SECTION 03100

CONCRETE FORMWORK

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies formwork for concrete structures and other facilities.

B. Related Work Specified Elsewhere:
1. Concrete reinforcement: Section 03200.
2. Cast-in-place structural concrete: Section 03300.
3. Structural precast concrete: Section 03400.
4. Prestressed concrete: Section 03415.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. ACI: 347, Publication # 4
3. Western Woods Producers Association : Western Lumber Grading Rules.
4. CE: CRD-C 572.
5. AASHTO: M153.
6. ASTM: D1056, D1149, D1692.
7. APA: HDO Plywood Exterior Grade.
8. U.S. Product Standard : PS 1

B. Responsibilities:
1. Design and construction of formwork is the responsibility of the Contractor, subject to review by the Engineer.

C. Design Criteria:
1. Design formwork for vertical loads and lateral pressures in accordance with ACI 347.
2. Design formwork system which is adequately braced and has adequate strength and stability to ensure finished concrete within the specified tolerances.
3. When necessary to maintain the specified tolerances, design camber into the formwork to compensate for anticipated deflection and creep due to the weight and pressure of the fresh concrete, prestressing forces and construction loads.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:
1. Working Drawings:
   a. Include details of form types, methods of form construction and erection, design computations and location of form joints and form ties, location and dimensions of blockouts and openings in structure, and embeds.
2. Samples:
   a. Each type of waterstop proposed for use, each one foot long: Two.
   b. Each type of premolded expansion-joint filler proposed for use, each six inches by 12 inches: Two.
   c. Proposed dovetail anchor slot, each twelve inches long: Two.
   d. Snap-off form ties: Two.

3. Certification:
   a. Manufacturer's certificates.
   b. Certified test reports of specified concrete tests.
4. Documentation:
   a. Calculations: Early form removal calculations as specified certified by a professional engineer registered in the area where the work is to be performed. Submit in advance for obtaining approval prior to form removal.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. General:
1. Wood forms:
   a. All framing lumber stress-graded.
   b. Lumber in direct contact with concrete, dressed on at least the contact side, with dressed or tongue-and-groove edges; other lumber may be dressed or rough.
   c. Where vertical board finish is shown or specified, use the following:
      1) Form board: Tongue-and-groove, Number 1 Common or better, Ponderosa or White pine, in accordance with the Western Lumber Grading Rules book published by WWPA (not the Southern Pine Inspection Bureau grading rules), one-inch nominal thickness, four-inch nominal width, groove S2S milled or beveled one side only and center matched with 45-degree beveled edges to produce sharp V-shaped 3/8-inch wide in concrete. Four-inch tongue-and-groove boards to be toenailed at edge or face-nailed to backer board.
      2) Smooth concrete: Tongue-and-groove, square cut unturned edges, Number 1 Common or better, Ponderosa or White pine, in accordance with the Western Lumber Grading Rules book published by WWPA (not the Southern Pine Inspection Bureau grading rules), one-inch nominal thickness, four inches nominal width, S2S and center-matched.
2. Plywood forms:
   a. APA grade-marked:
      1) B-B Plyform Exterior grade Group I or II for unexposed finished concrete.
   b. APA High-Density Overlay (HDO) plywood;
      1) B or better face veneer Exterior grade Group I for exposed to public view finished concrete..
   c. USPS : PS 1
3. Tubular fiber forms:
   a. Spirally constructed of laminated plies of fiber.
   b. Wall thickness as recommended by the manufacturer to meet load requirements of various uses and sizes.
   c. Outside surface wax-coated for moisture resistance.
   d. Inside surface of column forms coated with bond-breaker compound and fabricated so that finish concrete surfaces are smooth and free of spiral and seam marking.
4. Fibrous-glass reinforced plastic forms:
   a. One-piece dome system forms, fabricated of plastic reinforced with fibrous glass.
   b. Molded under heat and pressure using matched metal dies.

c. Special sizes and cross sections with thickness, reinforcement and surface finish as necessary to form concrete surfaces that are smooth and free of irregularities.

5. Steel forms:
   a. One-piece dome system forms.
   b. Special sizes and cross sections as shown, with metal gauges, reinforcement, stiffeners and surface finish as necessary to form concrete surfaces that are smooth and free of irregularities and concrete stain.
6. Hardboard:
   a. For concrete not exposed to public view: tempered, smooth-one-side (S1S) panels not less than 3/16-inch thick, in accordance with AHA IS 1.
7. Form ties:
   a. Factory-fabricated, snap-off metal type, of adequate design to minimize form deflection and preclude concrete spalling upon removal.
   b. Fabricated so that set-back in concrete is such that portion of tie remaining after snap-off and removal of exterior portions is at least 1-1/2 inches below concrete surface.
8. Form release agent: Chemically reactive liquid product that will not bond with, stain, or impair concrete surfaces. Follow form panel manufacturers approved product and recommendations for application. Agents containing castor oil are prohibited
9. Preformed expansion joint filler: AASHTO M153.
   a. Type I: Sponge rubber.
   b. Type II: Cork.Type III: Self-expanding cork.
10. Waterstops: PVC, CE CRD-C 572.
11. Dovetail-anchor slots: 22-gauge electrogalvanized steel, with removable felt filler.
12. Chamfer strips: Except where other sizes are shown, 3/4-inch by 3/4-inch triangular fillets milled from clear, straight-grain pine, surfaced-each-side, or extruded-vinyl tape.
13. Miscellaneous preformed strips for reveals, rustications and similar joints: Fabricated of wood, metal, plastic or other approved material formed to cross sections shown.
14. Hydraulic-cylinder well casing: Assembly of pipe, coupling and bottom end cap, of thermosetting-polymer vinylester resin reinforced with fibrous glass, with integral waterstop and anchor flange at invert slab as shown and concrete contact area surfaced with alkaline-resistant barrier, with the following additional requirements:
   a. Properties.
      1) Minimum density at 73F: 0.060 pound per cubic inch.
      2) Minimum tensile strength at 73F: 12,000 psi.
      3) Minimum compressive strength: 18,000 psi.
      4) Minimum flexural strength: 20,000 psi.
      5) Minimum flexural modulus of elasticity at 73F: 1,500,000 psi.
      6) Maximum fire-spread rate: 25.
      7) Maximum heat-distortion temperature at 264 psi: 215F.
      8) Maximum water absorption in 24 hours at 73F: 0.02 percent.
   b. Wall thickness: As shown but not less than 3/8 inch.
   c. Inside diameter: 20 inches.
   d. Pipe furnished with fewest number of joints, watertight, developing full strength of section, made true and straight, with not more than ½-inch deviation from vertical for entire length of pipe.
15. Conduit: Schedule 40, black steel pipe, butt-welded as specified in Section 15205.
16. Premolded Elastic Filler for elevator hoistways:
   a. Closed-cell neoprene:
      1) ASTM D1056, Grade SCE-45.
      2) Water absorption: No increase in weight in excess of two percent when tested in accordance with ASTM D1056 and completely immersed in water for 70 hours at room temperature.

3) Flame resistance: Self-extinguishing when tested in accordance with ASTM D1692.
4) Resistance to ozone cracking: No cracking when tested in accordance with ASTM D1149, after exposure to 100-pphm ozone in air for 100 hours at 100F with specimens under 20-percent strain.

17. Bonding adhesive: As recommended by manufacturer of premolded elastic filler.

PART 3 - EXECUTION

3.01 CONSTRUCTION AND WORKMANSHIP:

A. Concrete finishes and usage locations of various types of forms and form lining: As shown or specified.

B. Unless otherwise shown for concrete surfaces exposed to public view, use HDO Plywood in largest practicable continuous panels to produce plane, smooth surface free from grain imprint, patchmarks, and discoloration.

C. Construct adequately braced formwork so that resulting concrete surfaces conform to specified tolerances.

D. Brace forms, falsework and centering adequately to retain forms in position as shown on approved working drawings.

E. Provide mortar-tight forms of wood, plywood, fibrous-glass-reinforced plastic, steel or other approved materials which conform to shapes, lines and dimensions shown and produce smooth surface without fins and projections.

F. Where shown or directed because of lagging or form irregularity, and where concrete surfaces will not be exposed to public view, line inner form surfaces with hardboard as follows:
1. Use widest available width of hardboard.
2. Line areas less than four feet wide with single-width piece of hardboard.
3. Offset lining joints from those in backing.
4. Fasten securely to backing with galvanized or aluminum nails driven flush.

G. Forms shall be clean of any rust, molds, concrete scale..etc.

3.02 FIELD QUALITY CONTROL:

A. Allowable Tolerances:
1. Construct elements except concrete linings of tunnels to meet allowable tolerances of dimensions, elevations and positions shown and specified in Section 03300.
2. Prior to installation, test hydraulic cylinder well casing assembly hydrostatically at 60 psi pressure for two hours in the presence of the Engineer.

3.03 COATING FORMS:

A. Lightly coat form panels with chemically reactive release agent prior to initial concrete placement and before each subsequent placement.

B. Do not allow excess coating material to stand in puddles in forms nor to come into contact with concrete against which fresh concrete is to be placed.

C. Coat with release agent bolts and rods that are to be completely removed or to be free to move

3.04 EMBEDDED ITEMS:

A. Ensure that items to be embedded in concrete are free from oil and foreign matter that would weaken bond of concrete to such items.

B. Install in formwork inserts, anchors, sleeves and other items specified elsewhere. Close ends of conduits, piping and sleeves embedded in concrete with caps or plugs.

C. Install continuous dovetail-anchor slots where shown.

D. Complete tests on piping and other items before starting concrete placement.

E. Before depositing concrete, check location and support of piping, electrical conduits and other items which are to be wholly or partially embedded.

3.05 OPENINGS AND RECESSES IN CONCRETE:

A. Provide openings and recesses; place sleeves furnished by other trades.

3.06 JOINTS:

A. Unless otherwise directed, make contraction, expansion and construction joints only where shown. Where concrete will be exposed to public view, use largest practicable size sheets to minimize joints.

B. Form keyways as shown.

C. Continue reinforcing steel and wire fabric across joints unless they are shown as being free to move.

D. Make maximum distance between transverse contraction joints 50 feet or as shown, as measured along centerline of track on tangent alignment.

E. Install premolded joint filler at locations shown. Extend filler from bottom of concrete up flush to finish concrete surface or hold down below finish surface as shown.

F. Make splices in premolded filler in manner to preclude penetration of concrete between joint faces.

G. Where premolded joint filler is held below finish concrete face, install in the form a water-soaked wood strip of dimensions shown, to form, after removal, proper size slot to receive sealant compound specified in Section 07900.

3.07 WATERSTOPS:

A. Install waterstops in construction joints below grade and where shown. Use six-inch minimum width, except use nine-inch minimum width in tunnel structures, or as shown.

B. Support and protect that portion of waterstop which extends beyond bulkhead, during placing of concrete and subsequent removal of forms.

C. Position waterstops so as to clear reinforcement. Ensure that the waterstop does not get misaligned or misplaced during concreting.

D. Make field splices by heat-sealing square cut ends of waterstop using hot metal plate or thermostatically controlled electric-heating iron designed for such purpose. Join ends when material becomes molten, maintaining continuity of ribs and bulbs; allow to cool before stressing.

E. Make field splices to develop watertightness equal to that of unspliced material and tensile strength of not less than 50 percent of unspliced material. Have 90-degree splices and as many other splices as possible made in the factory.

3.08 REMOVAL OF FORMS, FALSEWORK AND CENTERING:

A. Maintain forms, falsework and centering in place until the concrete has attained minimum percentage of specified design strength in accordance with Schedule 1:

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Structural Member	Minimum Percentage of Specified Design Strength	
	Schedule 1	Schedule 2
Footings; inverts; sides of beams; slabs and girders; slabs and beams on grade	25	20
Free-standing walls, columns and piers	40	30
Cut-and-cover box structure exterior walls; retaining walls	50	30
Cut-and-cover box structure roofs	80	40
Stairways	80	60
Soffits, beams, slabs and girders; clear span between supports, under 20 feet over 20 feet	 80 90	 60 70
Tunnels, except intersecting sections	80	35
Station arches, except intersecting sections	80	40
Cantilevers	90	70

B. Early removal of forms, falsework and centering will not be allowed for concrete strength values below Schedule 2, but will be allowed for concrete strength values between Schedule 1 and Schedule 2 only after:

1. The Engineer has approved calculations showing anticipated concrete strengths at time of proposed early removal based on:
   a. Ratio of dead load over live load.
   b. Span, height and shape.
   c. Ratio of rise over span.
   d. Reshoring.
   e. Loads, resultant stresses and deformations to which concrete and reinforcing steel will be subjected at time of removal, subsequent to removal and until concrete has attained design strength.
   f. Prevailing site conditions.
2. Concrete strength attained prior to form removal has been determined by analysis of quality-assurance data in accordance with Section 03300.

C. Do not remove wood board forms within 48 hours of pouring concrete.

D. Do not alter loading conditions on concrete subsequent to removal of forms if it results in exceeding permissible stresses and deformations at attained concrete strengths.

E. The Engineer may permit early removal of concrete support without submittal of calculations prior to attainment of specified design strength if he considers such submittals to be unnecessary.

3.09 INSTALLATION OF HYDRAULIC-CYLINDER WELL CASINGS:

A. Cement bottom end cap to casing pipe with solvent cement prior to installation. Solvent cement, procedures, environmental requirements and instructions for proper cementing as recommended by pipe manufacturer.

B. Accurately position, plumb and set as shown. Separate casing, including anchor flange, two inches minimum from reinforcing steel and other metallic material.

C. Except as otherwise specified, perform excavation and backfill as specified in Section 02320. Do not jack or drive casing. Backfill excess excavation around exterior of casing with sand.

D. Recheck casing for orientation and secure immediately prior to pouring of concrete slabs in which it is to be set.

E. Deviation of alignment of centerline of casing not more than 1/2 inch from true vertical, end-to-end.

END OF SECTION

SECTION 03200

CONCRETE REINFORCEMENT

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies reinforcement for concrete structures and other facilities.

B. Related Work Specified Elsewhere:
   1. Concrete formwork: Section 03100.
   2. Cast-in-place structural concrete: Section 03300.
   3. Structural precast concrete: Section 03400.
   4. Prestressed concrete: Section 03415.
   5. Asphalt or bitumen fill in concrete notches at copper bonding: Section 07125.
   6. Additional copper bonding work adjacent to traction power substations: Section 16060.

C. Definitions:
   1. Cover: Thickness of concrete between outside surface of reinforcement and outside face of concrete.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
   1. Comply with codes and regulations of the jurisdictional authorities.
   2. ACI: SP-66, 318.
   3. CRSI: Manual of Standard Practice; Placing Reinforcing Bars.
   4. AASHTO: Standard Specifications for Highway Bridges.
   5. ASTM: A82, A185, A615, A775, A706.

B. Allowable Tolerances:
   1. Cut and bend reinforcing steel to conform to dimensions shown within the following tolerances:
      a. Sheared length: Plus-or-minus one inch.
      b. Depth of truss bars: Plus zero or minus 1/2 inch.
      c. Stirrups, ties and spirals: Plus-or-minus 1/2 inch.
      d. All other bends: Plus-or-minus one inch.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:
   1. Shop Drawings:
      a. Detail reinforcing in accordance with ACI SP-66.
      b. Bar lists showing the individual weight of each bar, total weight of each bar size and total weight of bars on list. Base calculated weights on theoretical unit weights shown in ASTM A615, Table 1.
      c. Details showing bonding of reinforcement for stray current and cathodic protection.
   2. Certification:
      a. Manufacturer's certificates.
      b. Mill tests on each heat showing chemical and physical analyses performed in accordance with ASTM A615, as modified by ACI 318.

c. Record of mill tests traceable to individual reinforcement bars supplied to the project.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Ship reinforcing steel in bundles limited to one size and length.

B. Tag each bundle at mill with waterproof tag showing name of mill, heat number, grade and size of bars and identifying number.

C. Protect reinforcing steel and wire fabric from damage; foreign matter such as dirt, oil and grease; and rust-causing conditions.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Reinforcing Steel Bars:
1. ASTM A615, Grade 60, modified in accordance with ACI 318.
2. ASTM A706, for all welding reinforcing bars, except for electrical bonding.
3. Epoxy Coating: ASTM A775, as shown.

B. Spiral Reinforcement: ASTM A82 or ASTM A615, Grade 60.

C. Welded Steel-Wire Fabric: ASTM A185.

D. Metal Accessories: As recommended by CRSI Manual of Standard Practice. Where concrete surfaces will be exposed to public view in finish structure, use supports with plastic-protected legs or stainless steel legs.

PART 3 - EXECUTION

3.01 CUTTING AND BENDING:

A. Perform cutting and bending in the shop. Bend steel cold. Do not bend or straighten bars so as to damage material.

B. Do not bend bars in the field except to correct minor errors and damage occurring during shipping and handling.

3.02 BAR SUPPORTS AND SPACERS:

A. Support bars by means of bolsters or chairs with no less than minimum required by ACI SP-66.

B. Reinforcing steel in bottom of slabs resting on earth may be supported by concrete brick or mortar blocks.

C. In walls, columns, piers and abutments hold reinforcing steel in position by means of mortar blocks, bar supports or spacers wired to reinforcing steel.

D. Do not use stones, clay bricks, wood blocks or pieces of broken concrete to support reinforcing steel.

E. Do not place bars or fabricated mats on layers of fresh concrete as work progresses.

3.03 PLACING AND FASTENING:

A. Arrange and place reinforcing steel as shown.

B. Secure reinforcement positively against displacement during placing of concrete.

C. Wire or clip bars together as recommended in CRSI Placing Reinforcing Bars.

D. Maintain reinforcing steel accurately in locations shown in tops of inverts to permit arrangements of anchor bolts for rail-tie plates.

E. Before placement, ensure that reinforcement is free from dirt, mill scale, rust scale, oil, grease and other foreign matter.

3.04 SPLICING:

A. Furnish reinforcing bars in full lengths as shown on the Contract Drawings and approved shop drawings.

B. Do not splice bars unless approved in writing.

C. Make splices when authorized, in accordance with ACI 318, except make all butt splices by welding with a capacity of not less than 125 percent of minimum yield strength of bar. Mechanical connections for tensile splice shall be by cadweld only.connections for t Cadweld only. However, mechanical connection for precast prestressed structures and parking garages, when the splice is located inside the precast member, may be made by NMB Splices instead of the Cadweld, with prior approval of the Authority.

3.05 ELECTRICAL BONDING:

A. Weld steel straps to transverse end reinforcing bars and longitudinal reinforcing bars adjacent to joints between pour sections at locations shown.

B. No electrical bonding is required for epoxy coated rebars.

C. Thermit weld or cadweld stranded, bare-copper conductors to adjacent steel strips at specified end locations. Likewise, weld copper conductors to lapped, welded-wire fabric at joints in slabs at locations shown.

D. Additional copper bonding work adjacent to traction power substations: Section 16060.

E. Asphalt or bitumen fill in concrete notches at copper bonding: Section 07125.

3.06 STUDS:

A. Install welded studs in track invert slabs on top of transverse bars 10 feet on center and on first transverse bar at each end of units. Expose tops of studs and set flush with top surface of slab.

3.07 INSPECTION:

A. Placement of concrete prior to approval of reinforcement and electrical bonding work is prohibited.

3.08 CONCRETE PROTECTION FOR REINFORCEMENT (COVER):

A. Underground Box Section Structures:
   1. Invert slab:
      a. Top steel: Two inches.
      b. Bottom steel: Three inches.
   2. Roof slab:
      a. Top steel: Two inches.
      b. Bottom steel: 1-1/2 inches.
   3. Exterior walls:
      a. Outer-face steel: Three inches.
      b. Inner-face steel: 1-1/2 inches.
   4. Center walls: 1-1/2 inches.
   5. Beams, girders and columns: 1-1/2 inches.
   6. Intermediate floors, platform slabs and stairs: 3/4 inches.

B. Retaining Walls:
   1. Footing:
      a. Top steel: Two inches.
      b. Bottom steel: Three inches.
   2. Wall:
      a. Outer-face steel: Three inches.
      b. Inner-face steel: Two inches.

C. Other Underground Structures:
   1. Outer-face steel: Three inches.
   2. Inner-face steel: Two inches.
   3. Drainage slot: Two inches.
   4. Safety walk: 1-1/2 inches.
   5. Beams, girders and columns: 1-1/2 inches.
   6. Intermediate floors, platform and slabs and stairs: 3/4 inch.

D. Above-Ground Structures:
   1. Prestressed concrete bearing highway or transit loads: In accordance with AASHTO Standard Specifications for Highway Bridges.
   2. Ancillary structures including precast prestressed structures: : ACI 318.

3.09 EPOXY COATING:

A. Preparation of surface: Perform the following in order given:
   1. Clean surface contaminated with oil and grease using naptha or xylol.
   2. Remove weld slag, rust and mill scale from surfaces by wire brushing.
   3. Coat surfaces immediately with methyl-methacrylate primer.
   4. Apply coating only to surfaces which are dry and free of contaminants.

END OF SECTION

SECTION 03300

CAST-IN-PLACE STRUCTURAL CONCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies providing portland-cement cast-in-place concrete.

B. Related Work Specified Elsewhere:
1. Concrete pavement: Section 02750.
2. Curbs, gutters and walks: Section 02772.
3. Chemical grout: Section 2415.
4. Concrete formwork: Section 03100.
5. Concrete reinforcement: Section 03200.
6. Structural precast concrete: Section 03400.
7. Prestressed concrete: Section 03415.
8. Asphalt or bitumen fill: Section 07125.
9. Copper bonding work: Section 16060.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. ACI: 201.2R, 211.1, 304, 309, 318, 318.1.
3. AASHTO: M182, T26.
4. NBS: Handbook 44.
5. USBR: Concrete Manual.
6. FS: A-A-341A, HH-I-521, K-P-146.
7. ASTM: A43, A47, A48, C31, C33, C39, C40, C42, C87, C88, C94, C131, C150, C171, C172, C260, C295, C309, C311, C330, C494, C535, C586, C595, C618, C665, C685, C881, C989, C1107, C1260, D98, E328.
8. CPMB (Concrete Plant Manufacturer's Bureau): Concrete Plant Standards.

