test specimens.

   b. Suitable containers for the storage, curing, and delivery of concrete test specimens in accordance with ASTM C31 and ASTM C470.

   c. Suitable storage for a supply of test cylinder molds, test specimens to be cured at the jobsite, and other items required for sampling and testing.

B. Methods of Sampling and Testing:

1. Sampling: Representative composite samples shall be taken by the Contractor in accordance with ASTM C172. Each sample shall be obtained from a different batch of concrete on a random basis.

2. Slump Tests: The above-specified Contractor-employed testing laboratory shall perform slump tests of concrete during placing of concrete, as required, in accordance with ASTM C143. At least one test shall be performed at the delivery trucks for each 50 cubic yards of concrete delivered.

3. Tests for Concrete Uniformity: The same testing laboratory shall perform tests for concrete uniformity in accordance with ASTM C94, Annex A1. Each batch of concrete shall be tested as specified in ASTM C94, Annex A1.

4. Tests for Concrete Temperature: Freshly mixed concrete shall be tested hourly when the ambient temperature is below 40 degrees F and above 80 degrees F, and each time compression test cylinders are made. The concrete temperature shall be recorded on all compression test cylinders made. Refer to Article 1.07 herein for hot and cold weather remedial requirements.

5. Strength Tests:

   a. The Contractor shall prepare, cast, and deliver to the same independent testing laboratory, cylinders for laboratory-cured compression test samples. Cylinders shall be made and cured in accordance with ASTM C31. Cylinders shall be tested in accordance with ASTM C39.

   b. The minimum number of test cylinders to be made for each class of concrete and for each placement shall be four cylinders for each 100 cubic yards or fraction thereof. When additional sets of test cylinders are required beyond the normal seven and 28-day tests, each set shall consist of a minimum of two test cylinders.

   c. All cylinders in a set shall be marked with a unique number on one end. The Contractor shall record this number on the record of concrete placed. All cylinders shall be cured by the Contractor's independent testing laboratory.

   d. From each set of cylinders cast, one cylinder shall be tested at seven days and two cylinders at 28 days in accordance with ASTM C39. If the 28-day tests are satisfactory, the fourth cylinder shall be discarded.

   e. In the event the 28-day tests are below the specified strength requirements, the Laboratory shall then test the fourth cylinder at the age selected by the Engineer.

6. Strength Tests for HVFAC: In additional to the strength test requirements specified above the following provisions apply to HVFAC:

   a. The minimum number of test cylinder to be made for HVFAC for each class and for each placement shall be six laboratory cured cylinders for each 100 cubic yards or fraction thereof.

   b. When the ambient air temperature at time of placement of HVFAC is less than 50 degrees F, four additional cylinders shall be taken hourly and tested.

c. From each set of HVFAC laboratory cured cylinders cast, two each shall be tested at seven, 28, and 56 days.

7. Tests for Contractor's Benefit: Tests required to verify early form removal, or other reasons for the Contractor's benefit, shall be performed at Contractor's expense as part of the Contractor's quality control program.

C. Evaluation and Acceptance of Tests:

1. Acceptance of Concrete: The strength of the concrete shall be considered satisfactory, provided the averages of all sets of three consecutive strength test results equal or exceed the specified 28-day compressive strength, and no individual strength test result falls below the specified 28-day compressive strength by more than 500 psi.

a. Acceptance of HVFAC: The strength of HVFAC shall be considered satisfactory, provided the averages of all sets of three consecutive strength test results equal or exceed the specified 56-day compressive strength, and no individual strength test result falls below the specified 56-day compressive strength by more than 500 psi.

2. Adjustments: The Contractor’s independent testing laboratory shall order adjustments to the mix proportions, increase in the minimum cement content, additional curing of the structure, or any combination of the above when strength tests acceptance criteria specified are not being met.

3. Test Cores:

a. When laboratory test results indicate concrete to be more than 300 psi below the specified strength, or if there is a likelihood of low strength concrete, a significant reduction in load-carrying capacity, or absence of desired durability in the concrete, the Engineer will require tests of cores to be drilled from the areas in question.

b. Test cores shall be obtained from each member or area of suspect strength, from locations designated by the Engineer, and test specimens shall be prepared by the Contractor in accordance with ASTM C42.

c. Three cores shall be taken for each determination of in-place strength. Concrete in the area represented by the core tests will be considered structurally adequate if the average of the three cores is equal to at least 85 percent of the specified design strength and no single core is less than 75 percent of the design strength. Locations represented by erratic core strengths shall be retested at the direction of the Engineer.

d. Fill core holes in accordance with the requirements of Section 03 35 00, Concrete Finishing, for repair of surface defects.

4. Rejection of Concrete; Repair and Replacement: The Engineer shall have authority to reject concrete work which does not meet specification requirements, and to require repair or replacement as necessary to complete the Work.

D. Acceptance of Structure: Acceptance of the completed concrete work requires conformance with the dimensional tolerances, appearance, and strengths specified in these Specifications, in ACI 301, and in ACI 117.

3.02 SCHEDULES

TABLE 03 05 15-A
PORTLAND CEMENT CONCRETE MIXES

CLASSIFICATION		MINIMUM CEMENT CONTENT
Compressive Strength (psi) at 28 days	Maximum Aggregate Size	94-Pound Sacks per cubic yard
A. Reinforced Concrete:		
2500	3/8 inch	5.0
2500	1 inch	4.5
2500	1-1/2 inch	4.5
3000	3/8 inch	5.5
3000	1 inch	5.0
3000	1-1/2 inch	5.0
3500	3/8 inch	6.0
3500	1 inch	5.5
3500	1-1/2 inch	5.0
4000	3/8 inch	6.5
4000	1 inch	6.0
4000	1-1/2-inch	5.5
4500	3/8 inch	7.0
4500	1 inch	6.5
4500	1-1/2 inch	6.0
5000	3/8 inch	7.0
5000	1 inch	6.5
B. Prestressed Concrete:		
5000	1 inch	7.0
6000	1 inch	7.5

CLASSIFICATION		MINIMUM CEMENT CONTENT
Compressive Strength (psi) at 56 days	Maximum Aggregate Size	94-Pound Sacks per cubic yard

C. High Volume Fly Ash Concrete:

4000[1]	1 inch	Note 2
4000[1]	1-1/2 inch	Note 2

[1] Compressive Strength at 7 days shall be 2,000 psi, at 28 days 4,000 psi.
[2] Cement content and maximum water to cementitious material ratio in accordance with the recommendations of the concrete technologist as approved by the Engineer.

END OF SECTION 03 05 15