DESCRIPTION

Work. The work shall consist of removal and disposal of unsound structural concrete and replacement with shotcrete where indicated in the contract documents and where ordered by the Engineer. The Contractor has the option of using either the Dry Mix Process or the Wet Mix Process. An American Shotcrete Association (ASA) certified nozzleman with a valid certification for the application type specified in the contract plans (Vertical, Horizontal and/or Overhead) will be required to perform this work.

Definitions

A. Shotcrete. This is mortar conveyed through a hose and pneumatically projected at high velocity onto a surface.

B. Dry Mix Process. This is a process in which the dry cement-sand mixture is carried by compressed air to the nozzle where water is injected and the resulting mixture is jetted from the nozzle at high velocity onto the surface to be shotcreted.

C. Wet Mix Process. This is a process in which all the ingredients including water are thoroughly mixed and then jetted from the nozzle at high velocity onto the surface to be shotcreted.

D. Delivery System. This consists of the nozzle, shotcrete pump, water ring(s) or air ring, and any necessary valves, connected to the delivery hose.

MATERIALS. Materials used in this work shall conform to the following requirements:

- Portland Cement, Types 1 or 2  701-01
- Quilted Covers (for curing)  711-02
- Concrete Sand  703-07
- Plastic Coated Fiber Blankets  711-03
- Water  712-01
- Membrane Curing Compound  711-05
- Wire Fabric for Concrete Reinforcing1  709-02
- Epoxy-Coated Bar Reinforcement  709-04
- Expansion Bolt Anchors  GSA FF-S-325, Group III, Type 1 or Group VIII, Type 1
- Hook Bolts Inserted in Expansion Bolt Anchors  ASTM A307 Grade A

All admixtures shall be from the same manufacturer and be accompanied by a letter from that manufacturer that confirms they are compatible with each other for the proposed application.

NOTE. The wire fabric shall be galvanized in accordance with ASTM A641M regular coatings. The wire fabric shall be fabricated from No. 12 wire spaced 2 inches (nominal) in each direction or No. 10 wire spaced 3 inches (nominal) in each direction. Wire used shall have a minimum yield strength of 35 ksi.
EQUIPMENT

A. Batching and Mixing Equipment. The mixing equipment shall be capable of thoroughly mixing the materials in sufficient quantity to maintain placing continuity.

B. Air Supply. The compressor shall be of adequate capacity (minimum of 375 CFM for Wet Mix, and 600 CFM for Dry Mix) to maintain a sufficient, constant nozzle velocity for all parts of the work while simultaneously operating a blow pipe for cleaning away rebound. The air hose shall be equipped with a filter to prevent any oil or grease from contaminating the shotcrete. Only full flow hoses and couplings with a minimum of 1.5-inch diameter will be allowed.

C. Delivery Equipment.

Dry Mix Process: The delivery equipment shall be capable of delivering a continuous, smooth, uniformly mixed material to the nozzle. The nozzle shall be equipped with a water ring and valve to permit adjustment of the water. The water added to the dry mix material at the nozzle shall be maintained at a pressure at least 16 psi greater than the air pressure at the nozzle. The nozzle shall be capable of delivering a conical discharge stream. A hydro nozzle is required for all dry mix applications. The introduction of water via hydro-mix nozzle must be 8 to 10 feet prior to the discharge nozzle. Both water valves must be needle valves or diaphragm valves to allow for precise metering of water. Pre-damping is also required unless accelerator or fast set mixes are being utilized, subject to the approval of the Director, Materials Bureau.

Wet Mix Process: Dual hydraulic cylinder concrete pumps with a swing tube are required. The delivery equipment shall be capable of delivering a continuous flow of fully mixed concrete material to the nozzle. The nozzle shall be equipped with an air ring for injecting compressed air into the material flow.

Nozzleman Qualification Test If encasement of reinforcing bars is required, this preconstruction test shall be performed to qualify the nozzleman and equipment, prior to beginning work. Each shotcrete nozzleman shall be qualified by constructing a 2 x 2-foot test panel fabricated to duplicate the project Shotcreting. Reinforcement shall be placed in the panel to provide a minimum 1 inch (front and rear) embedment and be of the same size and spacing encountered in the structure. Panels shall be shot in the vertical, horizontal, and overhead positions as expected to be encountered. After setting, the test panel shall be picked apart with a trowel, cored or sawed in a manner approved by and in the presence of the Engineer, to verify the reinforcement embedment. If unacceptable voids are discovered, the work shall not proceed; additional panels shall be constructed until results acceptable to the Engineer are achieved. Small non-interconnected voids, as determined by the Engineer, shall not constitute failure.