B. Testing Laboratory:
1. Furnish the services of an independent testing laboratory. Employment of an independent laboratory does not relieve the Contractor of the obligation to perform the work in accordance with requirements of the Specifications and Drawings. Submit certified results of the tests performed.
2. Furnish proof that the laboratory satisfies the requirements of the American Council of Independent Laboratories' Recommended Requirements for Independent Laboratory Qualification. Laboratory need not be a member of the American Council of Independent Laboratories.
3. Certify that testing equipment has been calibrated by an accredited calibration agency at not more than 12-month intervals using devices of accuracy traceable to the National Institute of Standards and Technology (NIST) or accepted values of material physical constants

C. Properties of Concrete:
1. General:
   a. Design mixes to produce concrete of proper workability, durability, strength, maximum density, minimum shrinkage and permeability.
   b. Design mixes to have minimum water content per cubic yard of concrete, cement content corresponding to appropriate water-cement ratio, largest

permissible maximum size specified of coarse aggregate available and optimum percentage of fine aggregate.

c. Use maximum size of coarse aggregate in accordance with ACI 211.1.

d. Use same brand from same source throughout the work.

e. Use aggregates from same source throughout the work.

f. Use ground-iron blast-furnace slag and fly ash from the same sources respectively throughout the work.

2. Durability:

a. Maximum water cementitious materials ratio as per ACI 318, Chapter 4 and ACI 201.2R.

b. Use a suitable combination of approved air-entraining admixture and water reducer to reduce water content and permeability of the concrete, provided such admixtures do not adversely affect other specified properties of concrete.

c. For precast prestressed parking garages -

1) The four-inch thick cast-in-place concrete overlay topping over the double tees on top level of the Parking Structure, the concrete shall attain 28 days minimum compressive strength of 7,000 psi with a water-cement ratio of 0.38 or less. The cast-in-place concrete overlay topping wash strips over the inverted tee beams on top level and wash strips over the inverted tee beams on all other levels, and all cast-in-place concrete wash areas over the double tees, the concrete shall attain 28 days minimum compressive strength of 5,000 psi with a water-cement ratio of 0.40 or less. And for all other cast-in-place concrete, the concrete shall attain 28 days minimum compressive strength with a water-cement ratio of 0.45 or less.

2) Use a calcium nitrite-based corrosion inhibitor as specified in Section 03300.2.1.T, in the cast-in-place wash strips or areas, in the cast-in-place concrete overlay topping.

3. Workability:

a. Use approved chemical admixtures as needed for workability so that concrete can be placed, consolidated, and finished without segregation or excessive bleeding.

4. Strength:

a. Design mix for each class and type of concrete of each specified strength based on overdesign factor in accordance with ASTM C94. Unless otherwise shown, working-stress method applies to structures.

b. Design each class of concrete in accordance with the following:

1) Not more than the following percentages of strength tests to have values less than specified strength:

2) Working-stress method: 20 percent.

3) Ultimate-strength method: 10 percent.

4) Prestressed structures: 10 percent.

5) Average of the following numbers of consecutive strength tests to be equal to or greater than specified strength:

a) Working-stress method: Six.

b) Ultimate-strength method: Three.Prestressed structures: Three.

c. When number of tests totals six or less, average to be in accordance with Note 21 of ASTM C94.

5. Appearance:

a. Cured concrete exposed to public view shall be uniform in color, texture and finish with no discernible form or patch marks, grain imprint, joint irregularities or discoloration. Use only manufacturer approved chemically reactive release agents on HDO plywood forms.

b. Final selection and approval for color shall be made by the Engineer.

D. Method of Proportioning:
   1. Proportion mixes as described in ACI 211.1.
   2. Approximate mixing-water and air-content requirements for mixes of different slumps and nominal maximum sizes of aggregates as specified in ACI 211.1, Table 5.3.3.
   3. Do not vary proportions of ingredients of approved mixes without written approval.

E. Demonstration Section:
   1. Before proceeding with tunnel lining, completely seal a 25-foot long demonstration section using materials and methods to be used in the work in accordance with specified requirements.

F. Ready-Mixed Concrete: ASTM C94.

1.03 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:
   1. Product Data: Manufacturer's literature completely describing each material, standard, test data, installation instructions and special instructions or safety precautions applicable to the materials.
      a. Samples:
         1) Concrete surface sealer: Two, each one pint.
         2) Membrane-forming curing compound: Two of each type, each one pint.
   2. Sandblast finish:
      a. Number 6 sandblast finish as specified, each 12 inches square by two inches: Two.
      b. Seal 1/2 of face of each sample with concrete surface sealer.
      c. If samples are not approved or if concrete mix is changed, submit additional samples until approved.
      d. When samples have been approved, submit details of procedures followed to produce approved surface finish including, but not limited to, the following:
         1) Size and type of nozzle.
         2) Air pressure.
         3) Distance of nozzle from surface blasted.
         4) Duration of blast.
   3. Concrete panels of each type of concrete used in the work: Two each, 18 inches square by two inches thick.
   4. Certification:
      a. Ingredients:
         1) Submit with mix design, laboratory test reports and mill or manufacturer's certificates verifying that ingredients conform to specified requirements. Use ingredients in design mix which are representative samples of materials to be used in the work.
         2) Submit test results whenever the aggregates, cement or other additives to be used in the concrete come from a different lot, source, other area of the quarry, different quarry or from other than the representative stockpile or batch from which the original material was tested and approved.
      b. In case the source, brand or characteristic properties of ingredients need to be varied during the term of the Contract, submit revised laboratory-mix report in accordance with procedures specified for original mix design.
      c. Batch tickets:

1) Before unloading at the site, submit certification or delivery ticket from concrete supplier with each batch delivered to the site bearing the following information:
   a) Name of supplier.
   b) Name of batching plant and location.
   c) Serial number of ticket.
   d) Date.
   e) Truck number.
   f) Specific job designation: Contract number and location.
   g) Volume of concrete in cubic yards.
   h) Class and type of concrete.
   i) Time loaded.
   j) Type and brand of cement.
   k) Weight of cement and fly ash or ground-iron blast-furnace slag.
   l) Maximum size of aggregates.
   m) Weights of coarse and fine aggregates.
   n) Maximum amount of water to be added and amount of water added at the site.
   o) Kind and amount of admixtures.

5. Documentation:
   a. Proposed methods for controlling concrete temperature and plans for placing concrete taking into account sun, heat, wind, ambient air temperature or other limitations of facilities that will prevent proper finishing or curing.
   b. Quality control plan for floor treatment. Submit as specified prior to installation.
   c. Quality control reports. Submit as specified after installation.
   d. Design mixes:
      1) Prior to placing concrete, submit design mixes for each class and type of concrete, certifying that proposed concrete ingredients and proportions will result in concrete mix meeting specified requirements.
      2) Include for each class and type of concrete as many mix designs as there are combinations of different ingredients or types of ingredients anticipated to cover requirements of the work.
      3) Establish mix designs through an approved design laboratory.
      4) Design concrete mix for protection against alkali-aggregate reactivity.
      5) The Contractor may present for approval a concrete mix previously approved for Authority work provided such mix is made with proposed ingredients that meet requirements and provided that concrete has complied with compressive-strength requirements based on control record of at least 30 consecutive-strength tests recently obtained.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Aggregates :
   1. Transport and stock pile aggregate separately according to sources and gradations. Handle so as to prevent segregation, loss of fines and contamination by earth or other foreign materials.
   2. If aggregates show segregation or if different grades become mixed, rescreen before placing in proportioning bins.

3. Do not combine aggregate from different sources or of different gradations except to obtain different gradations.
4. Do not transfer aggregates directly from trucks, railroads cars or barges to proportioning bins when moisture content is such that it will affect accurate proportioning of concrete mixture. In such cases, stockpile aggregate until excess moisture drains off.

B. Packaged Cement:
1. Deliver to project site in original sealed packages labeled with weight, name of manufacturer, brand and type.
2. Store packages in watertight building.
3. Do not use cement which has been reclaimed by cleaning bags.
4. Do not use cement which has been exposed to moisture or contaminated.
5. Deliver packages conforming to weight specified.
6. Packaged cement will be subject to testing.

C. Bulk Cement:
1. Store bulk cement separately from other cement and protect to prevent exposure to moisture and contamination.
2. In ready-mix plant, provide facilities to maintain separation of cement meeting specified requirements from other cement.
3. Provide in cement manufacturer's plant, facilities for sampling cement at weighing hopper or in feed line immediately before entering hopper.

D. Ready-Mixed Concrete: ASTM C94.

E. Blast-Furnace Slag or Fly Ash for use with Portland Cement:
1. Transport in covered carriers.
2. Store in watertight bins or silos to provide protection from dampness and contamination. When compartmented bins are used, conduct periodic, but not less than weekly checks between adjacent bins to avoid contamination of either of the stored materials.

F. Concrete Additives, Sealers and Corrosion Inhibitor . As required by the manufacturer.

1.05 WARRANTY

A. Penetrating Concrete Sealer: Provide a minimum effective service life warranty of 10 years for the penetrating concrete sealer.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Cementitious Materials:
1. Portland Cement: ASTM C150, Types I and II. Use Type II only for underground structures.
a. Alkali content not to exceed 0.6 percent.
2. Blended Hydraulic Cement: ASTM C595 Type IS and IP.

B. Ground-Iron Blast Furnace Slag: ASTM C989, Grade 100 or 120.

C. Fly Ash: ASTM C311 and ASTM C618, Class F:
1. Loss on ignition not to exceed 4 percent.

2. Maximum available alkalis (for combination of cement and fly ash) not to exceed 0.6 percent based on proportions to be used and alkalinity measurements for cement and fly ash individually or in combination.
   a. Fly ash used to be qualified for each source.
3. Uniform color when used in concrete exposed to public view.

D. Aggregates:
1. Aggregates for normal concrete and shotcrete: ASTM C33 with the following additional requirements:
   a. Coarse aggregate: Gravel, crushed gravel or crushed stone.
      1) Deleterious substances:
         a) Maximum allowable amounts:

Substance		Maximum Allowable Percentage by Weight
(1)	Soft particles:	5.0
(2)	Coal and lignite particles:	0.5
(3)	Friable particles:	0.25
(4)	Material passing Size 200 sieve:	1.0
(5)	Thin or elongated pieces:	15.0
(6)	Other local deleterious substances:	1.0

         b) Soft particles: Higher percentage may be approved where concrete is not subject to abrasion, provided concrete strength is achieved without the use of excess cement.
         c) Crushed aggregates: If material finer than Number 200 sieve consists of dust of fracture essentially free from clay or shale, percentage may be increased to 1.5.
         d) Thin or elongated pieces: Length of pieces to be greater than five times the smallest dimensions of a circumscribing rectangular prism.
      2) Percentage of wear: 45 maximum when tested in accordance with ASTM C131 and ASTM C535.
      3) Weighted percentage of loss: 15-percent maximum by weight when subjected to five cycles of magnesium sulphate soundness test in accordance with ASTM C88.
      4) Gradation: In accordance with ASTM C33, Table 2, and represented by a smooth gradation curve within required limits.
   b. Fine aggregate:
      1) Washed natural sand or washed stone sand. Stone sand may be subject to special gradation requirements as directed.
      2) Gradation in accordance with ASTM C33.
         a) Minimum percentages of material passing Size 50 and Size 100 sieves may be reduced to five and zero, respectively, if aggregate is to be used in concrete with three percent minimum air entrainment, or in concrete containing more than 517 pounds of cement per cubic yard.
      3) Weighted percentage of loss not more than 12 percent by weight when subjected to five cycles of magnesium sulphate soundness test in accordance with ASTM C88.
      4) Deleterious Substances:

Substance		Maximum Allowable Percentage by Weight
a)	Friable particles:	1.0
b)	Coal and lignite:	0.5
c)	Material passing the Size 200 sieve:	5.0
d)	Other deleterious substances, such as shale, alkali, mica, coated grains, soft and flaky particles:	2.0

5) Free from injurious amounts of inorganic impurities as determined by ASTM C40. Should materials fail to pass test for organic impurities in sand for concrete, retest in accordance with ASTM C87. If fine aggregate shows by colorimetric test a darker color than that of sample originally approved for the work, stop using such aggregate until approved tests have been made to determine whether change in color is indicative of injurious amount of deleterious substances.

c. Evaluate for potential alkali aggregate reactivity:

1) Perform a petrographic examination in accordance with ASTM C295. The petrographic analysis will identify the constituents of the fine and coarse aggregate and will also identify aggregate found to be potentially alkali-carbonate reactive. Fine and coarse aggregate containing more than the following quantities of constituents is unacceptable:

a) Optically strained, microfractured or microcrystalline quartz exceeding five percent (a common constituent or granite and granite gneiss).

b) Chert, Metaquarzite, Chalcedony or combination thereof exceeding three percent. However, fine aggregate may contain up to eight percent provided that mortar bar test results are acceptable.

c) Tridymite or cristobalite exceeding one percent.

d) Opal exceeding five percent.

e) Natural volcanic glass in volcanic rocks exceeding three percent.

2) Test aggregate for alkali-silica reactivity in accordance with ASTM C1260. Aggregate sources that exhibit a C1260 mean mortar bar expansion at 16 days greater than 0.08 percent are unacceptable.

3) Aggregate identified by the petrographic analysis to be potentially alkali-carbonate reactive is to be further evaluated in accordance with ASTM C586. Expansion of test specimen cylinders not to exceed 0.10 percent after 28 day immersion in NaOH solution.

d. Aggregate which fails the evaluation criteria for potential alkali aggregate reactivity may be reclassified as acceptable if prior field performance demonstrates that the aggregate is nonreactive. Include service records (material records, batch quantities, exposure conditions, and petrographic evaluation) demonstrating the aggregate to be nonreactive in the mix design submittal.

2. Aggregates for Lightweight Structural Concrete: ASTM C330, with the following additional requirements:

a. Coarse aggregate:

1) Composition: Expanded shale, clay or slate, predominantly lightweight, cellular and granular.

2) Percentage loss: 10-percent maximum by weight when subjected to five cycles of the magnesium sulphate soundness test in accordance with ASTM C88.
3) Gradation: In accordance with ASTM C330, Table 1.
4) Unit weight: In accordance with ASTM C330, Table 2.

b. Fine aggregate:
1) Composition: Particles of expanded shale, clay, slate or ASTM C33 natural sand as necessary to obtain specified compressive strength and comply with specified air-dry unit weight for lightweight structural concrete.
2) Gradation: In accordance with ASTM C330, Table 1.
3) Unit weight: In accordance with ASTM C330, Table 2.
4) Percentage loss: 10 percent maximum by weight when subjected to five cycles of magnesium sulfate soundness test in accordance with ASTM C88.

E. Water:
1. Natural potable water with no pronounced taste or odor.
2. Containing no impurities, suspended particles, algae or dissolved natural salts in quantities that will cause:
a. Corrosion of reinforcing steel.
b. Volume change that will increase shrinkage cracking.
c. Efflorescence.
d. Excessive air entraining.
3. pH: Not less than five.
4. When tested in accordance with AASHTO T26, standard mortar-briquette tests to show no indication of unsoundness, no change in setting time in excess of plus-or-minus 30 minutes and no reduction in strength in excess of 10 percent.

F. Ready-Mixed Concrete: ASTM C94, Option C.

G. Admixtures:
1. In accordance with the following:
a. Air-entraining admixtures: ASTM C260.
b. Chemical admixtures: ASTM C494.
2. Approved brands: Chlorides may be present in admixtures provided total chloride in mixing water of proposed concrete mixture, including chloride ions contributed by admixture or admixtures, aggregate and mixing water is not in excess of 150 ppm.
3. Meeting requirements of reference standards or documented to have five-year minimum history of demonstrably satisfactory performance for similar structures under equivalent conditions.

H. Aluminum Powder: FS A-A-341A, free of oil, grease, soluble alkalis and organic materials, gradation as approved.

I. Ferrous Aggregate:
1. Cast-iron particles, ASTM A43, ASTM A47, or ASTM A48, free of oil, grease, soluble alkalis and organic materials.
2. Aggregate graded as follows:

Sieve Designation US Standard Square Mesh	Percentage by Weight Passing Individual Sieves
3/8 inch	—
Size 4	100
Size 8	90 - 100
Size 16	75 - 90

Size 30	45 - 60
Size 50	15 - 25
Size 100	10 - 20

3. If recommended by manufacturer and approved, in lieu of the above gradation use lower percentage of aggregate passing Size 100 sieve.

J. Abrasive Aggregate: 60 to 75 percent silicon-carbide abrasive, bonded by vitreous ceramic material, black, graded from 12 to 30.

K. Floor Treatment:
1. Sealer: Zinc or magnesium fluosilicate and wetting agent formulated and mixed with water in concentration recommended by manufacturer.
2. Floor hardener system:
   a. Floor hardener:
      1) Free from non-ferrous metallic particles, filler material, silica sand, natural aggregates, rust and materials which disguise rust.
      2) Ready-to-use formulation proportioned, mixed and packaged at factory ready for application.
      3) Ingredients proportioned to maintain two parts well-graded iron aggregate to one part consisting of cement, plasticizing agents and other ingredients designed to absorb moisture from floor slab.
      4) Color: Per sample, or as selected by the Engineer.
      5) Masterplate 200, Master Builders, or equal.
   b. Floor curing compound:
      1) Clear modified-acrylic resin.
      2) Moisture retention: In accordance with ASTM C309 when applied at a rate of 400 square feet per gallon.
      3) Masterkure, Master Builders, or equal.

L. Penetrating Concrete Sealer:
1. Penetrating silane sealer, which is readily absorbed into concrete substrate and which reacts chemically to provide a hydrophobic barrier that will not wear off when exposed to sunlight or wheel traffic; which allows concrete to breath, allowing the escape of water vapor but preventing the absorption of surface water; colorless; not altering the surface texture of the concrete substrate. See Warranty requirements.
2. Provide one of the following:
   a. Chem-Trete BSM 40, Hüls America, Inc. (1-800-828-0919).
   b. Penetrating 40, Sonneborn Division Chemrex (1-800-CHEMREX).
   c. Master Seal SL40, Master Builders Technologies.

M. Curing Materials:
1. Plastic sheeting: Polyethylene, ASTM C171.
   a. Curing sheet: Type 1.1.1 and 1.1.2.
   b. Vapor barrier: Clear 10-mils thickness.
2. Burlap sheet: AASHTO M182, Class 3 or 4.
3. Tarpaulin: FS K-P-146.
4. Blanket insulation: FS HH-I-521.
5. Membrane-forming curing compound: ASTM C309, Type 1-D, 100 resin with fugitive dye, and Type 2.

N. Epoxy Mortar:
1. Epoxy: ASTM C881, Type III-C, grey.
2. Sand: Clean, dry, well-graded particles, passing Size 16 sieve, with the following additional requirements:

Individual Sieve Size	Percent by Weight Retained on Sieve

30	26 to 36
50	18 to 28
100	11 to 21
Pan	25 to 35 (range shown is applicable when 60 to 100 percent of pan is retained on Size 200 sieve)

O. Chemical Grout: Section 02415.

P. Paver Tile Setting Bed:
1. Concrete: 3500 psi.
2. Reinforcement: 4 x 4 - W4.0 x W4.0, Section 03200, furnish in sheets, not rolls

Q. Elastomeric Concrete:
1. Elastomeric Concrete to consist of an aggregate and binder mixture proportioned by the manufacturer.
2. Manufacturer qualifications: Manufacturer to have the following minimum qualifications:
   a. Ten years experience in the manufacturing of elastomeric concrete materials.
   b. Qualified personnel, factory trained and certified in the proper installation procedures, are to be available during construction.
3. Manufacturers: The naming of certain manufacturers is intended to establish a standard of quality. Elastomeric Concrete from the following manufacturers is acceptable:
   a. Delcrete Elastomeric Concrete by the DS Brown Company, PO Box 158, North Baltimore, OH 45872, telephone (419)257-3561.
   b. Wabocrete by Watson Bowman Acme Corporation, 95 Pineview Drive, Amherst, NY 14228, telephone (716)691-7566.
4. Equal Products: Other manufacturers or material suppliers who wish to propose their product as equal to this specification submit product information and a working sample along with independent physical test property verification, and product literature for review and approval.

R. Waterstop: Section 03100.

S. Chairs for Reinforcement: Plastic or stainless steel.

T. Corrosion-inhibitor in concrete. The corrosion-inhibitor shall be calcium nitrite-based admixture DCI or approved equal. Use four (4) gallons per cubic yard of the corrosion inhibitor when the water-cement ratio is 0.40 or less and use three and a half gallons (3-1/2) per cubic yard when water-cement ratio is 0.38 or less. For precast prestressed parking structures/garages use the corrosion -inhibitor in cast-in-place concrete overlay topping over the double tees and the inverted tee beams on top level and for cast-in-place concrete in wash strips and wash areas on all levels.

2.02 SAMPLING:

A. Sample concrete ingredients prior to use and have them tested by an approved laboratory in accordance with methods specified. Subsequently test materials as often as necessary to verify that materials conform to specified requirements and that quality of product is maintained.

B. Make arrangements for the Engineer to witness sampling and testing. Submit record of test results.

C. Ready-Mixed Concrete: ASTM C94.

2.03 GROUT MIXES:

A. Portland-cement grout:
1. Prepare grout composed of portland cement, sand and water.
2. Use portland-cement grout under bearing plates, in recesses, holes and surfaces under structural members and at other locations shown.
3. Do not use staining ingredients in grout exposed to view.
4. Formulation: Two parts sand and one-part cement measured by volume.
5. Mix grout with sufficient water to permit placing and packing, approximately 45 minutes prior to use.

B. Nonshrink grout: ASTM C1107.

C. Shrinkage-compensating grout:
1. Use shrinkage-compensating grout for setting structural members, anchor bolts, embedded items or items of equipment and machinery on hardened concrete.
2. Prepare nonstaining shrinkage-compensating grout with portland cement, sand and aluminum powder and use in accordance with manufacturer's recommendations.
3. Prepare shrinkage-compensating grout for use up to two inches thick as follows, measured by volume:
   a. One-part portland cement, Type I or II.
   b. One-part fine natural-sand aggregate, graded as specified.
   c. One-part ferrous aggregate, graded as specified, combined with Type-A chemical admixture, oxidation agent and water in sufficient amount to permit placing and packing.

