

SECTION 033713

SHOTCRETE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. The drawings and general provisions of the Contract, including General and Supplementary Conditions, and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes: This section describes the requirements for materials, proportioning, and application of shotcrete. All shotcrete shall be Wet-Mix Shotcrete, defined as shotcrete in which plastic concrete with cement, aggregate, and water are first mixed together before introduction into the delivery hose.
- B. Related Sections:
 - 1. 013300 – Submittal Procedures
 - 2. 014500 – Structural Testing, Inspection, and Quality Assurance
 - 3. 031000 – Concrete Forming and Accessories
 - 4. 032000 – Concrete Reinforcing
 - 5. 033000 – Cast-in-Place Concrete

1.3 REFERENCE STANDARDS

- A. The latest versions of the publications listed below form a part of this specification; comply with provisions of these publications except as otherwise shown or specified.
 - 1. ACI 117 Standard Specification for Tolerances for Concrete
 - 2. ACI 301 Standard Specifications for Structural Concrete, including other standards referred to in ACI 301, such as ASTM, etc.
 - 3. ACI 305.1 Standard Specification for Hot Weather Concreting
 - 4. ACI 306.1 Standard Specification for Cold Weather Concreting
 - 5. ACI 506.2 Standard Specification for Shotcrete, including other standards referred to in ACI 506.2, such as ASTM, etc.

1.4 SUBMITTALS

- A. General: Make submittals in accordance with Section 013300, "Submittal Procedures," and Section 033000, "Cast-in-Place Concrete."
- B. Submit a written description of all required procedures for both materials and application, including methods for thickness control. Submit samples of control pins, ground wires, and any other proposed fixture.
- C. Samples: Submit samples of finish material as requested by Architect.

- D. Placement Schedule: Submit proposed placement schedule. Include the following information:
 - 1. Method of placement
 - 2. Location
- E. Pre-Construction Testing: Submit samples and test reports for pre-construction testing in accordance with Quality Assurance requirements.
- F. Strength Tests: Submit Strength Test results for the Work in accordance with Quality Assurance requirements.
- G. Records: Retain records of all shotcrete, including exact mix proportions, slumps, test strength, date, time, location, weather conditions at time of shotcrete operation, and the source of concrete. Submit copy to Owner's Representative and Building Official.

1.5 QUALITY ASSURANCE

- A. Contractor is responsible for correcting Work that does not conform to the specified requirements, including strength, tolerances, and finishes. The Contractor shall submit their proposed solution for review and approval.
- B. Unless otherwise noted, maintain the allowable tolerances in ACI 117.
- C. Shotcrete work is subject to special inspection and testing; notify the Owner's Testing Agency at least 24 hours prior to shotcreting.
- D. The concrete used for shotcreting and the concrete producer are subject to all Quality Assurance requirements in Section 033000, "Cast-in-Place Concrete."
- E. Shotcrete Contractor Qualifications: An experienced shotcrete contractor who has completed shotcrete 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.
 - 1. The shotcrete contractor shall have experience in the placing of structural shotcrete (other than swimming pools) on previous projects, demonstrating a minimum of three successful recent projects of similar construction.
 - 2. The shotcrete contractor shall use only experienced shotcrete foremen, nozzle men, and delivery equipment operators on the Work.
 - 3. The applicator (nozzle man) shall qualify as a specified "Specialist" and have experience performing similar satisfactory work for a period of at least five years.
 - 4. The shotcrete contractor shall provide capable nozzle man helpers with air blowpipes to assist the nozzle man in keeping all rebound build-up out of the Work.
- F. Pre-Construction Conference: At least 30 days prior to start of shotcrete work, the Contractor shall hold a meeting to review the finish appearance requirements, reveal locations, joint spacing, concrete design mixes, requirements for submittals, construction procedures, schedules for testing, inspection, and certifications.
 - 1. Notify attendees 10 days prior to the scheduled date of the meeting.
 - 2. Required in attendance:
 - a. Contractor