Additional qualification panels will be required whenever, in the opinion of the Engineer, the shotcrete operation significantly changes.
CONSTRUCTION DETAILS

A. Preparation of Surfaces. All unsound concrete shall be removed until there are no offsets in the cavity which would cause an abrupt change in thickness, except for a transition from above to below reinforcement. Minimum 1/2 inch square shoulders shall be left at the perimeter of the cavity. The final cut surface shall be sound and properly shaped. The sound surface shall be blast cleaned. Abrasive material used for blast cleaning shall contain no more than one percent free silica by weight. Air clean the surface with oil-free compressed air. After the surface preparation has been accepted, every effort should be made to thoroughly wet the concrete surface and all porous surfaces to be in contact with new concrete for 12 hours. This may be accomplished by continuous wetting with soaker hoses or the use of burlap/burlene/etc. where moisture can be maintained. If in the opinion of the Engineer conditions or the situation prohibits this, then the surfaces should be wetted for as long as possible. Surfaces must be wetted by a means acceptable to the Engineer using potable water. The Contractor shall remove any puddles of free standing water with oil-free compressed air, and protect the surfaces from drying, so the existing concrete remains in a clean, saturated surface dry condition until placement of the new concrete.

<table>
<thead>
<tr>
<th>Thickness of Placement</th>
<th>Underside &amp; Vertical Surfaces Nominal Size and Spacing¹</th>
<th>Topside Nominal Size and Spacing¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1/4 dia. @ 18 ctrs.</td>
<td>1/4 dia. @ ctrs. 24</td>
</tr>
<tr>
<td>4</td>
<td>3/8 dia. @ 24 ctrs.</td>
<td>3/8 dia. @ ctrs. 36</td>
</tr>
<tr>
<td>5</td>
<td>3/8 dia. @ 21 ctrs.</td>
<td>3/8 dia. @ ctrs. 36</td>
</tr>
<tr>
<td>6</td>
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<td>3/8 dia. @ ctrs. 36</td>
</tr>
<tr>
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</tr>
<tr>
<td>8</td>
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</tr>
<tr>
<td>9</td>
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<td>10</td>
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<tr>
<td>11</td>
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</tr>
<tr>
<td>12</td>
<td>1/2 dia. @ 18 ctrs.</td>
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</tr>
</tbody>
</table>

NOTE: 1. Bolt diameters may be increased but not decreased. Spacing may be decreased but not increased.

No material shall be placed if the ambient air, or concrete surface temperature is at, or below 45°F.

Reinforcement may consist of either existing reinforcing bars or welded galvanized wire fabric, depending on the conditions and shall be clean and free from loose mill scale, loose rust, oil or other coatings that interfere with bonding. Chipping hammers shall meet the requirements of §580-3.02.
Sufficient clearance shall be provided around the reinforcement to permit complete encasement with sound shotcrete. The minimum clearance between the reinforcement and the form or other backup material shall be 1 inch.

Where the chipped area is equal to or less than 2 inches in depth, the use of wire fabric or mechanical concrete anchors will not be required except for overhead surfaces. Where the chipped areas are overhead, and are 1 inch in depth or greater, galvanized wire fabric and mechanical concrete anchors shall be used. Mechanical concrete anchors shall be placed as required by Table 583-1.

Where the chipped area is over 2 inches in depth and existing bar reinforcement is available, galvanized wire fabric shall be attached to the bars with tie wires. If existing bar reinforcement is not available, wire fabric shall be installed by means of mechanical concrete anchors in accordance with the requirements of Table 583-1.

Wire fabric shall be cut in sheets of the proper size and shall be carefully bent in such a manner as to follow closely the contours of the areas to be repaired. The wire fabric shall be securely tied to the hook-type bolts or the reinforcing bars.

Where sheets meet, they shall be lapped a minimum of 4 inches and shall be securely fastened together.

Expansion bolt anchors shall be placed in holes drilled in the existing concrete surface to the diameter and depth recommended by the manufacturer of the expansion bolt anchors. Hook-type bolts of the proper length shall be inserted and securely attached to the expansion bolt anchors so as to provide a positive connection to sound concrete.

Where the chipped area is 6 inches or greater in depth, the Contractor shall place galvanized wire fabric in layers 4 inches apart.