D. Premixed shrinkage-compensating grout:
1. In lieu of specified shrinkage-compensating grout, use premixed ready-to-use formulation when approved. Approval will be based on manufacturer's certification that:
   a. Material will perform as specified.
   b. Composition and proportioning of grout materials is essentially as specified for shrinkage-compensating.
   c. Formulation has been used successfully in like applications for at least five years.
2. Proportion ingredients in accordance with the manufacturer's recommendations.

E. Mixing water:
1. Proportion mixing water in accordance with grout manufacturer's recommendation or to produce flowable mixture without segregation or bleeding.

F. Curing:
1. After grout has attained initial set, keep damp for 24 hours minimum.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL:

A. Classes of Concrete:

1. Classes of concrete are designated by numerals corresponding to their specified 28-day compressive strength in pounds per square inch as determined by ASTM C94.
2. Concrete classes used in this project are specified. Unless otherwise indicated, use Class 3500.
3. Each class of concrete may comprise one or more mixes determined by maximum size of aggregate, cement factor and types of admixtures used.
   a. Portland cement may be used alone or mixed with either ground-iron blast-furnace slag or fly ash. Do not use fly ash in architectural concrete exposed to public view.
   b. Maximum allowable ground-iron blast-furnace slag: 50 percent of the total weight of the portland cement and ground-iron blast-furnace slag mixture.
   c. Maximum allowable fly ash: 20-percent of the total weight of the portland cement and fly-ash mixture.
4. Concrete with fly ash or ground-iron blast-furnace slag may be used at locations shown on the drawings.

B. Types of Concrete:
1. Types of concrete are designated as Concrete Other than Lightweight and Lightweight Structural Concrete.

C. Minimum Cement Factor:
1. Observe minimum cement factor for various classes of concrete other than lightweight, as follows:

Class of Concrete	Minimum Cement Factor Bags Per Cubic Yard Of Concrete
5,000	6.5
3,500 - 4,000	6.0
2,500 - 3,000	5.0

* one bag of cement = 94lbs. of cement

2. If a mix of portland cement and ground-iron blast-furnace slag or portland cement and fly ash is used, the mix is the basis of determining the bags per cubic yard of concrete.

D. Air Entrainment:
1. Determine air content of concrete in accordance with ASTM C94.

E. Testing of Concrete:
1. General:
   a. Provide the Engineer with molds and concrete, and cast specimens for testing. In addition, furnish necessary testing equipment and tools to perform sampling, slump tests and yield tests. Furnish boxes for shipping samples.
2. Perform strength tests by making not less than one set of standard cylindrical test specimens for each 100 cubic yards of concrete or any portion thereof for each structure.
   a. For each work shift, when concrete is delivered, make at least one set of specimens. A set of test specimens consists of at least three standard cylinders from a batch.
   b. Perform slump tests, unit weight and air content tests with no less frequency than that of strength-specimen sets.
3. Concrete strengths:

a. Determine strengths from standard test specimens according to ASTM C31 and ASTM C172 and cured and tested in accordance with ASTM C39 by the testing laboratory. Core drilling and testing in accordance with ASTM C42.Consider the effects of corrosion-inhibiting admixture and other admixtures on the strength of the concrete, in the concrete mix design. The corrosion-inhibiting admixture and other admixtures must be present in the concrete used for the test of the proposed mix strength.
b. Compute and evaluate in accordance with ASTM C94.

F. Variability of Constituents in Concrete:
1. Take representative samples of concrete mortar.
2. Maximum allowable unit-weight variation of air-free mortar taken from consecutive batches as discharged from mixer:
a. Average of two mortar weights: 0.8-percent maximum.
b. Average of six mortar weights: 0.5-percent maximum.
3. Maximum allowable weight variation of coarse aggregate per cubic foot of concrete taken from consecutive batches as discharged from mixer.
a. Average of two weights: Five-percent maximum.

G. Batching Plant:
1. Arrangement:
a. Provide separate bins or compartments for each size or classification of aggregate and for bulk portland cement, ground-iron blast-furnace slag or fly ash.
2. Compartments:
a. Provide compartments of ample size, so constructed that materials will be kept separated under working conditions. Equip batching plant so that flow of each material into its batcher is stopped automatically when designated weight has been reached.
b. Weigh aggregates in separate weight batches with individual scales or cumulatively in one batcher on one scale. Weigh bulk cement on separate scale in separate weight batcher. Weigh ground-iron blast-furnace slag or fly ash on the same scale in the same weight batcher containing the bulk cement. Weigh and record bulk cement first; then add to the bulk cement, weigh and record the ground-iron blast-furnace slag or fly ash. Weigh and record the cumulative bulk cement and ground-iron blast-furnace slag or the bulk cement and fly ash.
c. Water amount may be measured by weight or volume. If measured by weight, do not weigh cumulatively with other ingredients.
d. Interlock batching controls so that charging mechanism cannot be opened until scales have returned to zero. Satisfy these requirements by semi-automatic batching system as defined in the Concrete Plant Standards of the CPMB, with specified interlocking, or by automatic-batching system as defined in the Concrete Plant Standard.
e. Arrange plant so as to continuously facilitate inspection of operations. Provide facilities for obtaining representative samples of aggregate from each bin or compartment for test purposes.
f. Deliver materials from batching equipment within limits specified in ASTM C94.
g. Subject to approval, accomplish batching in accordance with ASTM C685, in lieu of weight batching, provided batching plant complies with requirements of CPMB Concrete Plant Standards.
3. Water batcher and admixture dispensers:
a. Provide equipment for batching water and air-entraining or other admixtures at batching plant except in cases where mixing is to be performed at jobsite in paving mixers or in truck mixers.

b. Provide water-measuring device capable of measuring mixing water within specified requirements for each batch. Provide mechanism for delivering water to mixers so that leakage does not occur when valves are closed.
c. Interlock filling and discharge valves for water batcher so that discharge valve cannot be opened before filling valve is fully closed.
d. Introduce admixtures in solution form.
e. Provide measuring devices for admixtures capable of ready adjustment to permit varying quantity of admixture to be batched. Interlock dispenser for admixtures with batching and discharging operations so that batching and discharging of mixture will be automatic.
f. If noninterlocked dispensers are permitted, check calibration of dispensers at directed intervals. Record results of such calibration for inspection by the Engineer.

4. Moisture control:
   a. Provide plant capable of ready adjustment to compensate for varying moisture contents of aggregate and to change weights of materials being batched. Provide approved electric moisture meter for measurement of moisture in fine aggregate. Calibrate as often as directed.
   b. Moisture content of fine aggregate not to exceed eight percent. Arrange sensing element so that measurement is made near batcher.
5. Scales:
   a. Provide accurate measurement facilities for and control of each of the materials entering each batch of concrete. Provide accurate weighing equipment in accordance with NBS Handbook 44.
   b. Include in each weighing unit a visual springless dial to indicate scale load at each stage of weighing operation or include beam scale with beam balance indicator to show scale in balance at zero load and at each beam setting, indicator to have undertravel and overtravel equal to at least five percent of capacity of beam.
   c. Provide standard test weights and other auxiliary equipment necessary to verify operating performance of each scale or other measuring device.
   d. Make periodic tests in the presence of the Engineer at directed intervals. Upon completion of each check test and before further use of indicating, recording and control devices, make adjustments, repairs or replacements as necessary to ensure satisfactory performance.
6. Recorders:
   a. Provide accurate recorder for producing digital printout of scale readings corresponding to each concrete ingredient of each concrete batch, including zero initial readings; indicate presence of each individual admixture by corresponding code in lieu of weight or volume record.
   b. Record water in gallons where batched by volume. In addition, on each printout show date and time of batching, identification number identical to that of concrete delivery ticket and codes for mix design and for project section.
   c. Prepare printout in duplicate and submit one copy with its corresponding concrete ticket at the time and site of concrete placement.
   d. House each recorder in locked cabinet.
   e. Place recorders in position convenient for observation by plant operator and the Engineer.
7. Protection:
   a. Protect weighing, indicating and control equipment against exposure to dust and weather; isolate against vibration or movement caused by other operating equipment.
8. Dry batching:
   a. When bulk cement and aggregates are hauled from central batching plant to mixers, place cement, ground-iron blast-furnace slag or fly ash for each

batch in an individual compartment which, during transit, will prevent cement from intermingling with aggregates and will prevent loss of cement.

b. Provide bins of batch trucks with suitable covers to protect materials.

c. Provide batch compartments of sufficient capacity to prevent loss in transit and to prevent spilling and intermingling of batches as compartments are being emptied.

H. Allowable Concrete Finish Tolerances:

1. Finish concrete elements to dimensions, elevations and positions shown within the tolerances specified for each:

a. Formed surfaces such as walls, roof soffits, columns, beams and girders: Plus-or-minus 1/4 inch.

b. Arches: Plus-or-minus 1/2 inch.

c. Bearing-assembly locations of aerial structure piers and abutments: Plus-or-minus 1/16 inch.

d. Traction-power substations, tie-breaker stations and ac-switchboard rooms: Plus zero or minus 1/4 inch.

e. Safety walks, vertical and horizontal: Plus-or-minus 1/2 inch.

f. Station platforms:

1) Vertical: Plus-or-minus 1/4 inch.

2) Horizontal, measured from centerline of track to edge of platform: Plus 1/4 inch or minus zero.

g. Invert slabs and floating slabs:

1) Maximum deviation from profile grade: Plus zero or minus 1/2 inch.

2) Maximum deviation from 10-foot steel straightedge: Plus-or-minus 1/8 inch, noncumulative.

3) Verify adequacy of finish for draining by hosing area. Ponding or obstructions to flow toward invert drains constitute defects.

h. Invert under floating slabs:

1) Maximum deviation from profile grade: Plus zero, minus 1/2 inch.

2) Maximum deviation from 10-foot steel straightedge: Plus-or-minus 1/8 inch, noncumulative.

I. Water tightness Criteria:

1. Maximum allowable water leakage:

a. Permanent-support lining for circular and horseshoe tunnels, including joints:

1) 0.14 gallons per minute per 250 linear feet.

2) 0.07 gallons per minute in any 10 linear feet.

b. Single-box, cut-and-cover line structures, including joints:

1) 0.12 gallons per minute per 250 linear feet.

2) 0.06 gallons per minute in any 10 linear feet.

c. Double-box or cross-over, cut-and-cover line structures, including joints:

1) 0.08 gallons per minute per 250 linear feet.

2) 0.04 gallons per minute in any 10 linear feet.

d. Passenger stations, other public spaces, NATM tunnels and two-pass system tunnels where full wrap-around waterproofing is used: No leakage permitted.

3.02 MATERIAL PREPARATION:

A. Mixing Concrete:

1. Operations:

a. Provide concrete mixers that discharge concrete of uniform composition and consistency.

b. Combine coarse aggregates of different gradation and identical sources, provided corresponding concrete mix has been approved. The use of alternate batches of gravel, crushed gravel or crushed stone of a single size is prohibited.
c. Adequacy of mixing will be determined by the Engineer by means of mixer performance tests in accordance with USBR Concrete Manual, Designation 26, Variability of Constituents in Concrete, in the appendix.
d. The Engineer may reduce size of batch to be mixed or increase mixing time when charging and mixing operations fail to produce concrete which conforms to specified requirements and which has uniform coloration and consistency.
e. Add water prior to, during and following mixer-charging operations. Do not overmix or add water to maintain consistency.
f. Use of concrete to which water in excess of amount permitted by approved design mix has been added to overcome conditions caused by excessive retention in mixer is prohibited.

2. Central-mixed concrete:
a. Arrange mixers in centralized mixing plant so that mixing action in mixers can be conveniently observed by the Engineer and plant operator.
b. Do not load mixers in excess of rated capacity. Mix concrete ingredients in batch mixer for not less than period of time specified for various mixer capacities after each ingredient except full amount of water is in mixer. Reduce mixing time if thorough mixing as specified can be obtained in less time and if approved.
c. Mixing time:

Cubic-Yard Capacity of Mixer	Mixing Time
2 or less	1-1/2 minutes
3	2 minutes
4	2-1/2 minutes
More than 4	To be determined per ASTM C94 tests by the Engineer

d. Equip each mixer with mechanically operated batch counter and timing and signaling device to indicate completion of mixing period.

3. Truck-mixed concrete: Use equipment and procedures that conform to the requirements of ASTM C94 and ACI 304, Chapter 5, with the following additional requirements:
a. Introduce materials, including water and mixtures, into the mixing drum only at the central batching plant, or
b. Transport aggregates from the central plant to the jobsite in the mixing drum and add measured and recorded cement, admixtures and water into the drum prior to mixing at discharge point.
c. When ice is used, add it with the water and counted as part of the water-cement ratio.

d. Place concrete within 90 minutes after cement is introduced into the mixing drum.
e. Accomplish initial mixing by 70 to 100 revolutions with drum rotating at the manufacturer's recommended speed. 30 revolutions at mixing speed will be required, if the addition of water is permitted. Do not exceed total of 300 mixing and agitating revolutions.

4. Temperature control:
a. Use preparation methods capable of producing concrete with temperature 85F maximum and 55F minimum at time of placement.
b. Do not heat concrete ingredients to temperature higher than that necessary to keep temperature of mixed concrete as placed within specified temperatures.
c. Do not heat water in excess of 140F.

B. Admixtures:
1. Introduce admixtures in solution form.
2. Air-entraining admixture: Use for concrete exposed to weathering or in contact with rock or moist soil.
3. Chemical admixtures:
a. Use water-reducing admixtures in concrete areas below grade in contact with rock, earth or fill.
b. Employ admixtures without interfering with specified air-content dosage of air-entrained concrete.
c. Except as otherwise specified or approved, use of water-reducing, set-retarding or set-accelerating admixtures is prohibited.
d. If introduction of certain admixtures to improve concrete strength is approved, do not reduce cement content below minimum amounts specified.

C. Consistency:
1. For concrete to be compacted by approved mechanical vibrators, maintain slump range at point of delivery within the following limits:
a. Concrete pavement, pavement base, sidewalk and incidental construction: Two to three inches.
b. Unreinforced concrete other than pavements: One to three inches.
c. Reinforced concrete: Two to four inches.
d. Concrete placed by pumping and concrete for filling steel-shell piles: Four to five inches.
e. Do not use concrete if slump exceeds maximum by 1/2 inch or more.

D. Lightweight Structural Concrete:
1. Prepare lightweight structural concrete with minimum cement content as follows:

Compressive Strength	Cement Content Bags Per Cubic Yard
2,000 psi	4 to 7
3,000 psi	5 to 8
4,000 psi	6 to 9
5,000 psi	7 to 10

2. Air-entrainment:
a. Use air-entraining admixture in lightweight structural concrete to provide not less than four nor more than six percent of entrained air.

3. Dry unit weight:
   a. Prepare lightweight structural concrete to provide air-dry weight required by design but not less than 90 pounds per cubic foot.
4. Consistency:
   a. Maintain slump range within two to four inches.

3.03 CONVEYING:

A. General:
1. Provide equipment for conveying concrete from mixer with continuous flow of concrete to point of placement without segregation.
2. Provide arrangement at discharge end of conveyor to prevent segregation.
3. Design long conveyor runs to discharge concrete into hopper, without segregation, before it is deposited in forms.
4. Ensure that pumps, pneumatic equipment, pipes, chutes and troughs are cleaned of dirt and concrete before use.

B. Chutes and Troughs:
1. Use only ferrous-metal-lined chutes and open troughs. Where steep slopes are unavoidable, equip chutes or troughs with baffles to minimize segregation of aggregates. Keep chutes or open troughs clean of hardened concrete by flushing with water after each use.
2. Discharge water used for cleaning outside lines of structure. Lay out chutes or open troughs with slope one-foot vertical to two feet horizontal maximum and one-foot vertical to three feet horizontal minimum.
3. Discharge chutes 20 feet or more in length into hopper before final distribution.

C. Adjustable Length Pipes (Elephant Trunks):
1. Use flexible pipes of ferrous metal, rubber or plastic, six inches minimum diameter so as to prevent segregation of concrete.
2. Position chutes or flexible pipes so that concrete is delivered in continuous flow to points not more than five feet horizontally and five feet vertically from final location. In vicinity of expansion and contraction joints, reduce horizontal distance to three feet maximum.
3. Clean flexible pipes and elephant trunks after each use.

D. Buggies:
1. Construct runways for buggies so they will not come into contact with or be supported by reinforcing steel of structure.

E. Pumping and Pneumatic Conveying Equipment:
1. Use pumping and pneumatic conveying equipment, designed to handle without segregation types, classes and volumes of concrete to be conveyed.
2. Operate pump or pneumatic equipment so that continuous stream of concrete without air pockets is produced. Position discharge end of line as near final position of concrete as possible but in no case more than five feet away.
3. At conclusion of placement, clean equipment. Discharge debris and flushing water outside of forms.

3.04 PLACEMENT:

A. General:
1. Prior to placing concrete, remove debris and extraneous material from interior of forms.

2. Place first lift of concrete on wet surface. Consolidate by dragging vibrator along edges of joints. Make sure there is no free or standing water over the surface.
3. Place concrete continuously and as rapidly as possible after mixing. Do not use vibrators for shifting mass of fresh concrete.
4. Place concrete in layers of such thickness that no concrete will be deposited on concrete which has hardened sufficiently to cause formation of seams or planes of weakness. Cover each layer of concrete with fresh concrete within 45 minutes.
5. Do not place concrete which has attained initial set or concrete which has contained mix water for more than 90 minutes.
6. Remove temporary spreaders in forms when concrete has reached elevation which makes them unnecessary.
7. Place column concrete using adjustable-length flexible pipes or elephant trunks to avoid dropping concrete over five feet. In monolithic placements, do not deposit concrete in supported elements such as beams, girders and slabs until concrete previously deposited in columns or walls has completed its settlement shrinkage, but not to the point at which concrete in supporting members will not permit vibrator to sink into its mass of its own weight.
8. Placing will not be permitted when sun, heat, wind or limitations of facilities will prevent finishing and curing.
9. Concrete temperature at time of placement:
   a. 55F, minimum.
   b. 85F, maximum.
10. Unless approved, do not continue concreting when descending ambient air temperature falls lower than 40F.
11. Prior to placing fresh concrete against rock or previously placed concrete, take necessary steps, such as flushing with water, to ensure removal of foreign matter which would adversely affect bond.
12. Maintain wire fabric and other reinforcing in proper position on chairs during concrete placement.

B. Underwater Concrete Placement:
1. Place concrete carefully and continuously in compact mass by means of tremie or underwater bottom-dump bucket; do not disturb after depositing. Maintain still water at point of deposit. Use tight forms. In placing concrete, produce approximately horizontal surfaces.
2. Do not perform pumping within area until concrete has set at least 48 hours.
3. Tremie:
   a. Provide tremie consisting of watertight tube, 10-inch minimum diameter, with hopper at top. Equip tube with device to close discharge end and prevent water from entering tube while charging tube with concrete.
   b. Support tremie so as to permit free movement of discharge end over entire top surface of work and to permit rapid lowering when necessary to retard or stop flow of concrete.
   c. Close discharge end at start of work to prevent water entering tube and maintain entirely sealed, except when concrete is being placed. Keep tremie tube full of concrete.
   d. Maintain continuous flow until work is complete and resulting concrete seal is monolithic and homogenous. Control tremies so that concrete will be effectively compacted into horizontal layers not more than 12 inches thick.
   e. Space tremies so as to avoid segregation.

C. Consolidation:
1. Consolidate concrete thoroughly as it is placed in order to secure a dense mass. Work concrete well around reinforcement, embedded items and into the corners of forms. Consolidate concrete in accordance with ACI 309.
2. Use internal vibrators unless external vibrators are approved.

3. Use vibrators capable of generating frequencies of not less than 7,000 impulses per minute. Verify that vibrators have power and amplitude factor so as to visibly affect mass of concrete of one-inch slump over radius of at least 18 inches. Prevent formation of laitance and accumulation of excessive water on surface of concrete as it is deposited. Remove excessive water by pumping or other approved means.
4. When consolidating concrete in haunches, girders, beams or slabs, ensure that vibrator penetrates and revibrates previously placed concrete in top of supporting members.
5. Do not use vibrators where internal vibration might cause damage to embedded items; in such cases spading is required.

3.05 CURING AND PROTECTING:

A. General:
1. Protect freshly placed concrete from excessively hot or cold temperatures. Maintain without drying for period of time necessary for hydration of cement and proper hardening of concrete.
2. Provide sufficient tarpaulins to cover completely or enclose forms and working areas prior to and during placing and finishing operations.
3. Cure newly placed concrete continuously for seven days at ambient temperature in excess of 55F.
4. Cure concrete in subway structures by normal curing method specified.
5. During curing period keep steel and wood forms wet. If forms are removed during curing, use one of the following methods of curing immediately and continue for remainder of the curing period.

B. Normal Curing and Protection:
1. Use one of the following methods for flat surfaces, weather permitting:
   a. Use ponding on horizontal surfaces providing surface is continuously submerged for required curing period.
   b. Apply continuous sprinkling with nozzle or nozzles which, during first 24 hours, atomize flow of water providing a mist and not a spray. Do not apply moisture under pressure directly upon concrete; avoid flowing or washing on surfaces while susceptible to erosion.
   c. Cover entire surface of concrete with double thickness burlap sheet, laid directly on concrete and kept continuously wet. Maintain in good condition.
   d. Sprinkle concrete surface as specified for at least 18 hours and immediately cover with waterproof curing sheet, free from holes or tears. Hold in position so that entire surface of concrete is fully and continuously covered.
   e. Do not damage burlap, waterproof sheet or concrete surfaces.

C. Membrane-Forming Curing Compound:
1. Use curing compound when approved for circumstances where application of moisture is impracticable and where such compounds will not jeopardize appearance of concrete. Except as otherwise specified, use Type-1 compound, uniformly applied over surface at thickness recommended by manufacturer. Thoroughly mix compound and apply within one hour after mixing.
2. Where surfaces are subject to sunlight, apply Type-2 compound. Except for surfaces exposed to public view and architectural finished concrete.
3. Do not apply wax-resin curing compounds to surfaces requiring bond for additional concrete or where bonded surface coating such as paint, tile, dampproofing, waterproofing or roofing is to be applied.
   a. Do not apply curing compound to floors to be chemically sealed.