- b. Shotcrete subcontractor
 - c. Testing Laboratory representative
 - d. Ready-mix producer
 - e. Architect/Engineer
 - f. All subcontractors with work to be installed in or affected by shotcrete work
- G. Pre-Construction Testing: Prepare pre-construction test panels for examination by Architect/Engineer prior to job shotcrete placement. Preparation and testing shall comply with the requirements of ACI 506.2 and ASTM C1140.
 - 1. Pre-Construction Test Panels: Shoot, cure, saw, examine, and test three test panels, simulating job conditions as closely as possible. Reproduce the thickest reinforced and most congested areas of the structural design. Shoot at same angle, using same nozzleman and equipment and using same concrete mix design used on the project. The panels shall be a minimum of 3'-0" square.
 - 2. Obtain three cores from each test panel for visual examination. The cores shall be 4 inches in diameter and cut through the entire thickness of the panel. The cores shall be intentionally located so as to intersect the most congested reinforcing intersections.
 - 3. Visually grade the reinforced specimens in accordance with ACI 506.2 Shotcrete Core Grades criteria. Only nozzlemen with a test panel mean core grade less than or equal to 2.0 shall be allowed to place job shotcrete. If the test panel is rejected, a second panel may be shot. If the nozzleman's second mean core grade is greater than 2.0, the nozzleman shall not be permitted to shoot on the project.
 - 4. Take strength test specimens as specified below.
- H. Field Mockup: Before proceeding with installation of shotcrete, apply a sample installation for the purpose of establishing surface appearance and workmanship standards.
 - 1. Sample section shall be at least 100 square feet and be full floor height. Provide one sample installation for each nozzleman and blow-off man crew. The mockup may remain in place if it is shown to meet all structural and architectural criteria included in this specification section.
 - 2. Shotcrete material for field mockup shall be applied in the same manner as that which will be used for the remaining work.
 - 3. Approved work shall become the standard of comparison for workmanship and appearance for all remaining work. The Contractor shall make all necessary adjustments in installation procedures to obtain Architect's approval at no additional cost to the Owner. No additional work shall begin until the Architect and the Owner's Testing Agency have approved sample area(s).
- I. Construction Testing: The Contractor shall produce strength test specimens for each mix and each work day, or every 50 cubic yards placed, whichever is less. The Owner's Testing Agency shall take the cores for strength verification. Specimens shall be taken in accordance with one of the following:
 - 1. From test panels: Made not less than once each shift but not less than one for each 50 cubic yards of shotcrete placed. When the maximum size aggregate is larger than 3/8 inch, the test panels shall have a minimum dimension of 18 by 18 inches. When the maximum size aggregate is 3/8 inch or smaller, the panel size shall be 12 by 12 inches minimum. Test panel thickness shall be a minimum of 3-1/2 inches. Panels shall be gunned in the same position as the Work, during the course of the Work, and by nozzlemen doing the Work. The condition under which the panels are cured is required to be the same as the Work.
 - 2. From the in-place work: Taken at least once each shift but not less than one for each 50 cubic yards of shotcrete.

- J. Strength Tests: Strength test for shotcrete shall be made on specimens that are representative of the Work and that have been water soaked for at least 24 hours prior to testing.
 - 1. When the maximum size aggregate is larger than 3/8 inch, take not less than three 3-inch diameter cores or 3-inch cubes. When the maximum size aggregate is 3/8 inch or smaller, take not less than three 2-inch diameter cores or 2-inch cubes.
 - 2. The average of three cores from a single panel is required to be equal to or exceed 0.85 f'c with no single core less than 0.75 f'c. The average of three cubes taken from a single panel is required to equal or exceed f'c with no individual cube less than 0.88 f'c. To check testing accuracy, locations represented by erratic core strengths may be re-tested.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."

PART 2 - PRODUCTS

2.1 CONCRETE MATERIALS

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."

2.2 RELATED MATERIALS

- A. Reinforcement and Wire Fabric: Refer to Section 032000, "Concrete Reinforcing."
- B. Thickness Control Pins: Non-corrosive materials, designed not to cause infiltration of water through the shotcrete.
- C. Dissipating Resin Curing Materials: Liquid type membrane forming curing compound complying with ASTM C309, Type I. Curing compound must be of a type that does not inhibit subsequent moist curing operations. The film shall chemically break down in a 2- to 4-week period. Acceptable products are Burke "RES-X Curing Compound," Euclid Chemical Co. "Kurez DR," Dayton "Day-Chem Rez Cure (J-11-W)," or approved equal.
- D. Moisture Retaining Cover: Use waterproof sheet materials that conform to ASTM C171.

2.3 PROPORTIONING AND DESIGN REQUIREMENTS OF SHOTCRETE MIXES

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."
- B. Shotcrete Mixes: Provide shotcrete mixes conforming to the requirements as indicated in Structural Drawing General Notes.
 - 1. Strength Requirements: Compressive strength requirements are indicated on drawings and are based on cylinder tests at indicated age.
 - 2. Aggregate Size: 3/4 inch maximum.
 - 3. Water/Cementitious Material Ratio: Not to exceed limits indicated on Structural drawings.

- 4. Slump: Slump shall be 2-1/2 inch maximum, 1-1/2 inch minimum at point of line discharge. Concrete used for the actual project shall be within +/- 1/2 inch of the slump used on the test panel.
- C. Batching and Mixing: Weight batching shall comply with the accuracy specified in ASTM C94. Volumetric batching is not permitted.
- D. Apply wet-mix shotcrete within the time and revolution limits specified in Section 033000, "Cast-in-Place Concrete."

2.4 EQUIPMENT

- A. Air Supply: Clean air adequate for maintaining sufficient nozzle velocity for parts of work, and for simultaneous operation of blow pipe for cleaning away rebound.
- B. Delivery Equipment: Capable of discharging aggregate-cement-water mixture accurately, uniformly, and continuously through delivery hose.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Do not apply shotcrete until data on materials and mixture proportions are accepted.
- B. Remove snow, ice, frost, water, and other foreign materials from form surfaces, reinforcement, and embedded items against which shotcrete will be applied.
- C. Verify that forms are to line and grade, braced against vibration, and constructed to permit escape of air and rebound.
- D. Verify that placement and clearance around reinforcement permits complete encasement.
- E. Verify that surfaces to receive shotcrete have been properly prepared according to the Contract Documents.
- F. Do not allow mud or foreign materials into the concrete during shotcrete applications.
- G. When the ambient temperature necessitates the use of cold or hot weather concreting, make provisions in advance of shotcrete application.
- H. Do not shotcrete when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing, and curing.
- I. Do not shotcrete while rain, sleet, or snow is falling unless adequate protection is provided.

