TO:
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ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: **SHOTCRETE SPECIFICATIONS SECTION 583**

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APPROVED: 7/7/93
A. M. Shirole, Deputy Chief Engr., Structures Division

W. J. Brune, Director, Materials Bureau

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Supersedes:

Effective with the letting of August 19, 1993, delete Shotcrete Item 583.01 and replace it with Shotcrete Items 583.02 and 583.03.

This Engineering Instruction transmits a new shotcrete specification that evolved from recent investigations of structural concrete repairs made with shotcrete. The investigations led to the discovery that the shotcrete failed to totally encapsulate existing reinforcement. After some research and discussions with industry, the problem was found to be the lack of proper technique on the part of the shotcrete operators. To minimize and monitor this problem, the Materials Bureau, in conjunction with the Structures Division, developed the attached specification that includes a qualification test to duplicate field conditions, and the taking of cores from repaired areas. Significant changes include:

1. Qualification Test revised to include a new test panel size of 2 ft. x 2 ft. to duplicate the project shotcreting including embedment of reinforcing in the test panel.

2. Added a requirement of coring by the Contractor for each structural element to verify embedment of reinforcement.

3. Cubic foot measurement replaces number of bags measurement.

4. Basis of Payment changed to two items, one for no reinforcement encasement, and one for encasement of reinforcing, per cubic foot pay unit.

5. The rebound test has been eliminated due to the change in method of measurement.

6. A sand moisture content between 3 and 6% has been added as recommended by ACI to improve consistency and reduce the potential for sand streaking.

If you have any questions or comments, please call Sam Candib or Ed Lucas of the Materials Bureau at (518) 457-5956.

SECTION 583 - SHOTCRETE

583-1 DESCRIPTION

583-1.01 Work. The work shall consist of removing unsound structural concrete and replacing it 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.

583-1.02 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, water ring or air ring, and any necessary valves, connected to the delivery hose.

583-2 MATERIALS. Materials used in this work shall conform to the following requirements:

Portland Cement, Types 1 or 2	701-01
Concrete Sand	703-07
Water	712-01
Quilted Covers (for curing)	711-02
Plastic-Coated Fiber Blankets (for curing)	711-03
Membrane Curing Compound	711-05

Wire Fabric for Concrete Reinforcement. Wire fabric for concrete reinforcement shall meet the requirements of subsection 709-02 and the following additional requirements.

The welded wire fabric shall be galvanized in accordance with ASTM A641, regular coatings. The wire fabric shall be fabricated from No. 12 wire spaced two inches in each direction or No. 10 wire spaced three inches in each direction.

Wire used shall have a minimum yield strength of 35 ksi (241.32MPa).

Expansion Bolt Anchors. Expansion bolt anchors shall be fabricated from steel meeting U.S. Government G.S.A. Specification No. FF-S-325, Group III, Type 1, or Group VIII, Type 1.

Bolts Inserted in Expansion Bolt Anchors. These bolts shall be a hook-type bolt conforming to the requirements of ASTM A307.

583-2.01 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 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.

C. Delivery Equipment.

1. 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 15 psi greater than the air pressure. The nozzle shall be capable of delivering a conical discharge stream.

2. Wet Mix Process. Only pneumatic-feed type of delivery equipment will be allowed. Positive displacement type of equipment will be allowed pending a qualification test prior to the beginning of the work which will also be the qualification test for the operator. The nozzle shall be equipped with an air ring for injecting compressed air into the material flow.

583-2.02 Qualification Test. If encasement of reinforcing bars is required, this test shall be performed to qualify the shotcrete operator and the equipment, prior to beginning work. Each shotcrete operator shall be qualified by constructing a 2 foot 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 broken open in a manner approved by and in the presence of the Engineer, to verify the reinforcement embedment. If 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.

583-3 CONSTRUCTION DETAILS

583-3.01 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 blastcleaned. Abrasive material used for blastcleaning shall contain no more than one percent (1%) free silica by weight. Just prior to shotcreting, the sound surface shall be thoroughly cleaned, wetted and air blown.

Chipping hammers shall meet the requirements of §580-3.02 Removal of Structural Concrete.

Reinforcement may consist of either existing reinforcing bars or welded galvanized wire mesh, depending on the conditions and shall be clean and free from loose mill scale, loose rust, oil or other coatings that interfere with bonding.

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 two inches in depth, the use of wire mesh or mechanical concrete anchors will not be required except for overhead surfaces. Where the chipped areas are overhead, and are one inch in depth or greater, galvanized wire mesh 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 two inches in depth and existing bar reinforcement is available, galvanized wire mesh shall be attached to the bars with tie wires. If existing bar reinforcement is not available, wire mesh shall be installed by means of mechanical concrete anchors in accordance with the requirements of Table 583- 1.

Wire mesh 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 mesh shall be securely tied to the hook-type bolts or the reinforcing bars. Where sheets meet, they shall be lapped a minimum of four 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 six inches or greater in depth, the Contractor shall place galvanized wire mesh in layers four inches apart.

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

Existing reinforcement which, in the Engineer's opinion, has lost significant section shall be repaired in a manner satisfactory to the Engineer. Payment for this work will be made in accordance with §109-05, Extra & Force Account Work.