4. Warm or stir curing compound if necessary for satisfactory application in accordance with manufacturer's recommendations. If film of compound is damaged before expiration of curing period, repair immediately with additional compound.
5. Inside surfaces of tunnels, cut-and-cover boxes and other surfaces specifically approved may be cured with Type-1 membrane curing compound.
6. Finish surfaces prior to application of curing compound. Do not use curing compound on construction joints.
7. Apply curing compound in two coats. Apply first coat immediately after stripping of forms and acceptance of concrete finish.
8. If surface is dry, thoroughly wet concrete with water and apply curing compound just as surface film of water disappears. Apply second coat after first coat has set.
9. Protect coating against damage for at least 10 days after application. If damage occurs, apply additional coating.
10. If use of curing compound results in streaked or blotchy appearance, cease operations and use other method of curing until cause of defective appearance is corrected.

D. Floor Treatment:
1. In accordance with recommendations of manufacturer of floor hardener, apply floor curing compound and curing sheet to surfaces to receive floor hardener.
2. Where such surfaces are subject to sunlight, protect them by tenting white opaque, polyethylene waterproof sheet.

E. Protection of Rod Reinforcement:
1. After forms are removed, coat rod reinforcement and dowels extending beyond concrete surfaces with application of neat cement paste.
2. Remove hardened cement paste and resultant debris immediately prior to extension of reinforcement or installation of formwork.

3.06 COLD WEATHER CONCRETING:

A. Do not place concrete when ambient temperature is less than 55 º F and falling. Do not place concrete unless the form temperature at the time of placement is at least 40 º F.

B. When ambient temperature is 40 º F and falling, carry out one of the following procedures to protect placed concrete:
1. Heating:
a. Enclose forms or structures and heat to maintain concrete and air within enclosure at not less than 55 º F for seven days after placement.
b. Maintain relative humidity at not less than 40 percent during curing period when heat is applied to enclosures. Arrange stoves, salamanders or heaters so as to provide uniform distribution of heat. Vent combustion gases to outside air. Do not let hot air blow across concrete surfaces.
c. After seven-day curing period, reduce temperature within enclosure gradually at maximum rate of 20 º F per day until outside temperature has been reached.
d. Provide continuous and adequate fire protection and watchmen when heating units are in operation.
2. Form insulation:
a. Insulate forms with blanket insulation of approved type and thickness to maintain concrete at 55 º F minimum for seven days.
b. Protect top of placed concrete by tarpaulins or other approved waterproof material over insulation.

C. Do not allow concrete to freeze in a saturated condition prior to achieving a strength of 4000 psi.

3.07 HOT WEATHER CONCRETING:

A. When temperature in forms is 75F or above, carry out the following procedures to protect placed concrete:
   1. Protect concrete from direct sunlight.
   2. Keep forms moist by means of cool-water sprinkling or application of wet burlap or cotton mats.
   3. At 90F or above cool aggregates with water spray hoses.
   4. Cool truck barrels with water spray system.

3.08 JOINTS:

A. General:
   1. Unless otherwise shown make construction joints bonded joints by roughening surface to expose aggregates. Clean and roughen surface by wet sandblasting, by cutting with high-pressure water jet with a minimum pressure of 2,000 psi or by other approved means. Perform cleaning after concrete has hardened to prevent raveling of surface.
   2. Exercise caution in cleaning concrete to prevent damage to waterstops.
   3. Treat overlays on slabs the same as for rock or other bonded joint.
   4. Place construction joints at locations shown, or at locations approved by the Engineer.

B. Horizontal Construction Joints:
   1. Joints within 18 inches of tops of faces are prohibited.
   2. Trowel top surface of concrete adjacent to forms smooth to minimize visible joints on exposed faces. Remove laitance and other objectionable materials from joint surface to expose sound concrete as soon as concrete is firm enough to retain its form.
   3. Immediately after placement of concrete, remove accumulations splashed on exposed reinforcement and surfaces of adjacent forms before concrete attains initial set.

C. Other Joints:
   1. Place concrete for rock tunnels with vertical contraction joints, with vertical or sloping construction joints or continuously without joints.
   2. Install forms for vertical joints. Remove forms as soon as concrete has attained sufficient strength to be self-supporting.

D. Waterstops:
   1. Provide waterstops per Section 03100, Article 3.7.
   2. Rework or replace concrete where waterstop has moved unacceptably.
   3. Support water stop in exact position, do not sink water stops in fresh concrete.

3.09 CONCRETE FINISHING:

A. When forms are removed, do not remedy voids, stone pockets and other defects until the Engineer has inspected them and given directions.

B. Finish concrete surfaces as shown and as follows:
   1. Number-1 Form Finish:

a. Immediately following form removal, remove fins and irregular projections from surfaces exposed to view or those that will receive waterproofing.
b. Prepare pointing mortar not more than 30 minutes prior to use.
c. Cure mortar patches as specified under curing and protection.
d. Leave contraction joints and articulated joints in completed work carefully tooled and free of mortar and concrete.
e. Leave joint filler exposed for its full length with clean and true edges.
f. Apply this finish to structures, unless otherwise shown.

2. Number-2 Wet-Rubbed Finish:
   a. Start rubbing of concrete after removal of forms and as soon as its condition will permit. Keep concrete thoroughly saturated with water before starting this work.
   b. Allow sufficient time to elapse before wetting down to allow pointing mortar to thoroughly set. Rub surfaces with medium-coarse carborundum stone.
   c. Continue rubbing until form marks, projections and irregularities have been removed, voids are filled and uniform surface is obtained.
   d. Leave paste produced by rubbing in place. Obtain final finish by rubbing with fine carborundum stone and water after concrete above surface being treated has been cast. Continue rubbing until entire surface is of smooth texture and uniform color. After final rubbing is completed and surface has dried, rub with burlap to remove loose powder and objectionable marks.
3. Number-3 Broomed Finish:
   a. Where floors and other areas are shown to have rough finish, strike-off surface with screeds and wood floats at elevation shown.
   b. Before concrete has achieved initial set, broom transversely to flow of traffic with stiff, medium-bristle broom especially made for intended purpose to develop corrugations not more than 1/8-inch deep.
4. Number-4 Steel-Troweled Finish:
   a. Where floors are shown to have a steel-troweled finish, screed concrete to established grades and compact with wood or power-driven disc float.
   b. After surface has hardened sufficiently, finish with steel trowel to dense hard finish, free of trowel marks.
   c. Do not use dry cement or mixture of dry cement and sand to absorb water.
5. Number-5 Wood-Float Finish:
   a. Screed inverts of subway structure, floors not specified or shown to be finished otherwise, areas below floating slabs and areas to receive dampproofing, waterproofing or roofing to a true and uniform surface conforming to shape and elevations shown.
   b. Follow with wood-float finish to tolerances specified.
   c. On slabs and floors, where drainage is shown, maintain accurate slopes for drainage.
   d. Protect floors and slabs until final acceptance.
6. Number-6 Sandblast-Sealer Finish:
   a. Where concrete surfaces are shown to receive sandblast finish and a sealer prepare sample using sandblast finish on file in the Engineer's office as criterion.
   b. Prepare samples with degree of sandblasting which will produce uniform texture on surface of concrete. Blast to achieve smooth, sanded surface approximately equivalent to 100-120 grit sandpaper finish.
   c. Sandblasted surfaces will be inspected before sealing and compared with approved samples.
   d. Apply concrete surface sealer to sandblast finish in accordance with approved procedures.
7. Number-7 Natural-Board Finish:
   a. After stripping forms, cut back form ties as specified. Touch-up holes created by form ties and damaged or defective finish using grout closely

matching surrounding concrete. Accomplish grouting and repairs as specified. Knock-off heavy elongated fins, but do not rub down.

8. Number-8 Abrasive-Aggregate Finish:
   a. After screeding and floating as for Number-4 Finish, apply abrasive aggregate at rate of not less than 0.6 pound per square foot.
   b. Sprinkle evenly in two applications using one half the amount for each application. Apply second half at right angle to first.
   c. Follow with wood float; lightly tamp or roll surface to embed aggregate flush with concrete surface.
   d. Lightly steel trowel to smooth, even finish.
   e. After curing, rub surface using abrasive brick with water to slightly expose abrasive aggregate.

C. Do not sprinkle water or cement on surfaces to be trowel finished.

3.10 FLOOR TREATMENT:

A. Sealer:
1. Water cure floor surfaces to be sealed for 28 days minimum and ensure that they are completely dry before treatment.
2. Complete overhead work before sealer is applied.
3. Apply liquid floor sealer in three separate coats as recommended by the manufacturer using maximum quantity recommended. Allow to dry between applications.

B. Floor-Hardener System:
1. Areas of application: Concrete floor surfaces as shown.
2. Preparation:
   a. Strike concrete to established grade using wooden strike-off bar. Further level and consolidate concrete with wood bull float or wood darby immediately following strike-off. Complete before free moisture rises to surface.
   b. Begin floating adjacent to columns, forms and walls where concrete is most likely to stiffen first.
3. Application:
   a. Apply at uniform rate of 1.8 to 2.2 pounds of hardener per square foot of floor surface.
   b. Apply first shake to floated concrete adjacent to forms, columns, and walls where moisture will be lost first. Apply 2/3 of specified total shake immediately following floating of total area as follows:
      1) Distribute evenly.
      2) Throwing shake is prohibited.
      3) Perform hand floating with wood floats. Magnesium floats are prohibited.
   c. Use finishing machines with float blades as soon as shake has absorbed moisture as evidenced by darkening of surface. Do not allow float blades to dig into surface. Float sufficiently to bring moisture from base slab through shake.
   d. Immediately after floating first shake, apply remaining 1/3 of total specified shake in the same manner and machine float as specified. Plan operations to avoid necessity of sprinkling water on surface.
   e. As surface stiffens as evidenced by loss of sheen, finish by hand steel trowel removing marks and pinholes; leave surface in uniform condition with relatively smooth but nonslip surface.
4. Field service:

a. During installation, provide services of qualified representative of manufacturer to aid in proper use of product. Notify manufacturer three days minimum prior to initial application of product.

5. Quality control:

a. Prior to installation, submit for approval detailed quality-control plan describing method of application of floor hardener and listing items to be checked to ensure that materials are placed at proper time and in proper manner to achieve optimum durability of finished floor surface. Prior to submittal, have quality-control plan authenticated by qualified representative of material manufacturer indicating manufacturer's approval.

b. Submit quality-control reports authenticated by manufacturer's representative verifying that installation has been made in accordance with approved quality-control plan.

3.11 DEFECTIVE CONCRETE:

A. Concrete will be considered defective unless it is structurally sound, watertight, properly finished and within specified tolerances.

B. Concrete in place that is deemed structurally defective will be checked by the Engineer by drilled core specimens. If testing of core specimens shows that strength is less than 85 percent of specified strength, costs incurred in taking and testing of core specimens will be borne by the Contractor.

C. Replace, strengthen or correct defective concrete as directed.

3.12 PROTECTION FROM AND REMOVAL OF STAINS:

A. Protect concrete structure from rust staining by structural-steel members or from other substances during the work.

B. If staining should occur, remove stains and restore concrete to its original color.

3.13 DAMAGED WORK:

A. Before final acceptance of the work, neatly repair damaged surfaces, corners of concrete and concrete finish.

B. Where surface repairs are permitted, finish damaged areas to smooth, dense watertight condition.

C. Replace concrete that is not satisfactorily repaired.

3.14 CORRECTIVE WORK:

A. Submit corrective action patching procedure.

B. If correction of defects is approved, remove defective concrete; key area to be repaired, soak surface with water and patch with approved materials. Patch architectural concrete so as to match existing. Use bonding agents applied to the substrate or mixed with patching material only as approved by the Engineer.

C. Clean surface cavities produced by form ties, other holes, honeycomb spots, broken corners or edges and other defects. Saturate with water and point with mortar paste consisting of

cement and fine aggregate mixed in proportions to give same appearance as original concrete.

D. Prepare pointing mortar not more than 30 minutes prior to use. Cure mortar patches properly. Carefully tool contraction and articulated joints in completed work and keep them free of concrete. Where necessary, leave joint filler exposed for its full length with clean and true edges.

E. Tolerance deviations and other surface defects may also be corrected, if approved, by grinding high areas and swales. Leaks in station electrical rooms, TPSS and TBS shall be epoxy injected.

F. Where necessary or when directed, repair leakage in excess of specified maximum allowable, by means of contact grouting, chemical grouting or other approved means.

G. Where corrective work is unsatisfactory, completely remove such work and replace with new work complying with specified requirements.

3.15 EPOXY MORTAR REPAIRS:

A. Surface Preparation:
1. Remove defective concrete with chipping hammers or other approved equipment. To prevent removing extra material and causing cracks, saw-cut concrete area to be removed into maximum six-inch square checkerboard pattern 4-1/2 inches deep.
2. Prepare exposed concrete surface by sandblasting clean and allowing to dry thoroughly. Surface drying may be accomplished by air jet. Ensure that compressed air used in cleaning and drying is free from oil or other contaminating materials.
3. Maintain concrete surface in sufficient depth at temperature of 65F minimum during first four hours after placement of epoxy bond coat. Preheating may be done with radiant heaters or other approved means. Do not preheat concrete in excess of 200F with final surface temperature below 105F at time of placing epoxy materials.

B. Application of Epoxy Bonding Agents:
1. Prepare epoxy bonding agent in accordance with manufacturer's recommendations.
2. Apply epoxy bonding agent to prepared dry concrete surface at coverage of 80 square feet per gallon maximum or as recommended by manufacturer
3. Epoxy bonding agent may be applied by any convenient and safe method which will yield effective coverage, such as squeegees, brushes or rollers.
4. During application of epoxy bonding agent, ensure that material is confined to area being bonded; avoid contamination of adjacent surfaces. Extend epoxy bond coat slightly beyond edges of repair area.

C. Application of Epoxy Mortar:
1. Mix epoxy components in accordance with manufacturer's recommendations.
2. Proportion: 5-1/2 parts sand by weight to one-part epoxy.
3. Mix components with slow-speed mechanical device.
4. Prepare mortar in small batches so that each batch can be completely mixed and placed within approximately 30 minutes.
5. Do not add thinners or dilutants to mortar mixture.
6. Immediately after application of epoxy bonding agent, place, tamp, flatten and smooth epoxy mortar.
7. Work mortar to grade.
8. Steel-trowel finish. Trowels may be heated to facilitate finishing.

D. Curing:

1. Cure epoxy mortar repairs immediately after completion at 60F minimum until mortar is hard.
2. Initiate post-curing of four hours minimum at surface temperature of 90F minimum, 110F maximum.
3. Heat may be applied by using portable propane heaters, infrared heaters or other approved sources positioned to attain necessary surface temperature.
4. Do not subject epoxy-bonded epoxy mortar to moisture until after specified post-curing has been completed.

3.16 CONCRETE OVERLAYS AND TILE SETTING BEDS:

A. General:
1. Water blast (3,000 - 5,000 psi) or sand blast the substrate.
2. Keep slabs continuously wet for 24 hours prior to concrete placement. Substrate to be air blown just prior to concrete placement.
3. Place concrete in two pours of equal thickness. Place welded-wire-fabric reinforcement on first pour and then place second pour.
4. Use a vibratory screed on overlays.
5. Float slab and apply light broom finish. Cure slabs with water.
6. Remove laitance by methods in number one above if the overlay requires a bonding surface for tile or other treatments.
7. Continuously moist cure of overlay(setting bed) for seven(7) days.

END OF SECTION

SECTION 03331

CAST-IN-PLACE ARCHITECTURAL CONCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This Section specifies cast-in-place architectural concrete, including form work reinforcement accessories, concrete materials, concrete mix design, placement procedures, and finishes.

B. Related Work Specified Elsewhere:
1. Concrete Formwork: Section 03100 .
2. Concrete Reinforcement: Section 03200.
3. Cast-in-Place Structural Concrete: Section 03300.
4. Seals and Sealants: Section 07900.

1.02 DEFINITION:

A. Cast-in-Place Architectural Concrete: Concrete that is exposed to view on surfaces of the completed structure or building and that requires special concrete materials, formwork, placement, or finishes to obtain specified architectural appearance.

B. Design Reference Sample: Sample designated by The Engineer in the Contract Documents that reflects acceptable surface quality and appearance of cast-in-place architectural concrete.

C. Reveal: Projection of the coarse aggregate from the matrix after exposure.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the Special Conditions and with the additional requirements as specified for each:
1. Product Data: For each type of manufactured material and product indicated.
2. Design Mixes: For each concrete mix. Include alternate mix designs when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant adjustments.
3. Shop Drawings: Show formwork construction including form-facing joints, rustications, construction and contraction joints, form joint-sealant details, form tie location and patterns, inserts and embedments, cutouts, cleanout panels, and other items that visually affect cast-in-place architectural concrete.
4. Samples: For each of the following materials
   a. Form-facing panel.
   b. Form-release agent.
   c. Form ties.
   d. Form liners.
   e. Cement.
   f. Coarse- and fine-aggregate gradations.
   g. Chamfers and rustications.
   h. Curing compound.
   i. Coloring admixtures.
5. Samples for Verification: Architectural concrete samples, cast vertically, approximately 18 by 18 by 2 inches, of finishes, colors, and textures to match the design reference sample. Include Sample sets showing the full range of variations expected in these characteristics.

6. Material Test Reports: From a qualified testing agency indicating and interpreting test results of the following for compliance with requirements indicated, based on comprehensive testing of current materials:
7. Material Certificates: Signed by manufacturers certifying that each of the following materials complies with requirements:
   a. Cementitious materials and aggregates.
   b. Admixtures.
   c. Curing compounds.
8. Placement Schedule: Submit concrete placement schedule before start of architectural concrete placement operations. Include location of all joints including construction joints.

1.04 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. ASTM C 33, C 94, C 144, C 150, C 171, C 260, C 309, C 494, C 618, C 881, C920, C 979, C989, C 1077, C 1059, E 329, E 548, M 182
2. ACI CP-1,117, 301, 303, 303.1, 309R.
3. AAMA 810.1.
4. AASHTO M 182.

B. Installer Qualifications: An experienced cast-in-place architectural concrete contractor who has specialized in installing cast-in-place architectural concrete similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.

C. Concrete Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products complying with ASTM C 94 requirements for production facilities and equipment.

D. Testing Agency Qualifications: An independent testing agency, acceptable to authorities having jurisdiction, qualified according to ASTM C 1077 and ASTM E 329 to conduct the testing indicated, as documented according to ASTM E 548.
1. 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 recognized by ASTM C 1077.

E. Source Limitations for Cast-in-Place Architectural Concrete: Obtain each color, size, type, and variety of concrete material and concrete mix from one manufacturer with resources to provide cast-in-place architectural concrete of consistent quality in appearance and physical properties.

F. ACI Standards: Comply with ACI 303.1, "Specification for Cast-in-Place Architectural Concrete"; ACI 301, "Specification for Structural Concrete"; and ACI 117, "Specifications for Tolerances for Concrete Construction and Materials," unless more stringent provisions are indicated.

G. Sample Panels: Before casting architectural concrete, produce sample panels to demonstrate the approved range of selections made under sample Submittals. Produce a minimum of 3 sets of full-scale sample panels, cast vertically, approximately 48 by 48 by 6 inches minimum, to demonstrate the expected range of finish, color, and texture variations.
1. Locate panels as indicated or, if not indicated, as directed by the Engineer.
2. Demonstrate methods of curing aggregate exposure, sealers, and coatings, as applicable.
3. In presence of The Engineer, damage part of an exposed-face surface for each finish, color, and texture, and demonstrate materials and techniques proposed for

repair of tie holes and surface blemishes to match adjacent undamaged surface

4. Maintain sample panels during construction in an undisturbed condition as a standard for judging the completed Work.
5. Demolish and remove sample panels when directed.

H. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1 Section "Project Meetings."

PART 2 - PRODUCTS

2.01 FORM-FACING MATERIALS:

A. General: Comply with Section 03300 for formwork and other form-facing material requirements.

B. Form-Facing Panels for As-Cast Finishes: Steel, glass-fiber-reinforced plastic, or other approved nonabsorptive panel materials that will provide continuous, true, and smooth architectural concrete surfaces. Furnish in largest practicable sizes to minimize number of joints.

C. Form-Facing Panels for As-Cast Finishes: Exterior-grade plywood panels, nonabsorptive, that will provide continuous, true, and smooth architectural concrete surfaces, high-density overlay, Class 1, or better.

D. Forms for Cylindrical Columns, Pedestals, and Supports: Metal, glass-fiber-reinforced plastic, paper, or fiber tubes that will provide surfaces with gradual or abrupt irregularities not exceeding specified formwork surface class. Provide units with sufficient wall thickness to resist plastic concrete loads without detrimental deformation.

E. Pan-Type Forms: Glass-fiber-reinforced plastic or formed steel, stiffened to resist plastic concrete loads without detrimental deformation.

F. Form Liners: Units of face design, texture, arrangement, and configuration indicated or to match design reference sample. Furnish with manufacturer's recommended liquid-release agent that will not bond with, stain, or adversely affect concrete surfaces and will not impair subsequent surface treatments of concrete.

G. Rustication Strips: Metal, rigid plastic, or dressed wood with sides beveled and back kerfed; nonstaining.

H. Chamfer Strips: Metal, rigid plastic, elastomeric rubber, or dressed wood, 3/4 by 3/4 inch, minimum; nonstaining.

I. Form Joint Tape: Compressible foam tape, pressure sensitive, AAMA 810.1, minimum 1/4 inch thick.

J. Form Joint Sealant: Elastomeric sealant complying with ASTM C 920, Type M or S, Grade NS, that adheres to form joint substrates.

K. Sealer: Penetrating, clear, polyurethane wood form sealer formulated to reduce absorption of bleed water and prevent migration from wood of set-retarding chemicals.

