

SECTION 03360

SHOTCRETE

PART 1 - GENERAL

1.01 DESCRIPTION

A. Work Included:

1. Preparing surfaces to receive shotcrete.
2. Furnishing and placing forms and ground wires.
3. Mixing, delivering, placing, finishing and curing of shotcrete.

1.02 RELATED WORK

- A. Cast-In-Place Concrete: Section 03300.
- B. Reinforcing Steel. Section 03200.

1.03 REFERENCES:

A. American Concrete Institute (ACI) Reference Standards, current edition

1. 305 Hot Weather Concreting
2. 306: Cold Weather Concreting.
3. 318: Building Code Requirements for Reinforced Concrete.
4. 5W. -Guide to Shotcrete Specification for Materials, Proportioning and Application of Shotcrete.

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

1. A1 85: Specification for Steel Welded Wire. Fabric, Plain, for Concrete Reinforcement.
2. A615: Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
3. C33: Standard Specification for Concrete Aggregates.
4. C39: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
5. C42: Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.
6. C94: Standard Specification for Ready-Mixed Concrete.
7. C150: Standard Specification for Portland Cement.
8. C260: Standard Specification for Air-Entraining Admixtures for Concrete
9. C309: Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.

10. C494 Standard Specification for Chemical Admixtures for Concrete.
11. C618: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete.

1.04 QUALITY CONTROL

A. Conform use of shotcrete to the following:

1. Limitation on Use:
 - a. Do not place shotcrete where the stream from the nozzle cannot directly impinge on the surface on which the concrete is to be placed.
 - b. Where placing condition precludes the possibility of obtaining cores from the structure, this method shall not be used.
2. Reinforcement:
 - a. Use small bar sizes with #5 bars as the normal maximum size.
 - b. Where structural design requires bars larger than #5 size, space at minimum of six bar diameters between all reinforcing bars and place splicers so that a line through the center of the two spliced bars is perpendicular to the surface of the wet mix shotcrete installation.
 - c. Do not exceed #8 bar size except where indicated.
 - d. Where size of the reinforcing exceeds #5 bars, only a qualified person on the shotcrete nozzle with a minimum of 3 years of structural wet mix shotcrete experience and having written documentation of that experience shall apply structural wet mix shotcrete.
3. Columns: Do not apply shotcrete to any tied spiral columns. Shotcrete may only be applied to tied columns where spacing of the reinforcing steel is the same as for walls.
4. Walls: Where shotcrete is to be applied to walls, minimum spacing of the reinforcing steel shall be six bar diameters for walls with one curtain of steel. Where two curtains of steel are provided, the curtain nearest the nozzle shall have a minimum spacing of 12 bar diameters and the remaining curtain shall have a minimum of spacing of six bar diameters, the reinforcing steel shall have minimum spacing of three bar diameters at splices. In all cases, minimum clear distance between reinforcing bars (other than mesh) shall be 2-1/2".
 - a. Exception: Contact splices shall not be made in bars larger than #5 size. Instead, splices shall be non-contact and back-to-back lap with bars placed and aligned as specified above under Subparagraph "Reinforcement"
5. Continuous inspection is required for all shotcrete.
6. Code:
 - a. All other requirements for inspection and concrete of the applicable Standards of ACI 506 shall be followed. Shotcrete Applicators shall have a copy of the latest edition of ACI 506 on each work site at the time of shotcreting. Substitute the word "shall" whenever the word "should" occurs in ACI 506.
 - b. The concrete mix shall not be batched volumetrically.
 - c. Test consisting of not less than 2 cylinders at 28 days is required.

B Qualified Persons:

1. Shotcrete supervisor and nozzle person shall furnish a resume for approval Architect prior to placing.
2. Shotcrete Subcontractor who will place the shotcrete:
 - a. Have at least 5 years experience in structural shotcrete construction and have constructed at least 20 significant structural shotcrete installations (other than swimming pools) which, on investigation, have been found to be completed in a satisfactory manner, furnish a written resume of that experience and a list of locations of previous jobs.
 - b. Employ only skilled nozzle persons, nozzle person helpers, and rod persons, each having not less than 3 years of structural shotcrete placing experience and furnish satisfactory written evidence of such experience upon request.
 - c. When the Architect approves the resume of the nozzle person, the shotcrete supervisor, the Shotcrete Subcontractor, and any member of the three persons no longer occupy the position on the approved team, a new resume shall be submitted.

