

SECTION 03310
SHOTCRETE WALLS

PART 1 GENERAL

1.01 – RELATED DOCUMENTS

- A. The Drawings and general conditions of the Contract including Division 1 Specification sections apply to work of this section.
- B. Examine all other sections of the Specifications for requirements that affect work of this Section whether or not such work is specifically mentioned in this Section.
- C. Coordinate work with that of all trades affecting or affected by work of this Section. Cooperate with such trades to assure the steady progress of all work under the Contract.

1.02 – DESCRIPTION OF WORK

- A. Extent of shotcrete wall work is shown on the drawings, including notes and details. The work shall consist of preparing existing CMU wall surfaces, furnishing, mixing, applying and curing shotcrete repair materials at vertical locations. Except as otherwise specified, either a dry mix or wet mix process may be used.

1.03 – RELATED SECTIONS

- A. Structural Steel – Section 05120/05 12 00

1.04 – QUALITY ASSURANCE

- A. Codes and Standards: Comply with provisions of the latest edition of the following except where more stringent requirements are shown or specified:
 - 1. ACI 506.2-95 “Specification for Shotcrete”
 - 2. ICRI Technical Guideline No. 03731 “Guide for Selecting Application Methods for the Repair of Concrete Surfaces”
 - 3. “Code of Federal Regulations, Part 1926” per the Occupational Safety and Health Administration (OSHA), Department of Labor (Latest Revision).
- B. Materials and installed work may require testing and retesting, as directed by the Engineer, at any time during progress of work. Allow free access to material stockpiles and facilities. Test not specifically indicated to be done at the Owner’s expense, including testing of rejected materials and installed work, shall be done at the Contractor’s expense.

1.05 – INSPECTION AND TESTING

- A. Procedures for preparing shotcrete test panels and the testing specimens sawed or cored from panels will be performed in accordance with ASTM Method C 1140. The compression test specimens will be cores taken from the test panels.
- B. One test panel shall be provided during the first shotcrete wall placement and shall not less than 18 inches square and not less than six (6) inches thick. Additional test panels may be made periodically as directed by the Engineer during the progress of the work.
- C. Cores, taken from the test panels, shall receive standard curing in lime-saturated water at $73.4^{\circ} \pm 3.0^{\circ}$ F within 24 hours after removal. Cores shall continue to receive the prescribed initial cure treatment until standard curing is commenced.
- D. For each strength test, three (3) cores will be tested in compression. The test result will be the average of the strengths of the three (3) specimens, except that if one specimen shows manifest evidence of improper sampling, coring, or testing, it will be discarded and the strengths of the remaining two (2) specimens will be averaged. If more than one (1) specimen representing a test shows such defects, the entire test will be discarded.
- E. The Contractor shall furnish the forms and make the required test panels and shall provide such facilities, materials and assistance as may be necessary for curing, handling, and protecting the panels. Test panels shall be cast only when the Engineer is present.

1.06 – NOZZLE OPERATOR QUALIFICATIONS

- A. The nozzle operator shall be able to document a minimum of 500 hours of experience as a nozzle operator and shall have completed at least one (1) similar application as a nozzle operator, unless otherwise specified.
- B. The nozzle operator and application crew members shall be required to meet pre-construction testing requirements administered by the Engineer on a test panel. The Engineer will carefully observe shooting of the test panel or area and note if the nozzle operator examinee:
 - 1. Cleans the shooting surface with air and water prior to shooting.
 - 2. Applies a bonding coat on the shooting surface ahead of the heavier shotcrete applications.
 - 3. Directs shotcrete application around reinforcement in a manner that prevents buildup on the face of the reinforcement and allows the shotcrete to flow and compact tightly around the back of the reinforcement.

4. If applicable, directs the finisher or nozzle helper to cutout any sags, sand or rebound pockets.
5. If applicable, and where necessary, directs the finisher or nozzle helper to broom the shotcrete surface prior to application of additional layers.

1.07 – EQUIPMENT

The Contractor shall furnish all equipment necessary for removing deteriorated concrete and for batching, mixing and placing the shotcrete. The equipment shall meet the following requirements:

- A. Chipping hammer for removal of existing concrete shall not exceed 15 pounds. Any damage caused to sound concrete due to the use of improper equipment or repair methods shall be repaired at no additional expense to the Owner.
- B. The placing equipment for DRY MIX shotcrete shall:
 1. Be designed and equipped to receive the dry mix, introduce the mix into a stream of compressed oil free dry air, convey the mix pneumatically through a delivery hose to a nozzle at the point of discharge, inject water under pressure into the suspended stream of dry sand and cement within the nozzle, and spray the resulting shotcrete mix onto the surface of the work at a uniform rate and at a controlled velocity.
 2. Be equipped with accurate gauges to indicate the air pressure and water pressure
 3. Be equipped with devices capable of accurately controlling the air pressure at any level between 50-psi and 80-psi.
 4. Be equipped with devices capable of accurately controlling the water pressure at any level between 50-psi and 100-psi, and the rate of application of water at the nozzle.
- C. The placing equipment for WET MIX shotcrete shall:
 1. Be designed and equipped to receive the shotcrete from the mixer, convey it through a delivery hose to a nozzle at the point of discharge, accelerate it in the nozzle by means of compressed oil free dry air, and spray it onto the surface of the work.
 2. Be capable of delivering shotcrete to the nozzle uniformly and continuously and discharging it from the nozzle at a uniform rate and at a controlled velocity sufficient for all parts of the work.
- D. Batch and continuous mixing equipment shall include:

1. A power-driven mixer capable of thoroughly mixing the materials at a rate adequate to insure uniform feeding of the mixture to the placing equipment;
2. A feeding apparatus capable of supplying the mixture to the placing equipment at an adequate and uniform rate.

1.08 – MEASURING MATERIALS

The proportions of the shotcrete mix shall be controlled on the basis of the weight of each component material, unless otherwise specified in this specification, except that water may be measured by volume.

- A. Materials shall have the following batch tolerances of their mix proportion weights:
 1. Cement, plus or minus two (2) percent;
 2. Aggregate, plus or minus four (4) percent;
 3. Admixtures, plus or minus six (6) percent.
- B. Weighing equipment used shall be accurate to within 0.4 percent of scale capacity.

PART 2 PRODUCTS

2.01 – REPAIR MATERIALS

- A. Portland cement shall conform to ASTM C 150, Type I or Type II, unless otherwise approved. Use one brand of cement throughout project, unless otherwise acceptable to Architect.
- B. Normal weight aggregates shall conform to ASTM C33. Provide from a single source for exposed concrete. Do not use aggregates containing soluble salts or other substances such as iron sulfides, pyrite, marcasite, or ochre, which can cause stains on exposed concrete surfaces. Lightweight aggregates shall conform to ASTM C330.
- C. Gradation shall be one of the three options specified by ACI 506R, Table 2.1 unless otherwise specified.
- D. Admixtures, if specified, shall meet the requirements indicated. Non-chloride chemical admixtures shall conform to ASTM C 494. Air-entraining admixtures shall conform to ASTM C 260. Fly ash or pozzolanic materials shall conform to ASTM C 618. Calcium chloride shall conform to ASTM D 98 and shall be in flake or pellet form.

- E. Water used in mixing or curing shotcrete shall be clean and free from injurious amounts of oil, salt, acid, alkali, organic matter or other deleterious substances.
- F. Curing compound shall conform to the requirements of Subsection 3.06.

2.02 – STRENGTH AND QUALITY

- A. The compressive strength of shotcrete at the age of 28 days shall be not less than 5000 psi.
- B. Shotcrete shall be uniform and dense, free from "drummy" areas that indicate laminations, voids, sand pockets, or disbanded material.

2.03 – CONSISTENCY

- A. The proportion of water added to the mixture shall be accurately controlled to produce thorough and uniform hydration of the shotcrete.
- B. The consistency of the shotcrete shall be such that the surface of the shotcrete in place shall have a rich, glossy appearance and that the shotcrete shall adhere to the supporting surface without flowing, slumping or sloughing.
- C. For application to vertical or overhanging surfaces the mix proportions shall be adjusted so that the placed shotcrete will adhere to a minimum thickness of 3/4-inch without sagging or sloughing.
- D. For adjustment of consistency the addition of fly ash or pozzolanic material to the mixture in amounts not greater than 20-percent (by weight) of cement in the mixture will be permitted.

2.04 – REINFORCING MATERIALS

- A. Reinforcing Steel Bars: ASTM A 615, Grade 60, deformed and ASTM A 706, Grade 60, deformed, weldable.
- B. Welded Wire Fabric: ASTM A 185, welded steel wire fabric. Provide welded wire fabric in flat sheets.
- C. Supports for Reinforcement: Provide supports for reinforcement including bolsters, chairs, spacers, and other devices for spacing, supporting and fastening reinforcing bars and welded wire fabric in place. Use plastic or wire bar type supports complying with CRSI recommendations, unless otherwise specified. Wood, concrete block, clay brick and other unspecified devices are not acceptable.