L. Form-Release Agent: Commercially formulated form-release agent that will not bond with, stain, or adversely affect architectural concrete surfaces and will not impair subsequent treatments of those surfaces.

1. Formulate form-release agent with rust inhibitor for steel form-facing materials.

M. Surface Retarder: Chemical liquid set retarder, for application on form-facing materials, capable of temporarily delaying final hardening of newly placed concrete surface to depth of reveal specified.

N. Form Ties: Factory-fabricated, glass-fiber-reinforced plastic, internally disconnecting or removable ties designed to resist lateral pressure of fresh concrete on forms and to prevent spalling of concrete on removal.
   1. Furnish ties with tapered tie cone spreaders that, when removed, will leave holes not larger than 3/4 inches in diameter on concrete surface.
   2. Furnish internally disconnecting ties that will leave no corrodible metal closer than 1-1/2 inches, plus reveal projection of exposed aggregate, from the plane of architectural concrete surface.
   3. Heavy-duty forms engineered to resist the concrete without ties, to avoid difficulty in matching concrete color and patching form tie holes, may be submitted for approval by the engineer. This procedure is applicable only for the architectural concrete arches indicated.
   4. Furnish ties with integral water-barrier plates to walls indicated to receive dampproofing or waterproofing.

2.02 REINFORCEMENT ACCESSORIES:

A. Comply with Section 03200 and 3300 for steel reinforcement and other accessory requirements.

2.03 CONCRETE MATERIALS:

A. Portland Cement: ASTM C 150, Type I, II, or III, white color, use Type I unless otherwise approved in writing by the engineer, single source for entire Project.
   1. Alkali content not to exceed 0.6 percent.
   2. Fly Ash: ASTM C 618, Class C or F.
   3. Ground Granulated Blast-Furnace Slag: ASTM C 989, Grade 100 or 120.

B. Normal-Weight Coarse Aggregate: ASTM C 33, single source for entire Project as follows:
   1. Weathering Region and Class shall be 5S (severe).
   2. Nominal Maximum Aggregate Size: 3/4 inch, uniformly graded.

C. Normal Weight Fine Aggregate: ASTM C144, natural sand from single source.

D. Water: Potable, complying with ASTM C94 except free of wash water from mixer cleanout operations.

E. Chemical Admixtures: Certified by manufacturer to contain not more than 0.1 percent water-soluble chloride ions by mass, compatible with other admixtures and cementitious materials. Admixtures containing calcium chloride are prohibited.
   1. Air-Entraining Admixture: ASTM C 260.
   2. Water-Reducing Admixture: ASTM C 494, Type A.
   3. High-Range, Water-Reducing Admixture: ASTM C 494, Type F.
   4. Water-Reducing and Accelerating Admixture: ASTM C 494, Type E.
   5. Water-Reducing and Retarding Admixture: ASTM C 494, Type D.

F. Coloring Admixture: ASTM C 979, synthetic mineral-oxide pigments or colored water-reducing admixtures, free of carbon black; color stable, nonfading, and resistant to lime and other alkalis.
   1. Color: As necessary or if necessary to match color of sample provided.

2.04 CURING MATERIALS:

A. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, washed to prevent concrete staining, weighing approximately 9 oz./sq. yd. when dry.

B. Moisture-Retaining Cover: ASTM C 171, polyethylene film or white burlap-polyethylene sheet.

C. Clear, Liquid Membrane-Forming Curing Compound: ASTM C 309, Type 1, ClassB.
   1. For integrally colored concrete, curing compound shall be pigmented type approved by coloring admixture manufacturer.
   2. For concrete indicated to be sealed, curing compound shall be compatible with sealer.

2.05 REPAIR MATERIALS:

A. Bonding Agent: ASTM C 1059, Type II, non-redispersible, acrylic emulsion or styrene butadiene.

B. Epoxy-Bonding Adhesive: ASTM C 881, two-component epoxy resin, capable of humid curing and bonding to damp surfaces, of class and grade to suit requirements, and as follows:
   1. Types IV and V, load bearing, for bonding hardened or freshly mixed concrete to hardened concrete.

2.06 CONCRETE MIXES:

A. Prepare design mixes for each type and strength of cast-in-place architectural concrete determined by either laboratory trial mix or field test data bases. Proportion concrete according to ACI 211.1 and ACI 301.

B. Use a qualified independent testing agency for preparing and reporting proposed concrete mix designs for the laboratory trial mix basis.

C. Proportion concrete mix as follows:
   1. Compressive Strength (28 Days): 4000 psi.
   2. Maximum Water-Cementitious Materials Ratio: 0.46.
   3. Maximum Slump: 4 inches.

D. Cementitious Materials: For cast-in-place architectural concrete exposed to deicers, limit percentage, by weight, of cementitious materials other than portland cement according to ACI 301 requirements.

E. Air Content: Add air-entraining admixture at manufacturer's prescribed rate to result in architectural concrete at point of placement having an air content of 6 percent within a tolerance of plus 1 percent or minus 1.5 percent.Delete below if integrally colored concrete is not required.

F. Coloring Admixture: Add coloring admixture to architectural concrete mix according to manufacturer's written instructions.

2.07 CONCRETE MIXING:

A. Ready-Mixed Concrete: Measure, batch, mix, and deliver cast-in-place architectural concrete according to ASTM C 94, and furnish batch ticket information.

B. When air temperature is between 85 and 90 deg F, reduce mixing and delivery time from 90 to 75 minutes; when air temperature is above 90 deg F, reduce mixing and delivery time to 60 minutes.

PART 3 - EXECUTION

3.01 FORMWORK:

A. General: Comply with Section 03100 Concrete Formwork for formwork and embedded items.

B. Comply with ACI 303.1 limits on form-facing panel deflection.

C. Fabricate forms for easy removal without hammering or prying against concrete surfaces. Provide crush or wrecking plates where stripping may damage cast-in-place surfaces. Provide top forms for inclined surfaces steeper than 1.5 horizontal to 1 vertical. Kerf wood rustications, keyways, reglets, recesses, and the like, for easy removal.
   1. Do not use rust-stained, steel, form-facing material.

D. Provide temporary openings for cleanouts and inspection ports where interior area of formwork is inaccessible. Close openings with panels tightly fitted to forms and securely braced to prevent loss of concrete mortar. Locate temporary openings in forms at inconspicuous locations.

E. Chamfer exterior corners and edges of cast-in-place architectural concrete.

F. Coat contact surfaces of wood rustications and chamfer strips with sealer before placing reinforcement.

G. Form openings, chases, offsets, sinkages, keyways, reglets, blocking, screeds, and bulkheads required in the Work. Determine sizes and locations from trades providing such items.

H. Clean forms and adjacent surfaces to receive concrete. Remove chips, wood, sawdust, dirt, and other debris just before placing concrete.

I. Seal form joints and penetrations at form ties with form joint tape or form joint sealant to prevent mortar leaks

J. Retighten forms and bracing before placing concrete, as required, to prevent mortar leaks and maintain proper alignment.

K. Coat contact surfaces of forms with form-release agent, according to manufacturer's written instructions, before placing reinforcement.

3.02 REINFORCEMENT AND INSERTS:

A. General: Comply with Section 03200 Concrete Reinforcement for fabricating and installing steel reinforcement.

B. Set wire ties with ends directed into concrete, not toward exposed concrete surfaces.

3.03 REMOVING AND REUSING FORMS:

A. Formwork, for sides of beams, walls, columns, and similar parts of the Work, that does not support weight of concrete may be removed after cumulatively curing at not less than 50 deg F for 24 hours after placing concrete, provided concrete is hard enough to not be damaged by form-removal operations and provided curing and protection operations are maintained.

B. Leave formwork, for beam soffits, joists, slabs, and other structural elements, that supports weight of concrete in place until concrete has achieved at least 70 percent of 28-day design

compressive strength. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.

C. Clean and repair surfaces of forms to be reused in the Work. Do not use split, frayed, delaminated, or otherwise damaged form-facing material. Apply new form-release agent.

D. When forms are reused, clean surfaces, remove fins and laitance, and tighten to close joints. Align and secure joints to avoid offsets. Do not use patched forms for architectural concrete surfaces.

3.04 JOINTS:

A. Construction Joints: Install construction joints true to line with faces perpendicular to surface plane of cast-in-place architectural concrete so strength and appearance of concrete are not impaired, at locations indicated or as approved by the Engineer.
   1. Place joints perpendicular to main reinforcement. Continue reinforcement across construction joints, unless otherwise indicated.
   2. Use bulkhead forms with keys of plywood, wood, or expanded galvanized steel sheet, unless otherwise indicated. Embed keys at least 1-1/2 inches into concrete. Align construction joint within rustications attached to form-facing material.
   3. Locate joints for beams, slabs, joists, and girders in the middle third of spans. Offset joints in girders a minimum distance of twice the beam width from a beam-girder intersection.
   4. Locate horizontal joints in walls and columns at underside of floors, slabs, beams, and girders and at the top of footings or floor slabs.
   5. Space vertical joints in walls as indicated. Locate joints beside piers integral with walls, near corners, and in concealed locations where possible.
   6. Use epoxy-bonding adhesive at locations where fresh concrete is placed against hardened or partially hardened concrete surfaces.

B. Contraction Joints: Form weakened-plane contraction joints true to line with faces perpendicular to surface plane of cast-in-place architectural concrete so strength and appearance of concrete are not impaired, at locations indicated or as approved by The Engineer.

3.05 CONCRETE PLACEMENT:

A. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections have been performed.

B. Do not add water to concrete during delivery, at Project site, or during placement, unless approved by The Engineer.

C. Deposit concrete continuously between construction joints. Deposit concrete to avoid segregation.

D. Deposit concrete in forms in horizontal layers no deeper than 24 inches and in a manner to avoid inclined construction joints. Place each layer while preceding layer is still plastic, to avoid cold joints.
   1. Consolidate placed concrete with mechanical vibrating equipment. Use equipment and procedures for consolidating concrete recommended by ACI 309R.
   2. Do not use vibrators to transport concrete inside forms. Insert and withdraw vibrators vertically at uniformly spaced locations no farther than the visible effectiveness of the vibrator.

E. Cold-Weather Placement: Section 03300.

F. Hot-Weather Placement: Section 03300.

3.06 FINISHES, GENERAL:

A. Architectural Concrete Finish: Match The Engineer's design reference sample, identified and described as indicated.

B. Related Unformed Surfaces: At tops of walls, horizontal offsets, and similar unformed surfaces adjacent to formed surfaces, strike off smooth and finish with a texture matching adjacent formed surfaces.
   1. Continue final surface treatment of formed surfaces uniformly across adjacent unformed surfaces, unless otherwise indicated.

C. Maintain uniformity of special finishes over construction joints, unless otherwise indicated.

3.07 AS-CAST FORMED FINISHES:

A. Rough-Formed Finish: As-cast concrete texture imparted by form-facing material with tie holes and defective areas repaired and patched. Remove fins and other projections exceeding ACI 347R limits for class of surface specified.

B. Smooth-Formed Finish: As-cast concrete texture imparted by form-facing material, arranged in an orderly and symmetrical manner with a minimum of seams. Repair and patch tie holes and defective areas. Remove fins and other projections exceeding 1/8 inch in height.

C. Sand Blast-Sealer Finish: Section 03300.

3.08 CONCRETE CURING:

A. Protect freshly placed concrete from premature drying and excessive cold or hot temperatures according to ACI 301.

B. Begin curing immediately after removing forms from concrete. Cure by one or a combination of the following methods that will not mottle, discolor, or stain concrete:
   1. Moisture Curing: Keep exposed surfaces of cast-in-place architectural concrete continuously moist for not less than seven days with the following materials:
      a. Water.
      b. Continuous water-fog spray.
      c. Absorptive cover, water saturated and kept continuously wet. Cover concrete surfaces and edges with 12-inch lap over adjacent absorptive covers.
   2. Moisture-Retaining-Cover Curing: Cover concrete surfaces with moisture-retaining cover for curing concrete, placed in widest practicable width, with sides and ends lapped at least 12 inches, and sealed by waterproof tape or adhesive. Cure for not less than seven days. Immediately repair any holes or tears during curing period; use cover material and waterproof tape.
   3. Curing Compound: Mist concrete surfaces with water. Apply curing compound uniformly in continuous operation by power spray or roller according to manufacturer's written instructions. Recoat areas subjected to heavy rainfall within three hours after initial application. Maintain continuity of coating and repair damage during curing period.

3.09 FIELD QUALITY CONTROL:

A. General: Comply with Section 03300 for field quality-control requirements

3.10 REPAIRS, PROTECTION, AND CLEANING:

A. Repair and cure damaged finished surfaces of cast-in-place architectural concrete when approved by The Engineer. Match repairs to color, texture, and uniformity of surrounding surfaces and to repairs on approved mockups.
   1. Remove and replace cast-in-place architectural concrete that cannot be repaired and cured to The Engineer's approval.

B. Protect corners, edges, and surfaces of cast-in-place architectural concrete from damage; use guards and barricades.

C. Protect cast-in-place architectural concrete from staining, laitance, and contamination during remainder of construction period.

D. Clean cast-in-place architectural concrete surfaces after finish treatment to removestains, markings, dust, and debris.

E. Wash and rinse surfaces according to concrete finish applicator's written recommendations. Protect other Work from staining or damage due to cleaning operations.
   1. Do not use cleaning materials or processes that could change the appearance of cast-in-place architectural concrete finishes.

END OF SECTION

SECTION 03370

SHOTCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies providing shotcrete in permanent lining work.

B. Related Work Specified Elsewhere:
1. Rock reinforcement: Section 02420.
2. Chemical grout: Section 02431.
3. Concrete: Section 03300.

C. Definitions:
1. Shotcrete: Portland-cement concrete applied from a nozzle by compressed air and containing, if necessary, admixtures to provide quick set, high early-strength and satisfactory adhesion.

D. Shotcrete Test Strengths:
1. Specified testing strengths have been modified by length to diameter ratio (L/DR) adjustments and coring correction factors that will achieve design strength of 5,000 psi.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. ASTM: C31, C33, C39, C42, C150, C192, C266, C494.

B. Qualifications of Applicator:
1. Have work performed by firm regularly engaged in shotcreting.
2. Employ qualified nozzle operators who have had previous experience or training in application of shotcrete on at least two projects of comparable nature. Perform work under immediate supervision of foreman with at least three years experience. Have each nozzle operator demonstrate for approval, acceptable proficiency in uniformity of application of shotcrete to vertical and overhead test panels before beginning production work.

C. Uniformity of Materials:
1. In applied production work, use same cement, aggregate and water used in approved test areas and test units. Minor adjustment permitted subject to prior approval. Maintain specified strengths.

D. Mix Design and Testing Prior to Production:
1. Develop shotcrete mix by laboratory compatibility tests and field trials as specified at least 60 days prior to the actual application of shotcrete.
2. Perform compatibility tests to determine cements and additives to be used in field trial mixes. Determine initial and final set for additive concentrations of varying percentages of cement content by weight contemplated for use in the work.
3. Make laboratory and field trial mixes with ingredients identical to those proposed for use in the work.

4. To ascertain compatibility of ingredients and optimum proportions, develop shotcrete mix having strength and characteristics necessary for actual application.
5. Accelerating admixture:
    a. Use approved accelerating admixture to develop quick set as follows:
        1) Time of initial setting: Three minutes maximum.
        2) Time for final setting: 12 minutes maximum.
    b. Determine time of setting in accordance with ASTM C266 with the following additional requirements:
        1) Add accelerator to 50 grams of cement in preparation of paste, together with water to produce water-cement ratio in varying percentages expected to be used in actual shotcrete application.
        2) Use minimum possible time interval to attain proper mixing without disturbing initial set of paste.
        3) Additional modifications to accommodate quick-set accelerators: As approved.
6. Standard concrete-cylinder testing:
    a. Choose materials and proportions so that three cast cylinders six inches by 12 inches made with no additive will achieve average minimum strength at 28 days of 7,000 psi. Cast cylinders in accordance with ASTM C192 and test in accordance with ASTM C39. Cast and test three cylinders minimum for each combination of materials proposed.
7. Field trial:
    a. After completion and approval of laboratory tests, make field trials using selected mixes to accommodate capability of equipment, workmanship and material under field conditions prior to actual application of shotcrete.
    b. Make field application of each mix selected for field trial on at least three horizontal overhead and three vertical test panels to simulate construction conditions.
    c. Shoot test panels measuring not less than 18 inches square by six inches.
    d. Cure test panels in accordance with ASTM C31.
    e. Within 24 hours after shooting, obtain from each panel and submit a minimum of seven full-depth cores each three inches in diameter.
    f. Average three cores from each panel to comprise one test.
    g. Perform field-trial work in the presence of the Engineer.
    h. The Engineer will cut specimens to length equal to diameter and test specimens in accordance with ASTM C42 except as otherwise specified. Soaking of specimens prior to testing is prohibited. The Engineer will make no L/DR correction in reporting results.
    i. Achieve strengths as follows:
        1) Average strength of six tests, three overhead and three vertical, at 24 hours: 2,000-psi minimum.
        2) Average strength of six tests, three overhead and three vertical, at 28 days: 5,540-psi minimum.
8. Proportions:
    a. Proportion shotcrete mixes equivalent to those of a concrete mix having between 6.5 and 8.5 bags of cement per cubic yard.

E. Testing:
1. Before proceeding with the work in accordance with manufacturer's published instructions, completely seal by the methods and materials to be used in the work the following:
    a. Circular or single-horseshoe tunnels: 25-foot section of area of tunnel roof described by arch of approximately 45 degrees on each side of tunnel's vertical centerline, extending to one-foot minimum beyond outside face of third-rail cover and on opposite side of track to one-foot beyond outside face of track rail.

b. Station vaults: 10-foot section of station-roof area described by arch of approximately 75 degrees on each side of station vault's vertical centerline, extending to one-foot minimum beyond back face of station's precast-concrete liner panels.

c. Crossover vaults: 10-foot section of area of crossover roof described by arch of approximately 67 degrees on each side of crossover's vertical centerline extending to one-foot minimum beyond outside face of third-rail cover on one side and on opposite side of track to one-foot beyond outside face of track rail.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:

1. Samples:
   a. On completion of field trial, submit 42 test specimens of each trial mix, seven from each test panel, proposed for use in the work together with relevant data which demonstrate conformance with specified requirements. These specimens will be tested by the Engineer to verify such conformance.
2. Certification:
   a. Mill or manufacturer's certificates with mix design verifying that materials meet specified requirements.
   b. Certified test reports without adjustment for type or size of specimen.
   c. Personnel documentation as required under Quality Assurance article above.
3. Documentation:
   a. Prior to making laboratory compatibility tests, submit detailed plan showing methods and proportions to be used in such tests. The Engineer may inspect tests and materials at any time.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Store and handle basic materials in accordance with Section 03300.

1.05 JOB CONDITIONS:

A. Alkali hydroxides and other chemicals contained in shotcrete admixtures are moderately toxic and can cause skin and respiratory irritation unless adequate safety measures are taken.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Portland Cement: ASTM C150 Type I or Type III. If Type II is specified, Type I or III may still be used provided tricalcium aluminate is less than eight percent.

1. Alkali content not to exceed 0.6 percent.

B. Aggregate: Section 03300, with following additional requirements:

1. Uniformly well-graded and not exhibiting extremes of gradation, in accordance with ASTM C33.
2. Specific gravity: 2.55 minimum.
3. Maximum aggregate size: No. 67.

C. Water: Section 03300.

D. Admixtures: ASTM C494, Type C, with the following additional requirements:
   1. Containing no water-soluble chlorides or materials corrosive to steel nor those which can cause other detrimental effects such as cracking or spalling.
   2. In accordance with reference standard or documented history of demonstrable satisfactory performance in mix of similar proportions.
   3. Chemical Grout: Section 02431. Use soil-solidification agent only when shotcrete is to be in contact with earth.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL:

A. Testing During Construction:
   1. Furnish three-inch diameter core test specimens with minimum length of six inches, three for each 50 cubic yards of material used in Stage-II and Stage-III shotcrete.
   2. Take cores from completed work at locations and on date directed.
   3. The Engineer will cut test cores to length equal to diameter and test cores in accordance with ASTM C42 and as specified. The Engineer will make no L/DR correction in reporting the results.
   4. Test specimens shall be cured/conditioned wet or dry, depending on wet/dry condition shotcrete will be under load.
   5. After application of the first 500 cubic yards of shotcrete, the Engineer may call for test specimens at the reduced rate of three per 100 cubic yards of material.
   6. Additional specimens will be required upon failure of original cores. Should additional specimens show acceptable strength, the work will be accepted. If additional specimens show unacceptable strength, the work will be rejected. Furnish additional specimens as directed.
   7. Plug voids caused by coring operation with material equal to shotcrete in-place and workmanship to ensure continuity of lining with respect to watertightness, strength and appearance.
   8. Shotcrete strengths determined by testing during construction:
      a. Average strength of three cores from one area: 4,670-psi minimum when tested at 28 days.
      b. Minimum strength of a single core: 4,120 psi at 28 days.

B. Watertightness Criteria:
   1. Permanent-support lining for circular or single-horseshoe tunnels:
      a. Maximum-allowable water leakage:
         1) 0.14 gallon-per-minute per 250 linear feet.
         2) 0.07 gallon-per-minute in any 10 linear feet.
   2. Permanent-support lining for station vaults or crossover vaults:
      a. Prior to application of Stage-III shotcrete:
         1) Control water flow by appropriate approved methods.
      b. Maximum allowable water leakage after application of Stage-III shotcrete:
         1) 0.08 gallon-per-minute per 250 linear feet.
         2) 0.04 gallon-per-minute in any 10 linear feet.

3.02 PROPORTIONING AND MIXING:

A. Have aggregate and cement proportioned by an approved batching plant based on weight or volume and in accordance with the applicable requirements of Section 03300.

B. For dry-mix process, maintain moisture content of combined aggregate in range of three to six percent of oven-dry weight of aggregate at time of mixing with cement.

C. Use mixed material within one-hour after adding cement.

D. Accurately proportion and thoroughly mix additive with other ingredients.

3.03 SHOTCRETE APPLICATION:

A. Remove loose material, mud and other foreign matter from new and previously shotcreted surfaces that are to receive shotcrete.