Where it is necessary to place more than one layer of galvanized wire fabric in an area to be repaired, the innermost layer shall be covered by a Shotcreting prior to the installation of the next outermost layer.

Existing reinforcement which has lost significant section shall be repaired in a manner satisfactory to the Engineer as extra work.

B. Preparation of Materials.

A. General. The sand shall be measured by weight, by means of batch boxes approved by the Engineer, or in a proportioning plant approved in accordance with section 501, Portland Cement Concrete - General. Wheelbarrows or shovels will not be permitted for measuring. The same source of sand and/or aggregate shall be used throughout each structure.

B. Dry Mix Process. Site batched Dry mix shotcrete shall be composed of one part of cement to three to four parts of sand by weight. Materials shall be stored in such a way that they are protected in order to ensure consistent moisture content. Proportioning of materials shall be performed with use of a Mobile Concrete Mixing Unit in accordance with 501-2.04, C.
Prior to mixing, the moisture content of the sand shall be between 3 and 6%. The sand shall be dampened or dried as required to bring the moisture within these limits. A wetting agent approved by the Engineer may be used at the Contractor's option in the dry mix process.

Sand-cement mixtures shall be applied within 45 minutes of the time the sand initially contacts the cement. Sand-cement mixtures which exceed the 45-minute limit shall not be incorporated in the work. They shall be disposed of in a manner acceptable to the engineer.

Prepackaged dry shotcrete materials proposed for use shall be submitted to the Engineer subject to approval by the Director, Materials Bureau.

C. Wet Mix Process. Wet mix shotcrete shall have a minimum cementitious content of no less than 564 lbs. per cubic yard of concrete. Wet mix shotcrete shall be composed of one-part cement to four parts sand (aggregate). Concrete mixtures with coarse aggregate shall have a nominal size no more than one-third the hose diameter used for shotcrete placement. The cement, aggregates and water shall be premixed to a desired consistency and in accordance with §501-3.03, Handling, Measuring and Batching Materials, and §501-3.04, Concrete Mixing, Transporting and Discharges - General Requirements.

Placement.

A. Weather. Shotcrete shall not be applied during any precipitation which is of sufficient intensity to cause the placed shotcrete paste to be eroded from the concrete surface. Shotcrete shall not be placed during a wind that disrupts the nozzle spray.

Shotcrete shall not be applied when the ambient air temperature is below 45°F unless it is placed in accordance with §555-3.08C.2., Provision of External Heat. Receiving surfaces shall be heated to, and maintained at, approximately 50°F by a method approved by the Engineer before Shotcreting operations begin. Under no conditions shall shotcrete be applied against surfaces upon which any frost adheres.

B. Application. Before starting to shoot, precautions shall be taken to protect property in the area. Adjacent construction, openings, shrubbery, and all areas that might be discolored or damaged by rebound, cement, water or dust must be covered with tarpaulins or plastic sheets to protect them from damage.

When projecting the shotcrete, the stream of flowing materials shall be directed from the nozzle as nearly at a right angle as possible to the surface being treated, and shall be held uniformly at the same distance, less than 4 feet away from the surface at all times. Manufacturer's recommendations shall be followed. The size of the nozzle shall be consistent with the manufacturer's recommendation for the maximum size of the aggregates used. The use of rebound material shall not be permitted.

Shotcrete on vertical and overhead surfaces shall be built up in 3 inch maximum layers to prevent sloughing in heavy applications. When shotcrete is placed on previous
layers that have reached or exceeded final set, surfaces shall be roughened and brought to SSD conditions before placing subsequent shotcrete.

When encasing reinforcing steel larger than No. 6 bar size, the stream from the nozzle shall be directed at a slight angle from perpendicular so as to fill the space behind the bars. An air lance producing a concentrated air jet shall be used to blow out any rebound ahead of the application of shotcrete. Should any such deposit of aggregate rebound or overspray be covered with shotcrete, it shall be cut out and removed by the Contractor without compensation.

Ground wires must be installed to establish the thickness and surface planes of the shotcrete build up when requested by the Engineer. Both horizontal and vertical ground wires may be installed at corners and offsets not clearly established by exterior corners of walls, column or beam corners, and other locations. They may also be used as screed guides. 18 or 20-gauge hard steel piano wire is recommended for this purpose. Ground wires shall be tight and true to line, and placed in such a manner that they may be further tightened.

C. Quality Control

1. **Product Sample Test Panels.** This test shall be used to determine the physical quality of the shotcrete and shall be performed immediately before Shotcreting operations begin, after each additional 100 sf, and immediately after operations are ended. Shotcrete panel cores will be tested 14 days after placement, and require a minimum compressive strength of 4,000 psi.