C. Preconstruction Testing:

1. Test panels:
 - a. Shooting and Examination: At the job site, each team of the person at the nozzle and helper shall shoot a test panel (minimum 4 feet by 4 feet) of the thickness and with the typical reinforcing steel pattern, using each shooting position anticipated on the job before commencing any shotcreting work on the building.
 - b. The Architect shall witness the assembly, reinforcing, shooting, and disassembly of the test.
 - c. After shooting, but before concrete has fully set, disassemble the test panel, to reveal if team and equipment to be used is capable of providing sound concrete behind reinforcing steel. Test panel shall be free of voids, sags, etc do not proceed with application of shotcrete in finished work until test panel has been shot, disassembled, inspected and approved by the Architect.
 - d. Special Test Panels: Special test panels as specified above are required for shotcrete to contain reinforcing bars larger than #8 size.
2. Core Tests
 - a. Cut 4" or larger diameter cores from the full depth of wall, with minimum of one core for each 1,000 square feet of wall and a minimum of two cores for each day's application by any one-nozzle team. Each core must be free of voids and rebound,
 - b. Core locations shall be as approved by the Architect.
 - c. Cut all cores within two to five calendar days of shotcrete placement, have cores visually inspected at the job site by the Architect, and then replace into the hole from which the core was cut. Seal the surface at each core to prevent hydration and mark location to aid in identification of the core for testing at a 28-day age. The cores shall be tested in accordance with ASTM C42, and in the condition they were in when removed from the wall with no further curing allowed.

3. Joints
 - a. Provide cold joints, including slope of joints as shown on the Drawings.
 - b. When shooting up to underside of existing concrete, dry pack the last two inches or use an approved method of dry shotcrete.
 - c. If the joint detail is sloped so closure of the cold joint made with shotcrete does not sag away from the upper surface, and if both sides of the cold joint have taken initial set, the joint closure may be made with shotcrete
 4. Reinforcement: Securely tie reinforcing steel in place so that any movement shotcreting is not possible,
 5. Placing Height: The height of each shotcrete layer shall be limited to six feet. Do not place a succeeding layer in less than two hours. No sloughing or sagging will be permitted.
 6. Slump: Measure at point of discharge from the mixer, except the Architect may require slump tests at the discharge point where water may have been added Slump shall be 1-1/2" minimum and 2-1/2" maximum.
 7. Rebound: Have a capable nozzle person's helper equipped with an air blow pipe to assist the nozzle person in keeping all rebound build-up out of the Work. If the rebound cannot be removed by the air blow pipe, provide additional workers to remove rebound from the Work.
 8. Obstructions: Do not place keyways or embedments in front face that will interfere with the stream from the nozzle.
- D. Structural Wet Mix Shotcrete Design:
1. The Testing Laboratory California registered Civil Engineer shall design the shotcrete mix, including recommendation for minimum time between shotcrete lifts.
 2. Minimum 28-compressive strength of shotcrete shall be the same as shown or specified for cast-in-place concrete in the same location. The trial batch strength for the shotcrete mix shall exceed the required 28-day compressive strength by 750 psi or a lesser amount based on standard deviations of strength test records according to ACI 318.
 3. The Contractor shall bear costs for shotcrete mix design and related testing.
 4. Do not change the mix proportions established by accepted mix designs without prior written approval.
 5. If any shotcrete mix develops less than the required minimum 28-day compressive strength, adjust the mix proportions and increase the amount of cement as necessary, at no extra cost to the University.
 6. Do not exceed the predetermined amount of mix water because of slowness of discharge from the mixer or for any other reason, but reduce water to minimum necessary to produce shotcrete that will shoot readily into corners and angles of forms and around reinforcements, without segregation of materials and without free water collecting on the surface.

1.05 ENVIRONMENTAL REQUIREMENTS

- A. Air and substrate temperature must be maintained at 40 degrees F. or higher during shotcreting and for a minimum of 7 calendar days following shotcreting. If heating and weather protection is required, use means acceptable to the Architect.
- B. Maintain shotcrete mixture at 55 degrees F or higher.
- C. Do not place shotcrete on any frozen or spongy substrate, or where there is freestanding water.