B. After cleaning, keep surfaces moist until shotcrete is applied.

C. Hold nozzle at predetermined distance and position so that stream of flowing material is applied as nearly as possible at right angles to surface to be covered.

D. Maintain steady nozzle motion as layer is built up to thickness shown or specified.

E. Apply shotcrete of uniform consistency to maximize binding, cohesion and density, to minimize rebound and segregation and to prevent sagging of applied shotcrete.

F. Acceptable shotcrete consists of dense, uniform concrete without segregation or discernible weakness of bond between layers accomplished without reuse of rebound.

G. Do not apply shotcrete to frozen surfaces.

3.04 SEQUENCE OF OPERATIONS:

A. Apply shotcrete lining in three stages.

B. Stage I:
   1. Apply first shotcrete layer to surface of excavation exposed by blasting. Complete operation within three hours.
   2. Install rock bolts, steel-rib supports and their assemblies after Stage-I shotcrete application.

C. Stage II: Apply shotcrete to provide continuous blocking of steel-rib supports within specified distance from heading.

D. Stage III: Apply shotcrete to surfaces to total thickness shown within specified distance from heading.

E. Cure final shotcrete layer for seven days in accordance with Section 03300. Remove laitance, loose material and rebound. Sound surface layer with hammer to verify absence of voids, rebound pockets, aggregate pockets and unbonded areas.

3.05 CONTROL OF WATER:

A. Prior to Stage-II shotcrete application, control water flows and seepage to comply with specified watertightness criteria. Control water by appropriate approved methods.

B. To eliminate water penetration, completely seal areas as specified for quality assurance using approved methods and materials.

3.06 DEFECTIVE SHOTCRETE:

A. All shotcrete which lacks uniformity or exhibits segregation, low strength, honeycombing or laminations will be regarded as defective. Stage-II and III shotcrete will be considered defective unless it is crack-free and watertight.

B. Remove and replace or otherwise correct all defective shotcrete as directed.

END OF SECTION

SECTION 03400

STRUCTURAL PRECAST CONCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies precast-concrete work.

B. Related Work Specified Elsewhere:
1. Concrete formwork: Section 03100.
2. Concrete reinforcement: Section 03200.
3. Cast-in-place structural concrete: Section 03300.
4. Prestressed concrete: Section 03415.
5. Flashing and reglets: Section 07600.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. ACI: 503.
3. ASTM: A666, C143, C50, C881,C1107.
4. PCI: MNL 116, Plant Certification Program.

B. Manufacturer's Qualifications: Use only a precast concrete manufacturing plant (or site) certified by PCI Plant Certification Program.
1. Certification is required at time of bidding and throughout construction time.
2. Furnish certification in the following product groups and categories: A1, C1, plus additional certification as appropriate to the visibility and use of precast units required.
3. Furnish name, qualifications and evidence of recent experience on work comparable to that specified.
4. Do not commence work until fabricator has been approved.

C. Test Units:
1. Prior to production runs of precast elements, cast at least two full-size test units as specified.
2. Color, texture, finish and workmanship subject to approval.

D. Uniformity of Materials:
1. To minimize irregularities in color and texture, use same cement, aggregate and water in delivered production units as that used in approved samples and test units.

E. Repair of Defective Concrete: Effect epoxy-mortar repairs in accordance with ACI 503.4-.7, except as otherwise specified.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:
1. Shop Drawings:
a. Have drawings and calculations certified by a registered professional engineer who is licensed to practice in the jurisdiction where the work is to be performed and is experienced in the work of this section.

b. Include details of form fabrication, profiles, joints, reinforcing steel, clips, anchors, inserts, reglets, lifting devices, connection to other work and placement and erection sequence.
c. Submit prior to fabrication of units and ordering material.

2. Samples:
a. Panels representing color, texture and general finish of test units and production panels, each 12 inches square by 1-1/2 inches: Two. Submit prior to fabrication.
b. Gasket and flashing materials proposed for use, each 12 inches long: Two.

3. Certification:
a. Certificates from concrete supplier as specified in Section 03300.
b. Certification or published listing of manufacturer per Quality Assurance paragraph above.

4. Documentation:
a. Prior to installation of units, submit schedule indicating sequence of installation, joints, support and bracing system and anchoring system.
b. Design mix. Submit prior to use for test units.
c. Delivery tickets from concrete supplier in lieu of certification as specified in Section 03300.

5. Quality Control Plan: Provide production quality control in accordance with the requirements of PCI MNL 116.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Store and handle basic materials in accordance with Section 03300.

B. After completion of fabrication and curing, transport and store units.

C. Avoid damaging of surfaces, edges and corners and creating of stresses within units.

D. Keep units under cover and protected until installed.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Concrete: Section 03300, Class 5000 unless otherwise shown; slump of 3-1/2 inches plus-or-minus 1/2 inch as determined by ASTM C143.
1. Color matching sample on file with the Engineer.

B. Formwork:
1. One of the following in accordance with Section 03100.
a. Fibrous-glass-reinforced plastic forms.
b. Steel forms.
c. Epoxy-coated concrete forms.
2. Use largest sizes possible to produce units without visible joints.

C. Reinforcement: Section 03200, welded-wire fabric to be galvanized.

D. Gaskets:
1. ASTM C509, preformed, expanded closed-cell neoprene sponge, acid-resistant, nonstaining, inert to temperature changes, sized to provide constant compression in joint and in pieces as long as practicable to minimize field splices.
2. Gasket cement: Type recommended by gasket manufacturer.

E. Anchors, Dowels and Accessories Cast Into Precast Units: Steel, hot-dip galvanized.

F. Joint Connections: Stainless steel, ASTM A666.

G. Surface Sealer:
1. Methyl-methacrylate-based water repellant.
2. Compliant with Federal and local VOC limitations.
3. Nonpeeling, low viscosity and surface penetrating.
4. Water-repellent, performing as a warrantied barrier to moisture penetration for minimum of five years under exterior exposure.
5. Colorless, nonyellowing, nonglossy, not affecting color, texture or surface of concrete for life of material.

H. Sandblasting Sand: One-size silica sand equivalent to Ottawa Sand Grade, graded to pass Size 20 sieve and retained on Size 30 sieve.

I. Non-shrink Grout: Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, portland cement, shrinkage-compensating agents, platicizing and water-reducing agents, complying with ASTM C1107, with fluid consistency and a 30-minute working time.

J. Epoxy Adhesive: Non-sagging. Consist of epoxy resin bonding material and a hardener. Epoxy shall conform to ASTM C881

PART 3 - EXECUTION

3.01 FABRICATION OF TEST UNITS:

A. In order to determine materials, proportions and techniques which will result in required color, texture, finish and strength and which will be used in precast concrete production, cast at least two full-size test units, using forms, concrete mix proportions, admixtures and methods proposed for production work.

B. Design mix to conform to Section 03300 and submit for approval prior to use in test units.

C. Cast test units as directed to simulate production run, incorporating reinforcing and embedded items as shown.

D. Maintain complete records of proportions, mixing, consolidation and curing procedures during casting.

E. Prepare a set of at least four test cylinders during casting of each test unit for compressive tests as specified in Section 03300.

F. If approved, precast-concrete elements may be cured by accelerated method such as steam treatment. The Engineer may direct that test cylinders be cured in accordance with curing process selected in order to determine satisfactory period of hardening of concrete in the units.

G. Sandblasting and Sealing:
1. After curing and when so directed, sandblast test units to determine conditions for achieving required texture of concrete surface. Use specified silica sand.
2. Determine required surface texture by varying blasting pressure, size of nozzle, duration of blasting and distance between nozzle and surface. Maintain complete records of sandblasting.

3. After sandblasting test units, seal surface with application of sealing compound as specified.
4. Prior to application of sealer, thoroughly clean surface by application of water or air. Apply sealer as recommended by manufacturer.
5. Keep complete record of each sealer application.
6. Utilize approved procedures and materials on the basis of test applications specified for sandblasting and sealing of surfaces of precast-concrete work.

H. After test units are approved, fabricate units using mix, ingredients, sandblasting technique and sealer formulation used to prepare test units.

I. If strength, color, texture, finish or workmanship of test units is rejected, cast additional units until units meet requirements and approval is obtained.

3.02 FABRICATION OF PRODUCTION UNITS:

A. Fabricate units in number and sizes shown and specified to match approved test units.

B. Deliver units to site in compliance with erection schedule.

3.03 DEFECTIVE AND DAMAGED CONCRETE UNITS:

A. Do not install units with surface imperfections such as air bubbles, joint lines, warpage, stains, uneven matrix plane or uneven exposure of aggregate or units which are warped, cracked, broken, spalled, stained or otherwise defective.

3.04 ERECTION:

A. Lift, support and erect precast members so as to prevent damage or overstressing. Handle precast members by means of lifting inserts, loops or other approved means.

B. After erection remove lifting loops, bend them over or cut them flush with the surface of the concrete. If insert material may cause stains to surfaces exposed to view, inset cut and patch concrete.

C. Set members in position properly leveled, aligned and braced as shown.

D. Install members so that their erected position does not differ from position shown on approved shop drawings by more than allowable tolerances.

E. Bring defects detected after erection to the attention of the Engineer who will conduct inspection. Where in his opinion structural adequacy is impaired, replace member.

END OF SECTION

SECTION 03415

PRESTRESSED CONCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies prestressed concrete work.

B. Related Work Specified Elsewhere:
1. Concrete formwork: Section 03100.
2. oncrete reinforcement: Section 03200.
3. Cast-in-place structural concrete: Section 03300.
4. Precast concrete: Section 03400.

C. Definitions:
1. Site or job site: Location where members are to be manufactured.

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. PCI: MNL 116, Plant Certification Program.
3. ASTM: A416, A421, A722, C109, C404, C618.

B. Fabricator Qualifications: Use only a prestressed concrete manufacturing plant (or site) certified by PCI Plant Certification Program.
1. Certification is required at time of bidding and throughout construction time.
2. Furnish certification in the following product groups and categories: A1, C1, plus additional certification as appropriate to the visibility and use of prestressed units required.
3. Furnish name, qualifications and evidence of recent experience on work comparable to that specified.
4. Do not commence work until fabricator has been approved.

C. Installer qualifications: Use only an experienced installer who has completed prestressed concrete work similar in material, design and extent to that indicated for this Project and with a record of successful in-service performance.

D. Allowable Tolerances:
1. Fabricate prestressed-concrete members in accordance with dimensional tolerances indicated in referenced PCI standard.

E. Sampling and Testing:
1. Concrete:
   a. Perform sampling, testing and frequency of testing in accordance with Section 03300, except as otherwise specified.
   b. Mold three sets of at least two cylinders for each casting bed each day it is used or for each 100 cubic yards of concrete or fraction thereof for each prestressed-concrete structure. In any case, have at least six cylinders cast for each group of members cast from each batch.
   c. Cure cylinders for stress transfer in same environment as members or structures they represent.

d. Test one set for compressive strength at stress transfer and one set on twenty-eighth day.
e. Have tests performed by approved independent testing agency.
f. The Engineer may test concrete at any time during fabrication operations.
g. For major members carrying rapid transit loads or underpinning loads or as directed, perform sampling and testing in accordance with ASTM A416 and ASTM A421.

2. Tendons:
a. Furnish samples for testing from each size and each heat of prestressing bars, from each manufactured reel of prestressing-steel strand, from each coil of prestressing wire and from each lot of anchorage assemblies and bar couplers to be used. With each sample of prestressing-steel wires, bars or strands furnished for testing, submit certificate stating manufacturer's minimum guaranteed ultimate tensile strength of sample furnished. Prior to installation submit certified test results from each manufacturer for each type of low-relaxation steel.
b. Furnish testing materials and equipment.
c. Assign individual lot number to bars of each size from each mill heat, wire from each coil, and strand from each manufactured reel to be shipped to site and tag so that each lot can be accurately identified at job site. Likewise, identify each lot of anchorage assemblies and bar couplers to be installed.
d. Unidentified prestressing steel, anchorage assemblies or bar couplers received at site will be rejected.
e. Submit the following samples of materials and tendons, selected by the Engineer from prestressing steel at plant or jobsite:
1) For wire, strand or bars: One sample of each size from each heat or reel.
2) If prestressing tendon is to be prefabricated, one completely fabricated prestressing tendon five feet in length for each size of tendon, including anchorage assemblies. If the prestressing tendon is to be assembled at jobsite, sufficient wire or strand and end fittings to make up one complete prestressing tendon five feet in length for each size of tendon, including anchorage assemblies.
3) If prestressed tendon is a bar, one five-foot length complete with one end anchorage; if couplers are to be used with the bar, two four-foot lengths of bar equipped with one coupler and fabricated to fit coupler.
f. For prefabricated tendons, notify the Engineer at least 10 working days prior to commencing installation of end fittings or heading of wires. The Engineer will inspect end-fitting installations and wire headings while such fabrication is in progress at the plant and will arrange for testing of material to be shipped to the site.
g. Do not ship prefabricated tendons to the site until they are released by the Engineer. Tag each tendon before shipment as specified.
h. Material released by the Engineer will be rejected if subsequently damaged or found defective.

1.03 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:

1. Shop Drawings:
a. Have drawings and calculations for prestressed products certified by a registered professional engineer who is licensed to practice in the

jurisdiction where the work is to be performed and who is experienced in the work of this section.

b. Include the following:

1) Description of equipment to be used and procedure for constructing prestressed-concrete members.

2) Ductwork and method of holding ducts in position, tendon or bar sizes, splicing of bars, unit weights, materials and stress grade, jack clearances and procedures, stressing sequence, initial-tensioning forces, pressure gauge or load cell for determining loads, calculated friction and elastic-shortening losses and tendon or bar elongation, anchorage details and anchorage-slippage losses, bonding and grouting procedures, mild-steel placement, provisions for camber and clearances and concrete dimensions.

3) Details of procedures for yard and site, handling, transporting, storing and erecting. If necessary, furnish design calculations. Show embedded items including, but not limited to, inserts, anchors, couplings, fittings, vent-hole openings and anchorage pockets. Show method of tendon support for post-tensioned systems during tendon-placing operations.

4) Complete details and substantiating calculations of method and materials proposed for use in prestressing operations, including additions or rearrangement of reinforcing steel from that shown. Calculate, detail and show individual tendon layout and anchorage arrangement to satisfy design requirements and to avoid interferences. Coordinate with embedded items. Changes or rearrangement of details shown permitted only with approval. Ensure that spacing of tendon is sufficient for full encasement of each tendon in concrete. Plan sequence of installation to minimize fitting problem of various components embedded in prestressed member. Show camber computations.

5) Stress/strain curve of tendons and bars. Show amount of slip normally expected in seating anchorage devices as opposed to that assumed in design calculations. Show friction-wobble coefficient and friction-curvature coefficient expected from tendons and bars and duct material. Show complete stress diagram for each tendon size or type.

6) Bills of materials, erection diagrams and details of connections to other work.

7) Details and design calculations for size and thickness of anchor plates and corresponding reinforcement necessary for each system to guarantee safe transfer of forces into end block. Show amount, size and arrangement of such reinforcement to be installed at anchorage zones and along path of tendons to prevent bursting and splitting concrete members when subjected to prestressing forces. Special Anchorage Devices, as defined by the AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges, shall be approved based on the results of testing representing actual jobsite conditions.

2. Working Drawings:

a. Complete working drawings and necessary calculations for formwork and falsework.

b. Include compensation for deflection as necessary to construct structure to lines and grades shown.

c. Consider loads, forces and stresses to be imposed during casting and post-tensioning elements of structure.

3. Samples: As previously specified.

4. Certification:
   a. Tendons:
      1) Certificates for each five reels or coils or fraction thereof.
      2) Submit certificates prior to delivery of tendons to jobsite.
      3) Applicable certificates to accompany each shipment of tendons.
   b. Hydraulic jacks:
      1) Certified calibration curves for each hydraulic jack.
   c. Certified test reports:
      1) Concrete tests.
      2) Tendons: For each size of strand to be used in the work, submit test certificates showing physical, chemical and stress/strain test properties including modulus of elasticity and stating guaranteed minimum ultimate tensile and yield strength.

5. Documentation:
   a. Specified calculations.
   b. Records of tendon elongation promptly upon completion of post-tensioning of each member.

B. Quality Control Plan: Provide production quality control in accordance with the requirements of PCI MNL 116.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Prestressing Steel:
1. Protect prestressing steel against physical damage and rust or other results of corrosion at all times from manufacture to grouting or encasing in concrete. Physically damaged prestressing steel will be rejected. Rust or other corrosion will be cause for rejection.
2. Package prestressing steel in containers or shipping forms for protection against physical damage and corrosion during shipping and storage. Place corrosion inhibitor and rust preventive in package or form or use corrosion-inhibiting carrier-type packaging material. If approved, apply corrosion inhibitor directly to steel.
3. Use corrosion inhibitor which has no deleterious effect on steel, concrete or bond strength of steel to concrete.
4. Replace or restore to original condition damaged packaging or forms.
5. Clearly mark shipping package or form with statement that package contains high-strength prestressing steel, and caution that care be used in handling. Show type, kind, amount and placement date of corrosion inhibitor used. Include safety recommendations and instructions for use.
6. When prestressing steel for post-tensioning is installed in members prior to placing and curing concrete, provide protection against rust or other corrosion, until grouted, by means of corrosion inhibitor placed in ducts or applied to steel in duct.
7. Do not stress tendons until 28 day compressive strength is verified.

B. Members:
1. Handle, store and transport completed members and member components so as to prevent damage.
2. Maintain beams in upright position.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Concrete:
   1. Section 03300: Class 5000, unless otherwise specified.

B. Grout:
   1. Materials for grout: Section 03300 and ASTM C404. Pozzolans, if used: ASTM C618.

C. Formwork and Accessories: Section 03100.

D. Reinforcing Steel: Section 03200.

E. Tendons, Anchorage, Couplers and Ducts:
   1. Pretensioning tendons:
      a. Steel strand: ASTM A416, Grade 270, regular or low-relaxation.
      b. Strand similar to specified steel strand but with different number of wires per strand: As approved.
      c. Steel wire: ASTM A421.
   2. Post-tensioning tendons:
      a. Strand as specified or shown for pre-tensioning either in single-strand units or in multiple-parallel-strand units, with wedge-type anchorages.
      b. Button heads to be cold-formed symmetrically about axes of wires so that butt develops minimum guaranteed ultimate tensile strength of wire. Use of cold-forming process that causes indentations in wire is prohibited.
      c. Prestressing bars:
         1) Fabricated and processed in accordance with ASTM A722 and as specified.
         2) High-tensile-strength hot-rolled alloy steel, individually cold-stretched and thermally stress-relieved to ensure uniform stress/strain characteristics and to obtain yield strength not less than 85 percent of required minimum guaranteed ultimate tensile strength.
         3) In accordance with the following minimum requirements:
         4)

Properties	Regular Grade	Special Grade
a) Ultimate tensile strength	150,000 psi	160,000 psi
b) Modulus of elasticity at 70 percent of manufacturer's minimum guaranteed ultimate strength	29×10^6 psi	30×10^6 psi

         5) High-strength, thermally stress-relieved, large steel cables with socketed ends fitted with anchorage nuts on peripheries of sockets and meeting required breaking strength, yield strength, elongation, composition and other pertinent requirements may be used if approved. Oil-tempered wires are prohibited.
   3. Unbonded tendons are prohibited unless approved.

4. Anchorages and couplers:
   a. Steel anchorages and couplers as approved if compatible with particular installation. Anchorage devices to hold prestressing steel at load-producing stress of not less than 95 percent of specified minimum ultimate tensile strength of prestressing steel. Anchorages with cut threads or notches are prohibited on prestressing steel. Fabricate stressing anchorages to provide adjustable-seating loss. Ensure that each anchorage is capable of lift-off, de-tensioning and re-tensioning tendon at any time prior to grouting.
5. Ducts:
   a. Galvanized ferrous metal.
   b. Strong enough to retain shape and resist damage during construction.
   c. Capable of preventing entrance of cement paste and water from concrete.
   d. Incapable of causing electrolytic action or deterioration in concrete.
   e. When grouting is necessary, ensure that:
      1) Inside diameter of duct is at least 1/4-inch larger than bar or strand tendons or, in the case of parallel-wire cable tendons, that inside area of duct is at least 100-percent larger than area of tendon.
      2) Ducts have grout holes at each end and at high points.
      3) Ducts have drain holes at low points.
   f. Grout and vent-hole connections to duct made with metallic structural fasteners. Connections to be mortar-tight, taped as necessary. Provide grout holes with means to inject grout. Provide positive shutoff valves.

F. Corrosion Inhibitor: Water-soluble oil; VISCONORUST 84-18, Viscosity Oil Company, or equal.

PART 3 - EXECUTION

3.01 CONCRETE:

A. Mixing and Placing:
1. Mix concrete in accordance with the requirements of Section 03300, with the following additional requirements:
   a. Do not use admixtures containing chlorides, fluorides or nitrates.
   b. Use more than one admixture only if compatible with each other. If used, add separately during batching sequence.
2. Placement of concrete: Section 03300.

B. Sampling and Testing:
1. Perform sampling and testing as specified.

C. Concrete Protection for Reinforcement: Section 03200

D. Compaction of Concrete:
1. Compact concrete by means of internal, external or surface vibrators as approved and as follows:
   a. Use internal vibrators on sections that are sufficiently large to admit them.
   b. Use external vibrators on smaller sections and sections produced by extrusion or slip-form method.
   c. Surface or screed vibrators may be used for flat slabs.
2. Use vibrators having operating frequencies of at least 7,000 impulses per minute and higher frequencies if approved. Use vibrators only for compacting, not for moving concrete along forms.

E. Patching:

1. Thoroughly clean and hammerpack holes left by tie rods, strand hold-down devices or other temporary inserts with stiff dry mortar made with same type of sand and cement used in concrete. In areas of tensile stress, bond hole patches with approved epoxy resin.
2. Members with honeycombs of such depth as to expose tendons will be examined by the Engineer for structural adequacy. Where in the Engineer's opinion impairment of structural adequacy is apparent, member will be rejected.
3. Where honeycombed areas are to be repaired, remove loose material and cut area back until coarse aggregate breaks under chipping; coat area with layer of epoxy bonding agent and patch with grout matching existing concrete color and strength. Obtain approval of proposed method and materials.