   The test panels shall be 12 inches square, 3/4-inch-thick plywood boards with galvanized mesh (1/2 inch square openings) strips projecting 4 inches attached around the perimeter of the board. The boards shall be erected horizontally, vertically, or overhead, depending on the anticipated shooting positions. The shotcrete operator shall completely fill the test panel; after which it shall be screeded or cut with a trowel such that it contains a uniform depth of 4 inches of the shotcrete. The test panels shall then be covered with wet quilted covers or wet polyethylene-coated blankets; put in a shaded, protected place; kept wet and cured for a minimum of seven days. The test panels shall be sent to the Department of Transportation's Materials Bureau for testing at fourteen days. Cores will be drilled from the panels and compressive strengths at fourteen days will be reported to the Engineer. Additional information on the conditions of the shotcrete such as sand pockets, voids, and laminations will also be reported with the strength results.

2. **Coring.** When requested by the Engineer, the Contractor will be required to obtain a core, at a location determined by the Engineer, from each structural element, such as pier, abutment, arch, etc., to verify acceptability of reinforcement encasement. Cores which do not contain reinforcing bars will not be used to determine encasement acceptability. If interconnected voids are found, the structural element represented by that core shall be rejected. All rejected shotcrete shall be repaired or replaced at the Contractor's expense.
Repair methods shall be proposed by the Contractor for approval by the Engineer. The Contractor may take additional cores at locations approved by the Engineer to establish the limits of rejected work. The additional coring shall not jeopardize the design integrity of the structural element. If additional cores are not taken, all work on that structural element shall remain rejected. Core holes shall be patched with an applicable concrete repair material from the Approved List.

D. Finishing. The natural gun finish will be sufficient (+/- ½”) for sites out of view of the traveling public, unless the plans call for one of the following finishes:

1. **Cut or Rodded Finish.** After the surface has taken its initial set, excess material outside the forms and ground wires shall be sliced off with a sharp-edged cutting screed. After screeding, the ground wires shall be removed.

2. **Broom Finish.** This type of finish may be applied after screeding.

3. **Flash Coat Finish.** This is a thin surface coating containing only sand aggregate. This finish shall be applied to the surface as soon as possible after screeding. Any of the remaining three types of finish may be applied following flash coat:
   
a. **Wood Float Finish.** This gives a granular finish.

b. **Rubber Float Finish.** This gives a coarse finish.

c. **Metal Trowel Finish.** This gives a very smooth finish. This is generally less durable, reduces freeze-thaw resistance and tends to have more cracking. Only Magnesium trowels are allowed. The use of Aluminum or Steel finishing trowels and tools are prohibited.

**Curing.** Curing shall be in accordance with §555-3.08, Curing, and the following modifications:

- All curing covers shall be pre-wet and kept wet during the entire curing period in a manner satisfactory to the Engineer.
- Curing compounds shall be applied at twice the specified rate. The second application shall be done when the first application has become tacky. The second application shall be done at a right angle to the first application. The rate of each application shall be that given in §555-3.08A.

**METHOD OF MEASUREMENT.** The quantity to be paid for under this item will be the number of square feet of finished shotcrete installed. Measurement will be taken as the plane projection of the finished surface. Measurement shall be made prior to the placement of shotcrete.
BASIS OF PAYMENT. The unit price bid per square foot shall include the cost of furnishing all labor, materials and equipment necessary to complete the work.

Removal of Structural Concrete - Replacement with Shotcrete. No Reinforcement Bar Encasement. The unit price bid per square foot shall include the cost of furnishing all labor, materials and equipment necessary to complete the work.

Removal of Structural Concrete - Replacement with Shotcrete, Reinforcement Bar Encasement. The unit price bid per square foot shall include the cost of furnishing all labor, materials and equipment necessary to complete the work, except that replacement of deteriorated reinforcement shall be paid for separately. Payment shall not be made until cores verify acceptability.

Payment will be made under:

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<tr>
<th>Item No.</th>
<th>Description</th>
<th>Pay Unit</th>
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<td>Removal of Structural Concrete - Replacement with Shotcrete, No Reinforcement Bar Encasement</td>
<td>Square Foot</td>
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<tr>
<td>583.03000008</td>
<td>Removal of Structural Concrete - Replacement with Shotcrete, with Reinforcement Bar Encasement</td>
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