1.06 SUBMITTALS

- A. Written documentation of Applicator's work experience.
- B. Certification by manufacturers of materials used in shotcreting process that requirements of this Section are met.
- C. Listing of proposed mix design, materials and equipment proposed for work of this Section.

PART 2 - PRODUCTS

2.01 MATERIALS

- A. Structural Shotcrete:
 - 1. Portland Cement: Meet requirements of ASTM C1 50, Type 11, low alkali.
 - 2. Fine aggregate: Washed hard dense durable sharp sand, from an approved source, free of organic matter, containing not more than 2% by weight of deleterious substances and meeting requirements of ACI 506, Gradation No. 1 or No. 2, and ASTM C33.
 - 3. Coarse aggregate:
 - a. Meet requirements of ASTM C33.
 - b. From an approved source and free of vegetable matter, opaline, feldspar, or any siliceous magnesium substances
 - c. Clean and hard fine-grained sound gravel or crushed stone containing maximum of 0.5% by weight of clay, shale, mica, coal, or other lightweight material, and a maximum of 5% by weight of flat, thin, elongated, friable or laminated pieces, if one dimension exceeds 2-1/2 times its average thickness, consider such pieces as flat or elongated.
 - d. Furnish coarse aggregates in two gradations, measured and introduced into mix separately.
 - 4. Pozzolanic materials Meet requirements of ASTM C618, Class F, except loss of ignition shall not exceed three percent.
 - 5. Water. Potable and from a domestic source.
- B. Reinforcing steel: Conform to Section 03200, except as modified in this Section.
- C. Epoxy crack repair system: Sika Chemical "Sikadur 31 Hi-Mod" with "Sika Injection-29", Symons "ResCon 306 HM HV" with "ResCon 302 HM-LV", or equal, for sealing all cracks. Include conventional pipe nipples, Zerk, Alemite, or equal fittings, or polyethylene 1-way valves, as recommended by the epoxy system manufacturer.

D. Admixtures:

1. Shotcrete accelerator shall be available on the job with proper dispensing equipment at all times and shall meet the requirements of ACI 506 and the following:
 - a. Test for compatibility in shotcreted test panels.
 - b. Contain no intentionally added chloride ions.
 - c. Not cause or promote corrosion of imbedded rebar or wire mesh.
2. Water-reducers, super-plasticisers and retarders:
 - a. Meet requirements of ASTM C494,
 - b. Shall contain no intentionally added chloride ions.
3. Air entraining admixtures
 - a. Meet or exceed requirements of ASTM C260.
4. Membrane-forming curing compounds:
 - a. Meet or exceed requirements of ASTM C309.

PART 3 - EXECUTION

3.01 PREPARATION

- A. Thoroughly clean and roughen concrete surfaces to receive shotcrete by sandblasting or by mechanical roughening as indicated on Drawings.
- B. Remove all loose and deteriorated concrete.
 1. Extend removal minimum of 6" on all sides of apparent deteriorated area.
 2. If rebar is deteriorated or poor quality concrete extends above mid point of steel, extend removal of concrete at least 1-1/2" behind steel to allow access for full encasement of rebar.
- C. Remove all rust from exposed reinforcing steel.
 1. If 20% or more of diameter of steel has deteriorated, report condition to the Architect before encasing steel.
- D. Leave no square shoulders on perimeter of repair cavity. Taper all edges
- E. All surfaces to be shotcreted must be free of dust, loose particles or other deleterious materials that would prevent bond.
- F. Just prior to shotcreting, dampen affected area lightly with potable water or a combination of air and potable water.