3.2 SURFACE PREPARATION

- A. Earth: Prepare surfaces to line and grade. Do not apply shotcrete to frozen surfaces. Dampen surface immediately prior to shooting.
- B. Concrete: When bonding is required, remove all deteriorated, loose unsound material or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Taper edges to eliminate square shoulders at the perimeter of a cavity. Taper construction joints at a 1-to-1 slope. Surface shall be saturated surface dry immediately prior to shooting.
- C. Reinforcement: The surface shall be free of deleterious materials that inhibit bonding. For new construction, reinforcement laps shall be separated with a clearance of at least three times the diameter of the largest aggregate. Reinforcement shall be secured to prevent movement. Continue reinforcement through construction joints.
- D. Forms: Use form-release coating material on removable forms. Secure forms to minimize the effects of vibration. Construct forms to allow escape of placement air and rebound.

3.3 JOINTS

- A. Construction Joints: Taper construction joints at a 1-to-1 slope where joint is not subject to compression loads. Surface preparation of joints shall comply with Section 3.2.B. Continue reinforcement through construction joint.
- B. Control Joints: Locate construction joints as indicated on the structural drawings.
- C. Except where permitted herein, unfinished work shall not be allowed to stand for more than 30 minutes unless edges are sloped to a thin edge. For structural elements that will be under compression and for construction joints shown on the approved Construction Documents, square joints are permitted. Before placing material adjacent to previously applied work, sloping and square edges shall be cleaned and wetted.

3.4 ALIGNMENT CONTROL

- A. Install taut ground wires or other means to establish thickness and plane of required surface. Install taut ground wires or other means at corners or offsets not established by forms. Ensure alignment wires are tight, true to line, and placed to allow further tightening.

3.5 SHOTCRETE APPLICATION

- A. Placement Techniques:
 - 1. Provide a platform that permits nozzleman unobstructed access to the receiving surface. Allow easy access to shotcrete surfaces for screeding and finishing to permit uninterrupted application. Shotcrete shall not be placed where the stream from the nozzle cannot directly impinge on the surface on which concrete is to be placed.

2. Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily.
3. Place shotcrete with nozzle held approximately perpendicular to the receiving surface to ensure maximum compaction with minimum rebound. In corners, direct nozzle at an approximately 45-degree angle or bisect the corner angle. Apply shotcrete so sag or sloughing does not occur.
4. Build up to the required thickness by making several passes of nozzle over work area. Sections shall be gunned to their full design thickness in one layer, thereby reducing the possibility of cold joints and laminations.
5. Remove rebound and overspray from previously prepared surfaces prior to shotcrete placement. Do not reuse rebound or overspray. Remove hardened overspray and rebound from adjacent surfaces, including exposed reinforcement. Remove laitance from shotcrete surfaces to receive additional shotcrete layers.
6. Discontinue shooting or shield the nozzle stream if wind causes separation of ingredients during shooting.
7. Do not apply shotcrete on surfaces with standing water or running water.

B. Encasement of Reinforcement:

1. Place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity and plasticity so material flows around and behind the reinforcement. Front face of reinforcement shall remain clean during encasement.
2. Do not place shotcrete through more than one layer of reinforcing steel in one application, unless demonstrated by pre-construction tests that steel is properly encased.
3. Place shotcrete to provide the concrete cover over reinforcement requirements in accordance with the Contract Documents.

3.6 FINISHING

- A. General: Finish shotcrete work in accordance with one of the finishes noted in Section 033000, "Cast-in-Place Concrete," as designated in the Contract Documents. Finish all joints and edges with proper tools as approved.
- B. Non-Specified Finish: When the type of finish is not specified in Contract Documents, provide a Steel Troweled Finish.

3.7 CONCRETE CURING AND PROTECTION

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."

3.8 COLD WEATHER SHOTCRETING

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."

3.9 HOT WEATHER SHOTCRETING

- A. General: In accordance with Section 033000, "Cast-in-Place Concrete."

3.10 DEFECTIVE WORK

- A. General: Shotcrete that lacks uniformity; exhibits segregation or variable density, honeycombing, laminations, or cracking; lacks water tightness; is drummy when sounded with a hammer; or fails to meet the required strength shall be regarded as defective. Defective work shall be removed and replaced with acceptable work at no additional cost to the Owner.

3.11 PATCHING

- A. General: After concrete has cured, allow to dry and inspect for shrinkage cracking. Patch cracks with patching compound as specified in Section 033000, "Cast-in-Place Concrete." Comply with manufacturer's recommendations for application of patching materials.

END OF SECTION