F. Curing: Section 03300.

G. Finishes:
1. Types of concrete finishing: As shown and specified.

3.02 FORMS:

A. Ensure that joints are smooth and tight to prevent leakage of mortar. Maintain accurate alignment of forms during casting operations. Check form alignment and grade for each casting.

B. Make provisions in form-anchorage system for anticipated differential movement of beds and forms during casting and curing operations. In details of forms, ties, inserts, bulkheads and other accessories, detail forms and anchor them so that differential movement cannot occur or loosen them so that movement can occur without damage to member or forms. Ensure that bearing devices supporting prestressed members are free to rotate and that expansion bearings are free to translate during post-tensioning operation.

C. Clean beds and forms thoroughly before casting. Do not allow coatings used for bond breakers to accumulate in bottoms of forms. For members to be cured by artificial heat, provide for ventilation of void forms.

D. In areas subject to freezing and thawing, make provisions for draining voids.

E. Treat surfaces in contact with concrete with effective bond breaker.

F. Prevent contamination of tendons by bond breaker, mud, grease or other detrimental substances.

G. Provide bolting fittings and welding plates for embedment in prestressed members to allow later attachment of conduits, pipes, boxes and similar items.

3.03 JACKS:

A. Equip each jack used to stress tendons with pressure gauge or load cell to determine jacking stress.

B. If pressure gauge is used, provide accurate, easily readable dial at least six inches in diameter. Calibrate each jack and its gauge as a unit with cylinder extension in approximate position in which it will be at final jacking force. Provide certified calibration chart as specified.

C. If inconsistencies occur between measured elongation and jack gauge reading, recalibrate gauge. If further discrepancies occur, determine cause and report to the Engineer. Agreement within seven percent will be satisfactory.

D. If load cell is used, calibrate and provide with indicator by means of which prestressing force in tendon may be determined. Ensure that range of load cell is such that lower 10 percent of manufacturer's-rated capacity will not be used in determining jacking stress.

3.04 TENDONS:

A. Placement and Tensioning of Tendons for Prestressing:

1. Prior to stringing tendons, inspect bottom of forms for cleanliness and accuracy of alignment.
2. String tendons singly or in multiples.
3. Splicing of wires or strands is prohibited.
4. Cut length of each tendon between tendon vise and coil or reel.
5. Do not string tendons incorporating points previously gripped by tendon vises or wedges within lengths to be stressed. Do not use notched, nicked, pitted, rusted or otherwise damaged tendons.
6. Provide tendon vises or wedges capable of anchoring stressing loads positively with a minimum of differential slippage. Have vises or wedges cleaned, lubricated and inspected between each use.
7. Discard grips which become visibly worn or distorted or which allow excessive slippage. Furnish full set of cleaned and inspected tendon vises or wedges before commencing each stressing operation. Ensure that vises and wedges are free of rust and physical damage.
8. Position tendons to conform to tensioning detail dimensions shown. Prevent sagging and kinking of tendons. Support tendons as necessary to maintain proper position and prevent vertical movement during pouring of concrete. Permissible deviations from profile shown on approved shop drawings as follows:

	Depth of Member	Permissible Deviation
a)	Less than 10 inches	Plus-or-minus 1/8 inch
b)	Ten inches or more	Plus-or-minus 1/4 inch

9. After straight wire tendons have been positioned, apply initial force to each tendon to eliminate slack and to provide uniform initial-stress condition in all tendons prior to final stressing. Initial force may be applied only by pressure jacks equipped with proper gauging system for measuring initial force.
10. Do not weld or make grounds for welding equipment on forms or on steel in member after prestressing steel has been installed.
11. Maintain records of elongation of each tendon and tension applied to each tendon.
12. Use load cells to calibrate load-measuring devices and to check initial force on at least 10 percent of tendons.
13. Regardless of method used, measure initial load within tolerance of plus-or-minus 50 pounds or two percent, whichever is larger.
14. Do not use elongation measurements as measure of initial stress.
15. Perform final stressing as shown on approved shop drawings.
16. If prestressing bars less than 30 feet long are used, measure elongation by means of dial indicators.

B. Tendon Vises for Pretensioning:
1. Use tendon vises for pretensioning capable of anchoring tendon positively without slippage after seating.
2. Have steel cases for tendon vises proof-tested by manufacturer to at least 95 percent of guaranteed minimum tensile stress of prestressing steel.
3. Maintain chucks in serviceable condition. Discard chucks that become visibly worn or show evidence of allowing post-seating slippage of tendon.

C. Post-Tensioning:
1. Perform sequence and staging of post-tensioning in accordance with approved shop drawings. Perform special techniques, such as overjacking with following reduction of load or jacking from both ends of the tendon, in accordance with approved shop drawings.
2. Stress post-tensioned prestressing steel by means of hydraulic jacks equipped with accurately calibrated, easily readable hydraulic pressure gauges or load cells to permit reading stress in prestressing steel throughout stressing operation.
3. Keep records of tension and elongation of each tendon at all stages and submit records as specified. Make readings of elongations to within plus-or-minus 1/32 inch when dial indicators are used, reading accuracy to be accordingly higher.
4. At the time of stressing first member of each type, check stresses in individual tendons and verify calculated frictional losses and seating losses to establish post-tensioning procedure and ensure uniform results.
5. Recheck may be directed if it appears that stress shown is not being obtained.
6. If the measured elongation is within seven percent, and the jacking force as measured by the pressure gauge is within five percent of theoretical, tendons may be cut and sealed for grouting. If an elongation or force is outside of these limits, obtain written approval before cutting and capping post-tensioned anchorage.
7. If friction losses in post-tensioned tendon exceed calculated friction losses shown, relieve tendons of stress, lubricate with water-soluble oil or graphite spray and retension.
8. Anchor prestressing steel at initial stresses (transfer) calculated to result in final force shown. Initial stress not to exceed 70 percent of minimum ultimate tensile strength of prestressing steel at any point of tendon.
9. During jacking of prestressing steel, do not exceed 80 percent of the minimum guaranteed ultimate tensile strength of tendon.
10. Make accurate measurements of anchorage slippage losses at time of anchoring first tendon of each type of member and compare with assumed slippage losses. In case of deviation, de-tension tendon; repeat tensioning in accordance with special approved procedure or by shimming as necessary for particular system.
11. When necessary and approved, make adjustments to post-tensioning procedure to obtain required stresses.
12. Submit for approval proposed remedy for inconsistencies which occur between measured elongation and jack-gauge readings and which cannot be corrected by specified recalibration of gauge nor by lubrication of tendons. Replace tendon, if necessary.
13. Immediately after concreting, check ducts for obstructions by drawing cleaning device through them, by blowing through or by movement of tendon. Immediately prior to installation of tendons in ducts, demonstrate that ducts are free of water, debris and other obstructions.

3.05 GROUTING:

A. Immediately prior to grouting, clean ducts of foreign materials and remove corrosion inhibitor by thoroughly flushing duct with water and dry by blowing. Unless prestressing steel is

adequately protected from corrosion, complete grouting operation within 28 days after concrete is placed around ducts but not later than 10 days after stressing.

B. Mix grout as recommended by manufacturer, as tested and approved or for 1-1/2 minutes in high-speed mechanical mixer; pass through strainer into pumping equipment which has provision for recirculation. Begin pumping grout as soon as possible after mixing. Pumping may be continued as long as grout retains proper consistency.

C. Use grout consisting mainly of cement and water unless gross inside area of duct exceeds five times tendon area, in which case fine sand may be added.

D. When approved, add aluminum powder of proper fineness or other approved material in quantity sufficient to obtain a maximum of 10-percent expansion of grout when measured unconfined.

E. Base proportions of materials on results of tests made on grout to achieve the following:
1. Water content: Minimum necessary for proper placement.
2. Water-cement ratio: Limited to maximum of 0.45 by weight.
3. Minimum seven-day compressive strength: 2,500 psi for two-inch cubes molded, cured and tested in accordance with ASTM C109.

F. Do not retemper grout.

G. Inject grout into ducts and anchorage fittings. Continue flow until grout of consistency equivalent to that injected, flows from vent openings without presence of air in bubbles. Ensure that there is enough grout in supply bin to prevent suction of air.

H. Close vent openings progressively in direction of flow. After vent openings are closed, raise grouting pressure to 100-psi minimum and plug injection hole. Keep accurate records of progress of grouting operations.

I. In the event of blockage or interruption of grouting, remove grout from duct by flushing with water. Provide water pump in standby condition.

J. Prevent water trapped in ungrouted ducts from freezing.

K. Maintain temperature of concrete around grouted tendons at 45F or higher for at least three days after grouting.

3.06 STRESS TRANSFER:

A. Perform stress transfer to pretensioned or post-tensioned members only after concrete strength, as demonstrated by test cylinders, is in accordance with the transfer strength specified or shown.

B. Minimum transfer strengths of concrete:
1. Concentrically stressed members: 3,000 psi.
2. Eccentrically stressed members: 3,500 psi.
3. Bridge beams or other members in which camber must be minimized: 4,000 psi.
4. Post-tensioned members: 4,000 psi or as shown.

C. If precast concrete has been moist-heat cured, perform de-tensioning immediately following curing period while concrete is still warm and moist.

D. In de-tensioning operations, release tension so as to minimize eccentricity between resultant of prestressing forces and the vertical centroidal axis of member and so as to minimize

sudden or shock loading. Limit maximum eccentricity about vertical centroidal axis to one strand.

E. Prior to detensioning, remove or loosen forms, ties, inserts, holddowns or other devices that would restrict longitudinal movement of members along bed.

END OF SECTION

SECTION 03450

PLANT - ARCHITECTURAL PRECAST CONCRETE

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies providing precast architectural concrete units andthin-brick-faced, precast architectural concrete units.

B. Related Work Specified Elsewhere:
   1. Concrete Unit Masonry: Section 04220.
   2. Flashing and Sheet Metal: Section 07600.
   3. Seals and Sealants: Section 07900.

1.02 PERFORMANCE REQUIREMENTS:

A. Structural Performance: Provide precast architectural concrete units and connections capable of withstanding design loads within limits and under conditions indicated.

B. Structural Performance: Provide precast architectural concrete units and connections capable of withstanding the following design loads within limits and under conditions indicated:
   1. Dead Loads: <Insert applicable dead loads.>
   2. Live Loads: <Insert applicable live loads.>
   3. Wind Loads: <Insert applicable wind loads or wind-loading criteria including basic wind speed, importance factor, and exposure category.>
   4. Earthquake Loads: <Insert applicable earthquake design data including seismic coefficient and importance factor.>
   5. Design framing system to maintain clearances at openings, to allow for construction tolerances, and to accommodate live load deflection of primary building structure as follows:
      a. Upward and downward movement of 1/2 inch.

1.02 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements and with the additional requirements specified for each:
   1. Product Data: For each type of product indicated.
   2. Design Mixes: For each concrete mix.
   3. Shop Drawings: Detail fabrication and installation of precast architectural concrete units .Indicate member locations, plans, elevations, dimensions, shapes, cross sections, limits of each finish, and types of reinforcement, including special reinforcement.
      a. Indicate separate face and backup mix locations and thicknesses.
      b. Indicate locations and extent and treatment of dry joints if two-stage casting is proposed.
      c. Indicate welded connections by AWS standard symbols. Detail loose and cast-in hardware, inserts, connections, and joints, including accessories.
      d. Indicate locations and details of anchorage devices to be embedded in other construction.
      e. Indicate locations and details of thin brick units and joint treatment.
      f. Comprehensive engineering analysis signed and sealed by the qualified professional engineer responsible for its preparation.

4. Samples: For each type of finish indicated on exposed surfaces of precast architectural concrete units, in sets of 3, illustrating full range of finish, color, and texture variations expected; approximately 12 by 12 by 2 inches.
5. Samples for each thin brick unit required, including special shapes, showing the full range of colors, textures, and dimensions expected.
    a. Grout Samples for Initial Selection: Color charts consisting of actual sections of grout showing the manufacturer's full range of colors.
6. Welding Certificates: Copies of certificates for welding procedures and personnel.
7. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names and addresses of architects and owners, and other information specified.
8. Material Certificates: Signed by manufacturers certifying that each of the following items complies with requirements:
    a. Concrete materials.
    b. Reinforcing materials and prestressing tendons.
    c. Admixtures.
    d. Bearing pads.
    e. Water-absorption test reports.
    f. Thin brick units and accessories.

1.04 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Comply with codes and regulations of the jurisdictional authorities.
2. AASHTO: M251
3. ACI: 211.1, 211.2, 216/TMS 0216.1, 305R, 306.1, 318.
4. AISI: 1018-1020.
5. ANSI: A118.6, 108.10.
6. APA: Architectural Precast Concrete-Color and Texture Selection Guide.
7. ASTM: A27, A36, A47, A82, A108, A123A, A184, A185, A276, A283, A307, A416, A496, A497, A500, A572, A615, A618, A666, A675, A706, A767, A775, A884, C33, C42, C67, C144, C150, C260, C330, C494, C567, C618, C979, C1088, C1017, C1107, C1240, D412, F593.
8. AWS: D1.1, D1.4.
9. CRSI: Manual of Standard Practice.
10. DOD: P-21035A.
11. FS: TT-P-664.
12. PCI: MNL 117, MNL 120, MNL 124.
13. SSPC: PA 1, Paint 20, Paint 25, SP 3.

B. Installer Qualifications: An experienced installer who has completed precast architectural concrete work similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.

C. Fabricator Qualifications: A firm that complies with the following requirements and is experienced in manufacturing precast architectural concrete units similar to those indicated for this Project and with a record of successful in-service performance.
1. Assumes responsibility for engineering precast architectural concrete units to comply with performance requirements. This responsibility includes preparation of Shop Drawings and comprehensive engineering analysis by a qualified professional engineer.
2. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are

defined as those performed for installations of precast architectural concrete that are similar to those indicated for this Project in material, design, and extent.

3. Participates in PCI's Plant Certification program and is designated a PCI-certified plant for Group A, Category A1--Architectural Cladding and Load Bearing Units [or in APA's Plant Certification Program for Production of Architectural Precast Concrete Products and is designated an APA-certified plant].
4. Has sufficient production capacity to produce required units without delaying the Work.
5. Is registered with and approved by authorities having jurisdiction.

D. Design Standards: Comply with ACI 318 and the design recommendations of PCI MNL 120, "PCI Design Handbook--Precast and Prestressed Concrete."

E. Quality-Control Standard: For manufacturing procedures and testing requirements, quality-control recommendations, and dimensional tolerances for types of units required, comply with PCI MNL 117, "Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products."

F. Welding: Qualify procedures and personnel according to AWS D1.1, "Structural Welding Code--Steel"; and AWS D1.4, "Structural Welding Code--Reinforcing Steel."

G. Calculated Fire-Test-Response Characteristics: Where indicated, provide precast architectural concrete units whose fire resistance has been calculated according to [PCI MNL 124, "Design for Fire Resistance of Precast Prestressed Concrete,"] [ACI 216.1/TMS 0216.1, "Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies,"] and is acceptable to authorities having jurisdiction.

H. Sample Panels: Before fabricating precastarchitectural concrete units, produce sample panels to establish the approved range of selections made under sample Submittals. Produce a minimum of 3 sets of full-scale sample panels, approximately 48 inches long by 48 inches high, to demonstrate the expected range of finish, color, and texture variations.

1. Locate panels where directed by the Engineer.
2. In presence of the Engineer damage part of an exposed-face surface for each finish, color, and texture, and demonstrate materials and techniques proposed for repair of surface blemishes to match adjacent undamaged surfaces.
3. Maintain sample panels during construction in an undisturbed condition as a standard for judging the completed Work.
4. Demolish and remove sample panels when directed

I. Preinstallation Conference: Conduct conference at Project site to comply with requirements of Division 1 Section "Project Meetings."

1.05 PRODUCT DELIVERY, STORAGE, AND HANDLING:

A. Deliver precast architectural concrete units to Project site in such quantities and at such times to ensure continuity of installation. Store units at Project site to prevent cracking, distorting, warping, staining, or other physical damage, and so markings are visible.

B. Lift and support units only at designated lifting and supporting points as shown on Shop Drawings.

1.06 SEQUENCING:

A. Furnish anchorage items to be embedded in or attached to other construction without

delaying the Work. Provide setting diagrams, templates, instructions, and directions, as required, for installation.

PART 2 - PRODUCTS

2.01 MOLD MATERIALS:

A. Molds: Provide molds and, where required, form-facing materials of metal, plastic, wood, or another material that is nonreactive with concrete and dimensionally stable to produce continuous and true precast concrete surfaces within fabrication tolerances and suitable for required finishes

B. Form Liners: Units of face design, texture, arrangement, and configuration indicated.

2.02 REINFORCING MATERIALS:

A. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.

B. Low-Alloy-Steel Reinforcing Bars: ASTM A 706/A 706M, deformed.

C. Galvanized Reinforcing Bars: ASTM A 767/A 767M, Class II zinc coated, hot-dip galvanized after fabrication and bending, as follows:
1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60] [ASTM A 706/A 706M], deformed.

D. Epoxy-Coated Reinforcing Bars: ASTM A 775/A 775M or ASTM A 934/A 934M, as follows:
1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60] [ASTM A 706/A 706M], deformed.

E. Steel Bar Mats: ASTM A 184/A 184M, assembled with clips, as follows:
1. Steel Reinforcement: [ASTM A 615/A 615M, Grade 60] [ASTM A 706/A 706M], deformed bars.

F. Plain-Steel Wire: ASTM A 82, [as drawn] [galvanized].

G. Deformed-Steel Wire: ASTM A 496.

H. Epoxy-Coated-Steel Wire: ASTM A 884/A 884M, Class A coated, [plain] [deformed].

I. Plain-Steel Welded Wire Fabric: ASTM A 185, fabricated from [as-drawn] [galvanized] steel wire into flat sheets.

J. Deformed-Steel Welded Wire Fabric: ASTM A 497, flat sheet.

K. Epoxy-Coated-Steel Welded Wire Fabric: ASTM A 884/A 884M, Class A coated, [plain] [deformed].

L. Supports: Manufacturer's bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire fabric in place according to CRSI's "Manual of Standard Practice," PCI MNL 117, and as follows:
1. For uncoated reinforcement, use [all-plastic] [CRSI Class 1 plastic-protected] [CRSI Class 2 stainless-steel] bar supports.
2. For epoxy-coated reinforcement, use [CRSI Class 1A epoxy-coated or other dielectric-polymer-coated wire] [all-plastic] bar supports

3. For zinc-coated reinforcement, use [galvanized wire or dielectric-polymer-coated wire] [all-plastic] bar supports.

2.03 PRESTRESSING TENDONS:

A. Prestressing Strand: ASTM A 416/A 416M, Grade 250 or 270, uncoated, 7-wire, low-relaxation strand.

2.04 CONCRETE MATERIALS:

A. Portland Cement: ASTM C 150, Type I or Type III, [gray] [and] [white], of same type, brand, and source.
   1. Standard gray portland cement may be used for nonexposed backup concrete.

B. Normal-Weight Aggregates: Except as modified by PCI MNL 117, ASTM C 33, with coarse aggregates complying with Class 5S.
   1. Face-Mix Coarse Aggregates: Selected, hard, and durable; free of material that reacts with cement or causes staining.
      a. Gradation: [Uniformly graded] [Gap graded] [To match design reference sample].
   2. Face-Mix Fine Aggregates: Selected, natural or manufactured sand of the same material as coarse aggregate, unless otherwise approved by the Engineer.

C. Lightweight Aggregates: ASTM C 330.

D. Coloring Admixture: ASTM C 979, synthetic mineral-oxide pigments or colored water-reducing admixtures, temperature stable, nonfading, and alkali resistant.

E. Water: Potable; free from deleterious material that may affect color stability, setting, or strength of concrete and complying with chemical limits of PCI MNL 117.

F. Air-Entraining Admixture: ASTM C 260, certified by manufacturer to be compatible with other required admixtures.

G. Water-Reducing Admixture: ASTM C 494, Type A.

H. Retarding Admixture: ASTM C 494, Type B.

I. Water-Reducing and Retarding Admixture: ASTM C 494, Type D.

J. High-Range, Water-Reducing Admixture: ASTM C 494, Type F.

K. High-Range, Water-Reducing and Retarding Admixture: ASTM C 494, Type G.

L. Plasticizing Admixture: ASTM C 1017.

M. Fly Ash Admixture: ASTM C 618, Class C or F.

N. Metakaolin Admixture: ASTM C 618, Class N.

O. Silica Fume Admixture: ASTM C 1240.

2.05 STEEL CONNECTION MATERIALS:

A. Carbon-Steel Shapes and Plates: ASTM A 36/A 36M.

B. Carbon-Steel Headed Studs: ASTM A 108, AISI 1018 through AISI 1020, cold finished; AWS D1.1, Type A or B, with arc shields.

C. Carbon-Steel Plate: ASTM A 283/A 283M.

D. Malleable Steel Castings: ASTM A 47.

E. Carbon-Steel Castings: ASTM A 27/A 27M, Grade 60-30.

F. High-Strength, Low-Alloy Structural Steel: ASTM A 572/A 572M.

G. Carbon-Steel Structural Tubing: ASTM A 500, Grade B.

H. Wrought Carbon-Steel Bars: ASTM A 675/A 675M, Grade 65.

I. Deformed-Steel Wire or Bar Anchors: ASTM A 496 or ASTM A 706/A 706M.

J. Carbon-Steel Bolts and Studs: ASTM A 307, Grade A; carbon-steel, hex-head bolts and studs; carbon-steel nuts; and flat, unhardened steel washers.