PART 3 EXECUTION

3.01 – MIXING

- A. Dry Mix Shotcrete – The cement and admixtures and other additives (except accelerator) shall be mixed into a predampened homogeneous mass that thoroughly coats the aggregate before being fed through a vibratory screen into the placing equipment. Proper pre-dampening shall be indicated by the "ball-in-hand" test as follows: When a small amount of mix is tightly squeezed the resulting ball will hold together or crack slightly but essentially remain whole. The mix has too little pre-dampening moisture if the ball crumbles into discrete particles when the hand is opened and/or color is light gray. If moisture comes off on the hand, too much pre-dampening moisture is in the mix. The properly pre-dampened dry mix shall be used within 45 minutes after mixing (15 minutes in hot weather conditions with temperatures over 85° F) and any material that becomes dried out or caked after mixing shall be wasted. Rebound material shall not be remixed or reused.
- B. Wet Mix Shotcrete – Air-entrainment and chemical admixtures may only be used in wet mix concrete. The cement, sand, admixtures (except accelerator) and water shall be thoroughly mixed in the mixer drum sufficiently to produce shotcrete of the required consistency that is uniform within each batch and uniform from batch to batch when discharged into the placing equipment.
- C. Accelerators, if specified, shall be mixed at the nozzle. Ready-mix concrete shall conform to the requirements of ASTM C 94 unless otherwise specified.
- D. The entire contents of the mixer shall be discharged from the drum before materials for a succeeding batch are placed therein. A mix that becomes difficult to pump shall be discarded; otherwise, a batch shall be gunned within 1 1/2 hours of batching in normal weather and within 45 minutes during hot weather conditions (temperatures over 85° F). Rebound material shall not be remixed or reused.

3.02 – PREPARATION OF SURFACES TO RECEIVE SHOTCRETE

- A. All surfaces to receive or support shotcrete shall be carefully prepared and conditioned. All such prepared surfaces shall be inspected and approved by the Engineer prior to the application of shotcrete.
- B. Concrete surfaces shall be thoroughly cleaned by water blasting or sand blasting to remove all dirt, laitance, weak or unbonded mortar, loose material, grease or other deleterious substances.
- C. Surfaces on which the shotcrete is to be placed shall be sufficiently rough to insure the adherence of the shotcrete. Offsets which would cause an abrupt and substantial change in thickness of the shotcrete shall be removed or tapered.

- D. All surfaces shall be maintained in a moistened condition for three (3) hours before application of shotcrete. Shotcrete shall not be applied to rebound material, or surfaces on which free water exists. All ice, snow and frost shall be removed and the temperature of all surfaces, to be in contact with the new shotcrete shall be no colder than 40° F.

3.03 – PLACEMENT

- A. The Contractor shall have all equipment and materials required for curing available at the site and ready for use before placement of shotcrete begins. No shotcrete shall be placed except in the presence of the Engineer or authorized representative. The Contractor shall give reasonable notice to the Engineer each time shotcrete placement is scheduled. Such notice shall be far enough in advance to give the Engineer adequate time to inspect the surfaces to which the shotcrete is to be applied, the forms, steel reinforcement, and other preparations for compliance with the specifications prior to the start of placement operations.
- B. During placement of shotcrete the air pressure shall be adjusted as required to control rebound and density of shotcrete. For a given application, once the optimum operating pressures have been established they shall be maintained constant throughout the application. For dry mix shotcrete, the air pressure at the material outlet or air-inlet on the gun shall be not less than 40 psi plus 5 psi for each 50 feet of length of the discharge hose greater than 100 feet and 5 psi for each 25 feet the nozzle is above the gun (shotcrete delivery equipment). The water pressure at the nozzle shall be not less than 15 psi greater than the air pressure at the material outlet or air-inlet on the gun.
- C. For most applications the placing nozzle shall be held between two (2) and six (6) feet from and approximately normal to the surface of the work. At longer distances it may be necessary to increase the nozzle velocity so that the impact velocity will suit the requirements of the application. Corners shall be filled first to establish 45° edge taper.
- D. Shotcrete shall be applied in a single thickness or to a layer thickness no greater than that which will cause sagging, sloughing, or dropout. Sags and sloughs shall be cut out and regunned. Replacement shall be accomplished before the previously placed shotcrete has completely set. When shotcrete is placed on a vertical surface, application shall be started at the bottom and be completed at the top.
- E. In any case when the placing of shotcrete is interrupted for more than one (1) hour, the edge of the layer shall be sloped off at an angle of approximately 45° to the surface being shot, and the sloped portion shall be covered with a double layer of six (6) ounce burlap and kept continuously moist until the application of shotcrete is resumed. Before applying new material, the sloped portion shall be thoroughly cleaned and wetted by means of an air and water blast or an equally effective method approved by the Engineer.

- F. Material that rebounds and accumulates on subgrade surfaces or reinforcing steel ahead of the shotcrete being placed shall be removed and discarded.

3.04 – FINISHING

- A. Rebound material shall be carefully swept off the finished shotcrete surface and discarded before it becomes too hard for removal.
- B. After the shotcrete has been placed to the depth required, the surface shall be checked with a straightedge or template and any low spots shall be brought up to grade by placing additional shotcrete.
- C. The finished surface of the shotcrete shall be left as a smooth gun finish unless screeding and or further finishing are specified.