- 3.02 FORMS
- A. Erect rigid forms of plywood, steel, or other materials specified on Drawings, that produce smooth plane surfaces built to permit escape of air and rebound. Leave the forms open on two sides where possible, open corners formed with a wire ground to which the two open sides are rodded. Other methods of producing the same result may be used if approved.
- 3.03 DEPTH GUIDES
- A. Set depth guides for use as screeds to set the thicknesses, surface planes, and form of shotcrete. Place the ground wires tight and true to line and in such a manner that they are easily tightened.
- 3.04 EMBEDDED ITEMS
- A. Coordinate with work of other Sections to be sure that all items to be embedded in shotcrete are installed, properly located, and rigidly secured in place.
- 3.05 PROTECTION
- A. Protect adjacent surfaces not to receive shotcrete with waterproof paper or other adequate means from damage during shotcreting operations, and repair all damage as approved, at no extra cost to the University.
- 3.06 PLACEMENT OF SHOTCRETE
- A. Conform to requirements of ACI 506.
1. Dispense shotcrete in steady uninterrupted flow.
 2. Completely encase reinforcing steel with no voids or trapped rebound.
 3. Remove and replace any areas exhibiting sagging without disrupting adjacent sound material.
 4. Where succeeding layers are to be placed, and first layer has reached its initial
- 3.07 REBOUND: Shall not be used in the work. Remove from site.
- 3.08 PUDDLED SHOTCRETE
- A. Use of "puddled shotcrete" in which the water content is increased to facilitate placing in difficult locations is not allowed.
- B. Do not place shotcrete where the material stream cannot impinge directly onto the involved surfaces.
- C. For difficult shooting conditions obtain the proper results by maintaining correct air pressure and water-cement ratio and reduce supply of material.
- 3.09 CONSTRUCTION JOINTS
- A. Form joints with sloped, beveled edges. Clean and dampen hardened joint surfaces before placing additional material.
- 3.10 FINISHING
- A. Leave areas underneath structure and not visible with natural gun finish.
- B. Exposed areas Finish as required by the Architect.
- 3.11 CURING

- A. Clear, non-staining curing compound conforming to ASTM C309 may be used on surfaces not to receive additional finish,
- B. For areas to receive additional layers of shotcrete or to be finished. Use curing compound that will not retard bonding.
- C. For areas to receive additional finish keep installed and float finished shotcrete continuously damp for not less than 7 days.

3.12 CRACK REPAIR

- A. Repair cracks more than 1/16" wide in shotcrete, or between shotcrete and concrete.
 - 1. Cut cracks out 6 inches, slope bevel and dampen the cut edges.
 - 2. Repair with new shotcrete cured and finished to match adjoining surfaces
 - 3. In lieu thereof, cracks may be repaired with epoxy pressure grouting system using epoxy crack sealer, nipples and pressure epoxy injection. Conform to epoxy system manufacturer's instructions.
 - 4. Remove nipples and fittings, and fill holes with epoxy.
 - 5. Finish repairs flush with adjoining surface
 - 6. Delay crack repair as long as possible and perform just prior to final completion of the work.

3.13 FIELD QUALITY CONTROL

- A. Inspection: Construct structural shotcrete under continuous inspection of Inspectors according to requirements stated in this Section. Obtain inspection and approval of forms and reinforcing by the Architect prior to placing shotcrete.
- B. Compressive Strength Tests:
 - 1. Test Cylinders in accordance with ASTM C39.
 - a. The testing laboratory will prepare and test at least 2 cylinders for each day's placing performed by each nozzle person
 - b. Date cylinders and record the name of the nozzle person shooting the cylinder and the parts of the structure represented by the cylinder
 - c. Test one cylinder at 14-day age and one cylinders at 28 days age.
 - 2. Required compressive strengths:
 - a. Minimum 75% of required strength for 14-day cylinder
 - b. Full required strength for 28-day cylinder.
 - 3. Mix Adjustment: If the 14-day cylinders develop less than the above required compressive strength, adjust mix proportions by increasing quantity of Portland cement while maintaining same water-cement ratio and same slump so resulting shotcrete meets requirements at no extra cost to the University. Determine full compressive strengths by specified core tests.

C. Core Tests:

1. Testing laboratory shall take and test cores as specified in this Section.
2. Core test compressive strengths shall meet the specified strength requirements
3. If any core shows deficient strength, additional cores shall be taken and tested at the Contractor's expense from the adjoining areas as directed. Two additional cores are required for each deficient core. If any additional test core proves deficient, the Contractor shall remove and replace deficient shotcrete as approved, at no extra cost to the University.
4. Should deficiency be evident in any of the 14-day cylinders, the Contractor may proceed with the work on his responsibility and risk until the 28 cores are tested and found to be adequate.

- D. Defective work: Cut out and replace all defective shotcrete, including rebound, sand pockets, sags, sloughing, and other defects, at no extra cost to the University.

3.14

CLEANUP

- A. Keep premises reasonably free of all debris and waste materials resulting from the work remove from site at end of each day.

END OF SECTION