K. Finish: For exterior steel items, steel in exterior walls, and items indicated for galvanizing, apply zinc coating by [hot-dip process according to ASTM A 123/A 123M, after fabrication, and ASTM A 153/A 153M, as applicable] [electrodeposition according to ASTM B 633, SC 3].
   1. Galvanizing Repair Paint: High-zinc-dust-content paint with dry film containing not less than 94 percent zinc dust by weight, and complying with DOD-P-21035A or SSPC-Paint 20.
   2. Shop-Primed Finish: Prepare surfaces of nongalvanized steel items, except those surfaces to be embedded in concrete, according to requirements in SSPC-SP 3 and shop-apply [lead- and chromate-free, rust-inhibitive primer, complying with performance requirements in FS TT-P-664] [SSPC-Paint 25] according to SSPC-PA 1.

L. Reglets: [PVC extrusions.] [Stainless steel.] [Copper.] [Reglets are specified in Section 07600, Flashing and Sheet Metal."]

M. Welding Electrodes: Comply with AWS standards.

N. Accessories: Provide clips, hangers, plastic shims, and other accessories required to install precast architectural concrete units.

2.06 STAINLESS-STEEL CONNECTION MATERIALS:

A. Stainless-Steel Plate: ASTM A 666, Type 304, of grade suitable for application.

B. Stainless-Steel Bolts and Studs: ASTM F 593, alloy 304 or 316, hex-head bolts and studs; stainless-steel nuts; and flat, stainless-steel washers.

C. Stainless-Steel Headed Studs: ASTM A 276.

2.07 BEARING PADS:

A. Provide bearing pads for precast architectural concrete units as follow
   1. Elastomeric Pads: AASHTO M 251, plain, vulcanized, 100 percent polychloroprene

(neoprene) elastomer, molded to size or cut from a molded sheet, 50 to 70 Shore A durometer, minimum tensile strength 2250 psi per ASTM D 412.

2. Random-Oriented, Fiber-Reinforced Elastomeric Pads: Preformed, randomly oriented synthetic fibers set in elastomer. Surface hardness of 70 to 90 Shore A durometer.
3. Cotton-Duck-Fabric-Reinforced Elastomeric Pads: Preformed, horizontally layered cotton-duck fabric bonded to an elastomer. Surface hardness of 80 to 100 Shore A durometer.
4. Frictionless Pads: Tetrafluoroethylene, glass-fiber reinforced, bonded to mild-steel plate, of type required for in-service stress.
5. High-Density Plastic: Multimonomer, nonleaching, plastic strip.

2.08 GROUT MATERIALS:

A. Sand-Cement Grout: Portland cement, ASTM C 150, Type I, and clean, natural sand, ASTM C 144. Mix at ratio of 1 part cement to 2-1/2 parts sand, by volume, with minimum water required for placement and hydration.

B. Nonmetallic, Nonshrink Grout: Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, portland cement, shrinkage-compensating agents, plasticizing and water-reducing agents, complying with ASTM C 1107, of consistency suitable for application.

2.09 THIN BRICK UNITS AND ACCESSORIES:

A. Thin Brick Units: ASTM C 1088, Grade Exterior, Type TBX, [not less than 1/2 inch] [3/4 inch] [1 inch] thick, and as follows:
1. Face Size: Standard, 2-1/4 inches high by 8 inches long.
2. Face Size: Modular, 2-1/4 inches high by 7-1/2 to 7-5/8 inches long.
3. Face Size: Engineer modular, 2-3/4 to 2-13/16 inches high by 7-1/2 to 7-5/8 inches long
4. Face Size: Closure modular, 3-1/2 to 3-5/8 inches high by 7-1/2 to 7-5/8 inches long.
5. Face Size: Utility, 3-1/2 to 3-5/8 inches high by 11-1/2 to 11-5/8 inches long.
6. Where shown to "match existing," provide face brick matching color, texture, and face size of existing adjacent brickwork.
7. Special Shapes: Include corners, edge corners, and end edge corners.
8. Initial Rate of Absorption: Less than 30 g/30 sq. in. per minute when tested per ASTM C 67.
9. Efflorescence: Provide brick that has been tested according to ASTM C 67 and is rated "not effloresced."
10. Surface Coloring: Brick with surface coloring, other than flashed or sand-finished brick, shall withstand 50 cycles of freezing and thawing per ASTM C 67 with no observable difference in the applied finish when viewed from 10 feet
11. Face Color and Texture: [Match Architect's samples] [Medium brown, wire cut] [Full-range red, sand molded] [Gray, velour].
12. Back Surface Texture: Scored, combed, wire roughened, or ribbed.

B. Setting Mortar: Portland cement, ASTM C 150, Type I, and clean, natural sand, ASTM C 144. Mix at ratio of 1 part cement to 4 parts sand, by volume, with minimum water required for placement.

C. Latex-Portland Cement Pointing Grout: ANSI A118.6 and as follows:Select one or both types of grout from first two subparagraphs below.
1. Dry-grout mixture, factory prepared, of portland cement, graded aggregate, and dry, redispersible, ethylene-vinyl-acetate additive for mixing with water; uniformly colored

2. Commercial portland cement grout, factory prepared, with liquid styrene-butadiene rubber or acrylic-resin latex additive; uniformly colored.
3. Colors: [As indicated by manufacturer's designations] [Match Engineer's samples] [As selected by Engineer from manufacturer's full range].

2.10 CONCRETE MIXES:

A. Prepare design mixes for each type of concrete required.Delete subparagraph below if fly ash or silica fume is not permitted. Revise percentage to suit Project.
1. Limit use of fly ash and silica fume to not exceed, in aggregate, 25 percent of portland cement by weight.

B. Design mixes may be prepared by a qualified independent testing agency or by qualified precast plant personnel at precast architectural concrete fabricator's option.

C. Limit water-soluble chloride ions to the maximum percentage by weight of cement permitted by ACI 318.

D. Normal-Weight Concrete Face and Backup Mixes: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.1, with materials to be used on Project, to provide normal-weight concrete with the following properties:
1. Compressive Strength (28 Days): 5000 psi or greater
2. Maximum Water-Cementitious Materials Ratio: 0.45.

E. Water Absorption: 12 to 14 percent by volume, tested according to PCI MNL 117.

F. Lightweight Concrete Backup Mixes: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.2, with materials to be used on Project, to provide lightweight concrete with the following properties:
1. Compressive Strength (28 Days): 5000 psi or greater.
2. Unit Weight: Calculated equilibrium unit weight of 115 lb/cu. ft., plus or minus 3 lb/cu. ft., according to ASTM C 567.

G. Add air-entraining admixture at manufacturer's prescribed rate to result in concrete at point of placement having an air content complying with PCI MNL 117.

H. When included in design mixes, add other admixtures to concrete mixes according to manufacturer's written instructions.

2.11 MOLD FABRICATION:

A. Molds: Accurately construct molds, mortar tight, of sufficient strength to withstand pressures due to concrete-placement operations and temperature changes and for prestressing operation
1. Place form liners accurately to provide finished surface texture indicated. Provide solid backing and supports to maintain stability of liners during concreting. Coat form liner with form-release agent.

B. Maintain molds to provide completed precast architectural concrete units of shapes, lines, and dimensions indicated, within fabrication tolerances specified.
1. Edge and Corner Treatment: Uniformly [chamfered] [radiused].

2.12 THIN BRICK FACINGS:

A. Place form liner templates accurately to provide grid for thin brick facings. Provide solid backing and supports to maintain stability of liners while placing thin bricks and during concreting.

B. Securely place thin brick units face down into form liner pockets.

C. Completely fill joint cavities between thin brick units with sand-cement mortar, and place precast concrete backing mix while sand-cement mortar is still fluid enough to ensure bond
   1. Mix and install grout according to ANSI 108.10. Completely fill joint cavities between thin brick units with grout, and compress into place without spreading grout onto faces of thin brick units. Remove excess grout immediately to prevent staining of brick.
   2. Tool joints to a [slightly concave] [grapevine] [V-]shape when pointing grout is thumbprint hard.

D. Clean faces and joints of brick facing.

2.13 FABRICATION:

A. Cast-in Anchors, Inserts, Plates, Angles, and Other Anchorage Hardware: Fabricate anchorage hardware with sufficient anchorage and embedment to comply with design requirements. Accurately position for attachment of loose hardware, and secure in place during precasting operations. Locate anchorage hardware where it does not affect position of main reinforcement or concrete placement.

B. Furnish loose steel plates, clip angles, seat angles, anchors, dowels, cramps, hangers, and other hardware shapes for securing precast architectural concrete units to supporting and adjacent construction.

C. Cast-in reglets, slots, holes, and other accessories in precast architectural concrete units to receive windows, cramps, dowels, reglets, waterstops, flashings, and other similar work as indicated.

D. Cast-in openings larger than 10 inches in any dimension.

E. Reinforcement: Comply with recommendations in CRSI's "Manual of Standard Practice" and PCI MNL 117 for fabricating, placing, and supporting reinforcement.
   1. Clean reinforcement of loose rust and mill scale, earth, and other materials that reduce or destroy the bond with concrete.
   2. Accurately position, support, and secure reinforcement against displacement during concrete-placement and consolidation operations. Completely conceal support devices to prevent exposure on finished surfaces.
   3. Place reinforcement to maintain at least 3/4-inch minimum coverage. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position while placing concrete. Direct wire tie ends away from finished, exposed concrete surfaces.
   4. Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.

F. Reinforce precast architectural concrete units to resist handling, transportation, and erection stresses.

G. Prestress tendons for precast architectural concrete units by either pretensioning or posttensioning methods. Comply with PCI MNL 117.
   1. Delay detensioning or posttensioning of precast, prestressed architectural concrete units until concrete has reached its indicated minimum design release compressive

strength as established by test cylinders cured under the same conditions as concrete.

H. Mix concrete according to PCI MNL 117 and requirements in this Section. After concrete batching, no additional water may be added.

I. Place face mix to a minimum thickness after consolidation of the greater of 1 inch or 1.5 times the maximum aggregate size, but not less than the minimum reinforcing cover.

J. Place concrete in a continuous operation to prevent seams or planes of weakness from forming in precast concrete units. Comply with requirements in PCI MNL 117 for measuring, mixing, transporting, and placing concrete.
   1. Place backup concrete to ensure bond with face mix concrete.

K. Thoroughly consolidate placed concrete by internal and external vibration without dislocating or damaging reinforcement and built-in items. Use equipment and procedures complying with PCI MNL 117.

L. Comply with ACI 306.1 procedures for cold-weather concrete placement.

M. Comply with ACI 305R recommendations for hot-weather concrete placement.

N. Identify pickup points of precast architectural concrete units and orientation in structure with permanent markings, complying with markings indicated on Shop Drawings. Imprint or permanently mark casting date on each precast architectural concrete unit on a surface that will not show in finished structure.

O. Cure concrete, according to requirements in PCI MNL 117, by moisture retention without heat or by accelerated heat curing using low-pressure live steam or radiant heat and moisture.

P. Discard precast architectural concrete units that are warped, cracked, broken, spalled, stained, or otherwise defective unless repairs are approved by the Engineer.

2.14 FABRICATION TOLERANCES:

A. Fabricate precast architectural concrete units straight and true to size and shape with exposed edges and corners precise and true so each finished panel complies with the following product tolerances:
   1. Overall Height and Width of Units, Measured at the Face Exposed to View: As follows:
      a. 10 feet or under, plus or minus 1/8 inch.
      b. 10 to 20 feet, plus 1/8 inch, minus 3/16 inch.
      c. 20 to 40 feet, plus or minus 1/4 inch.
      d. Each additional 10 feet, plus or minus 1/16 inch.
   2. Overall Height and Width of Units, Measured at the Face Not Exposed to View: As follows:
      a. 10 feet or under, plus or minus 1/4 inch.
      b. 10 to 20 feet, plus 1/4 inch, minus 3/8 inch.
      c. 20 to 40 feet, plus or minus 3/8 inch.
      d. Each additional 10 feet, plus or minus 1/8 inch.
   3. Total Thickness or Flange Thickness: Plus 1/4 inch, minus 1/8 inch.
   4. Rib Thickness: Plus or minus 1/8 inch.
   5. Rib to Edge of Flange: Plus or minus 1/8 inch.
   6. Distance between Ribs: Plus or minus 1/8 inc
   7. Variation from Square or Designated Skew (Difference in Length of the Two

Diagonal Measurements): Plus or minus 1/8 inch per 72 inches or 1/2 inch total, whichever is greater.

8. Length and Width of Block-outs and Openings within One Unit: Plus or minus 1/4 inch.
9. Location and Dimension of Block-outs Hidden from View and Used for HVAC and Utility Penetrations: Plus or minus 3/4 inch.
10. Dimensions of Haunches: Plus or minus 1/4 inch.
11. Haunch Bearing Surface Deviation from Specified Plane: Plus or minus 1/8 inch.
12. Difference in Relative Position of Adjacent Haunch Bearing Surfaces from Specified Relative Position: Plus or minus 1/4 inch.
13. Bowing: Plus or minus L/360, maximum 1 inch.
14. Local Smoothness: 1/4 inch per 10 feet.
15. Variation between Adjacent Thin-Brick-Facing Products: 1/16 inch.
16. Warping: 1/16 inch per 12 inches of distance from the nearest adjacent corner.
17. Tipping and Flushness of Plates: Plus or minus 1/4 inch.
18. Dimensions of Architectural Features and Rustications: Plus or minus 1/8 inch.

B. Position Tolerances: For cast-in items measured from datum line location, as indicated on Shop Drawings.

1. Weld Plates: Plus or minus 1 inch.
2. Inserts: Plus or minus 1/2 inch.
3. Handling Devices: Plus or minus 3 inches
4. Reinforcing Steel and Welded Wire Fabric: Plus or minus 1/4 inch where position has structural implications or affects concrete cover; otherwise, plus or minus 1/2 inch.
5. Reinforcing Steel Extending out of Member: Plus or minus 1/2 inch of plan dimensions.
6. Tendons: Plus or minus 1/4 inch, vertical; plus or minus 1 inch, horizontal
7. Location of Rustication Joints: Plus or minus 1/8 inch.
8. Location of Opening within Panel: Plus or minus 1/4 inch.
9. Flashing Reglets: Plus or minus 1/4 inch.
10. Flashing Reglets at Edge of Panel: Plus or minus 1/8 inch.
11. Reglets for Glazing Gaskets: Plus or minus 1/8 inch.
12. Electrical Outlets, Hose Bibs: Plus or minus 1/2 inch.
13. Haunches: Plus or minus 1/4 inch.
14. Allowable Rotation of Plate, Channel Inserts, Electrical Boxes: 2-degree rotation or 1/4 inch maximum over the full dimension of the unit.

2.15 FINISHES:

A. Finish exposed-face surfaces of precast architectural concrete units to match approved design reference sample and as follows:

1. Design Reference Sample: <Insert description and identify fabricator and code number of sample.>
2. PCI and APA's "Architectural Precast Concrete--Color and Texture Selection Guide," of plate numbers indicated.
3. Smooth-Surface Finish: Provide surfaces free of pockets, sand streaks, and honeycombs, with uniform color and texture.
4. Textured-Surface Finish: Impart by form liners or inserts to provide surfaces free of pockets, streaks, and honeycombs, with uniform color and texture.
5. Bushhammer Finish: Use power or hand tools to remove matrix and fracture coarse aggregates.
6. Retarded Finish: Use chemical retarding agents applied to concrete forms and washing and brushing procedures to expose aggregate and surrounding matrix surfaces after form removal.

7. Abrasive-Blast Finish: Use abrasive grit, equipment, application techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces.
8. Acid-Etched Finish: Use acid and hot-water solution, equipment, application techniques, and cleaning procedures to expose aggregate and surrounding matrix surfaces.
9. Honed Finish: Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures.
10. Polished Finish: Use continuous mechanical abrasion with fine grit, followed by filling and rubbing procedures.
11. Sand-Embedment Finish: Use selected stones placed in a sand bed in bottom of mold, with sand removed after curing.
12. Finish exposed [top] [bottom] [and back] surfaces of precast architectural concrete units to match face-surface finish.

B. Finish exposed [top] [bottom] [and back] surfaces of precast architectural concrete units by smooth, steel-trowel finish.

C. Finish unexposed surfaces of precast architectural concrete units by float finish.

2.16 SOURCE QUALITY CONTROL:

A. The Authority will employ an independent testing agency to evaluate precast architectural concrete fabricator's quality-control and testing methods.
1. Allow the Authority's testing agency access to material storage areas, concrete production equipment, concrete placement, and curing facilities. Cooperate with the Authorityâ€™s testing agency and provide samples of materials and concrete mixes as may be requested for additional testing and evaluation.

B. Quality-Control Testing: Test and inspect precast concrete according to PCI MNL 117 requirements.

C. Strength of precast concrete units will be considered deficient if units fail to comply with ACI 318 requirements.

D. Testing: If there is evidence that the strength of precast concrete units may be deficient or may not comply with ACI 318 requirements, the Authority will employ an independent testing agency to obtain, prepare, and test cores drilled from hardened concrete to determine compressive strength according to ASTM C 42.
1. A minimum of three representative cores will be taken from units of suspect strength, from locations directed by the Engineer.
2. Cores will be tested in an air-dry condition.
3. Strength of concrete for each series of 3 cores will be considered satisfactory if the average compressive strength is equal to at least 85 percent of the 28-day design compressive strength and no single core is less than 75 percent of the 28-day design compressive strength.
4. Test results will be made in writing on the same day that tests are performed, with copies to the Engineer, Contractor, and precast concrete fabricator. Test reports will include the following:
a. Project identification name and number.
b. Date when tests were performed.
c. Name of precast concrete fabricator.
d. Name of concrete testing agency.
e. Identification letter, name, and type of precast concrete unit or units represented by core tests; design compressive strength; type of break; compressive strength at breaks, corrected for length-diameter ratio; and

direction of applied load to core in relation to horizontal plane of concrete as placed.

E. Patching: If core test results are satisfactory and precast concrete units comply with requirements, clean and dampen core holes and solidly fill with precast concrete mix that has no coarse aggregate, and finish to match adjacent precast concrete surfaces.

F. Defective Work: Precast architectural concrete units that do not comply with requirements, including strength, manufacturing tolerances, and finishes, are unacceptable. Replace with precast concrete units that comply with requirements.

PART 3 - EXECUTION

3.01 EXAMINATION:

A. Examine substrates and conditions for compliance with requirements for installation tolerances, true and level bearing surfaces, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Do not install precast concrete units until supporting concrete has attained minimum design compressive strength.

3.02 INSTALLATION

A. Install clips, hangers, and other accessories required for connecting precast architectural concrete units to supporting members and backup materials.

B. Install precast architectural concrete. Provide temporary supports and bracing as required to maintain position, stability, and alignment as units are being permanently connected.
1. Install bearing pads as precast concrete units are being erected.
2. Maintain horizontal and vertical joint alignment and uniform joint width as erection progresses.
3. Remove projecting hoisting devices and use sand-cement grout to fill voids within recessed hoisting devices flush with surface of concrete.

C. Anchor precast architectural concrete units in position by bolting, welding, grouting, or as otherwise indicated. Remove temporary shims, wedges, and spacers as soon as possible after anchoring and grouting are completed.

D. Welding: Perform welding in compliance with AWS D1.1 and AWS D1.4, with qualified welders
1. Protect precast architectural concrete units and bearing pads from damage by field welding or cutting operations and provide noncombustible shields as required.
2. Repair damaged steel surfaces by cleaning and applying a coat of galvanizing repair paint to galvanized surfaces.
3. Repair damaged steel surfaces by cleaning and repriming damaged painted surfaces.

E. At bolted connections, use lock washers or other acceptable means to prevent loosening of nuts.

F. Grouting Connections: Grout connections where required or indicated. Retain grout in place until hard enough to support itself. Pack spaces with stiff grout material, tamping until voids are completely filled. Place grout to finish smooth, level, and plumb with adjacent concrete

surfaces. Keep grouted joints damp for not less than 24 hours after initial set. Promptly remove grout material from exposed surfaces before it affects finishes or hardens.

3.03 ERECTION TOLERANCES:

A. Install precast architectural concrete units level, plumb, square, and true, without exceeding the following noncumulative erection tolerance
   1. Plan Location from Building Grid Datum: Plus or minus 1/2 inch.
   2. Plan Location from Centerline of Steel: Plus or minus 1/2 inch.
   3. Top Elevation from Nominal Top Elevation: As follows:
      a. Exposed Individual Panel: Plus or minus 1/4 inch.
      b. Nonexposed Individual Panel: Plus or minus 1/2 inch.
      c. Exposed Panel Relative to Adjacent Panel: 1/4 inch.
      d. Nonexposed Panel Relative to Adjacent Panel: 1/2 inch.
   4. Support Elevation from Nominal Support Elevation: As follows:
      a. Maximum Low: 1/2 inch.
      b. Maximum High: 1/4 inch.
   5. Maximum Plumb Variation over the Lesser of Height of Structure or 100 Feet: 1 inch.
   6. Plumb in Any 10 Feet of Element Height: 1/4 inch.
   7. Maximum Jog in Alignment of Matching Edges: 1/4 inch.
   8. Joint Width (Governs over Joint Taper): Plus or minus 1/4 inch.
   9. Maximum Joint Taper: 3/8 inch.
   10. Joint Taper in 10 Feet: 1/4 inch.
   11. Maximum Jog in Alignment of Matching Faces: 1/4 inch.
   12. Differential Bowing or Camber, as Erected, between Adjacent Members of Same Design: 1/4 inch.

3.04 FIELD QUALITY CONTROL:

A. Testing: The Authority will engage a qualified independent testing and inspecting agency to perform field tests and inspections

B. Field welds and connections using high-strength bolts will be subject to tests and inspections.

C. Testing agency will report test results promptly and in writing to Contractor and the Engineer.

D. Remove and replace work that does not comply with specified requirements.

E. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of corrected work with specified requirements.

3.05 REPAIRS:

A. Repair exposed exterior surfaces of precast architectural concrete units to match color, texture, and uniformity of surrounding precast architectural concrete if permitted by the Engineer.

B. Remove and replace damaged precast architectural concrete units if repairs do not comply with requirements.

3.06 CLEANING:

A. Clean exposed surfaces of precast concrete units after erection to remove weld marks, other markings, dirt, and stains.
   1. Wash and rinse according to precast concrete fabricator's written recommendations. Protect other work from staining or damage due to cleaning operations.

2. Do not use cleaning materials or processes that could change the appearance of exposed concrete finishes.

END OF SECTION