TABLE 583-1

SIZE AND SPACING OF HOOK-TYPE BOLTS		
Thickness of Placement	**Underside & Vertical Surfaces Size and Spacing**	**Topside Size and Spacing**
2"	1/4" diam. @ 1' - 6" ctrs.	1/4" diam. @ 2' - 0" ctrs.
4"	3/8" diam. @ 2' - 0" ctrs.	3/8" diam. @ 3' - 0" ctrs.
5"	3/8" diam. @ 1' - 9" ctrs.	3/8" diam. @ 3' - 0" ctrs.
6"	3/8" diam. @ 1' - 8" ctrs.	3/8" diam. @ 3' - 0" ctrs.
7"	3/8" diam. @ 1' - 6" ctrs.	3/8" diam. @ 3' - 0" ctrs.
8"	1/2" diam. @ 1' - 11" ctrs.	1/2" diam. @ 3' - 0" ctrs.
9"	1/2" diam. @ 1' - 10" ctrs.	1/2" diam. @ 3' - 0" ctrs.
10"	1/2" diam. @ 1' - 9" ctrs.	1/2" diam. @ 2' - 0" ctrs.
11"	1/2" diam. @ 1' - 8" ctrs.	1/2" diam. @ 2' - 0" ctrs.
12"	1/2" diam. @ 1' - 6" ctrs.	1/2" diam. @ 2' - 0" ctrs.

583-3.02 Preparation of Materials.

A. General. The sand shall be measured either by volume or 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 shall be used throughout each structure.

B. Dry Mix Process. Dry mix shotcrete shall be composed of one part of cement to three to four and one-half parts of sand.

Prior to mixing, the moisture content of the sand shall be such that the sand cement mixture will flow at a uniform rate (without slugs) through the delivery hose. The sand moisture content shall be between 3 and 6%.

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 75 minutes of the time the sand initially contacts the cement. Sand-cement mixtures which exceed the 75 minute limit shall not be incorporated in the work. They shall be disposed of in a manner acceptable to the engineer.

C. Wet Mix Process. Wet mix shotcrete shall be composed of one part of cement to three parts of sand. The cement, sand and water shall be premixed to a desired consistency and in accordance with subsections 501-3.03, Handling, Measuring and

Batching Materials, and 501-3.04, Concrete Mixing, Transporting and Discharging-General Requirements.

583-3.03 Placement.

A. Weather. Shotcrete shall not be applied during any precipitation which is of sufficient intensity to cause the placed shotcrete to run. 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 degrees F unless it is placed in accordance with §555-3.06 B, Provision of External Heat. Receiving surfaces shall be heated to, and maintained at, approximately 45 degrees 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. All shotcrete shall be cured in accordance with §555-3.09, Curing.

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 shall 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 shotcreted and shall be held uniformly at the same distance (usually between two and five 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 sand used. The use of rebound material shall not be permitted.

Shotcrete on vertical and overhead surfaces shall be built up in 3/4 inch maximum layers to prevent sloughing in heavy applications. Succeeding layers shall be applied just prior to the initial set to maintain a good bond.

When encasing reinforcing steel, the stream from the nozzle shall be directed at an angle so as to fill the space behind the bars. An air jet shall be used to blow out any rebound ahead of the application of shotcrete. Should any such deposit of sand rebound be covered with shotcrete, it shall be cut out and removed by the Contractor without compensation.

Ground wires may be installed to establish the thickness and surface planes of the shotcrete build up. Both horizontal and vertical ground wires may be installed at corners and offsets not clearly established by the structure lines (at exterior corners of walls, column or beam corners, and other locations). They may also be used as screed guides. Eighteen or 20 gage 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. 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 bags, and immediately after operations are ended.

The test panels shall be 12-inch square, 3/4 inch plywood boards with galvanized mesh (1/2 inch square openings) strips projecting four inches attached around the perimeter of the board. The boards shall be erected horizontally, vertically, overhead or any combination of positions, depending on the anticipated corresponding 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 4-inch uniform depth of shotcrete. The test panels shall then be covered with wet quilted covers or wet plastic-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. The Contractor shall take 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 unless the plans call for one of the following finishes:

Screed 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.

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

Flash Coat Finish. This is a thin surface coating containing finer sand than normal, and the application nozzle is held well back from the work. 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:

Wood Float Finish. This gives a granular finish.
Rubber Float Finish. This gives a coarse finish.
Steel Trowel Finish. This gives a very smooth finish.

E. Curing. Curing shall be performed in accordance with 555-3.09, Curing.

583-4 METHOD OF MEASUREMENT.

583-4.01 Removal of Structural Concrete - Replacement with Shotcrete. Measurement will be made as the number of cubic feet of repair made in accordance with this specification. Measurement will be made prior to placement of shotcrete.

583-5 BASIS OF PAYMENT.

583-5.01 Removal of Structural Concrete - Replacement with Shotcrete, No Reinforcement Bar Encasement. The unit price per cubic foot shall include all labor, materials and equipment necessary to complete the work.

583-5.02 Removal of Structural Concrete - Replacement with Shotcrete, Reinforcement Bar Encasement. The unit price bid per cubic 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 in accordance with §109-05. Payment shall not be made until cores verify acceptability.

Payment will be made under:

Item No.	Item	Pay Unit
583.02	Removal of Structural Concrete - Replacement With Shotcrete, No Reinforcement Bar Encasement	Cubic Foot
583.03	Removal of Structural Concrete - Replacement With Shotcrete, Reinforcement Bar Encasement	Cubic Foot