3.05 – CURING

- A. Shotcrete shall be prevented from drying for a curing period of at least seven (7) days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period or until curing compound is applied as specified below. Moisture shall be maintained by sprinkling, flooding or fog spraying, or by covering with continuously moistened canvas, cloth mats, straw, sand or other approved material. Water, or covering, shall be applied in such a way that the shotcrete surface is not eroded or otherwise damaged.
- B. Water for curing shall be clean and free from any substances that will cause discoloration of the shotcrete where finished surfaces will be exposed to view.
- C. Except as otherwise specified in Section 4.02 of this specification, and except for surfaces to which additional shotcrete is to be applied, shotcrete may be coated with curing compound as an alternative to the continued application of moisture.
- D. The compound shall be sprayed on the moist shotcrete surfaces as soon as rebound has been removed and any required repairs are completed, or as soon as water curing is discontinued.
- E. The curing compound shall be thoroughly mixed immediately before applied and continuously agitated during application. It shall be applied at a uniform rate of not less than one (1) gallon per 100 square feet of surface for natural gun finishes. Curing compound shall be applied in two (2) applications, one (1) in each direction. If a natural rod, broom, or float finish is specified, the curing compound application rate shall be at least one (1) gallon per 150 square feet. Curing compound shall not check, crack or peel, and shall be free from pinholes or other imperfections.
- F. Curing compound shall not be applied to subgrade surfaces or other surfaces requiring bond with subsequently placed shotcrete, such as construction joints, reinforcing steel and other embedded items.

- G. Surfaces damaged by subsequent construction operations during the curing period shall be resprayed in the same manner as for the original applications.

3.06 – PLACING REINFORCEMENT

- A. Comply with Concrete Reinforcing Steel Institute's recommended practice for "Placing Reinforcing Bars", for details and methods of reinforcement placement and supports, and as herein specified.
 - 1. Clean reinforcement of loose rust and mill scale, earth, ice, and other materials which reduce or destroy bond with concrete.
 - 2. Accurately position, support and secure reinforcement against displacement by formwork, construction, or concrete placement operations. Locate and support reinforcing by metal chairs, runners, bolsters, spacers and hangers, as required.
 - 3. Install welded wire fabric in flat sheets in as long lengths as practicable. Lap adjoining pieces at least two full mesh and lace splices with wire. Offset end laps in adjacent widths to prevent continuous laps in either direction.

PART 4 RELATED WORK

4.01 – PLACING IN COLD WEATHER

When the atmospheric temperature may be expected to drop below 40° F at the time shotcrete is placed, or at any time during the curing period, the following provisions shall also apply:

- A. Shotcrete placement shall be permitted when the air temperature is at least 40° F and rising. Placement shall be discontinued if the temperature falls to 40° F and is expected to continue to fall.
- B. The temperature of the shotcrete at time of placing shall not be less than 50° F nor more than 90° F. The temperature of neither aggregates nor mixing water shall be more than 100° F just prior to mixing with the cement.
- C. When the daily minimum temperature is less than 40° F, shotcrete shall be insulated or housed and heated after placement. The temperature of the shotcrete and air adjacent to the shotcrete shall be maintained at not less than 50° F nor more than 90° F for the duration of the curing period.
- D. Methods of insulating, housing and heating the structure shall be in accordance with "Standard Specification for Cold Weather Concreting," ACI Standard 306.1.
- E. The use of accelerators or antifreeze compounds will not be allowed unless otherwise specified.

- F. When dry heat is used to protect shotcrete, means of maintaining an ambient humidity of at least 40 percent shall be provided unless the shotcrete has been coated with curing compound as specified in Section 3.05 of this specification or is covered tightly with an approved impervious material.

4.02 – PLACING IN HOT WEATHER

When climatic factors such as high air temperature, reduced relative humidity and increased wind velocities are present, or conditions are such that the temperature of placed shotcrete exceeds 90° F at, or during the first 24 hours after placement, the following provisions shall also apply:

- A. The Contractor shall maintain the temperature of the shotcrete below 90° F during mixing, conveying, and placing using the methods given in items B, C, and D below.
- B. Exposed shotcrete surfaces that tend to dry or set too rapidly shall be continuously moistened by means of fog sprays or otherwise protected from drying immediately after placement.
- C. Shotcrete surfaces exposed to the air shall be covered as soon as the shotcrete has hardened sufficiently and shall be kept continuously wet for at least the first 24 hours of the curing period, and for the entire curing period unless curing compound is applied as specified in Subsection D, below.
- D. If moist curing is discontinued before the end of the curing period, white pigmented curing compound shall be applied immediately, following the procedures specified in Section 3.06 of this Specification.

4.03 – REPLACEMENT OR REPAIR OF SHOTCRETE APPLICATION

- A. When shotcrete lacks uniformity, exhibits segregation, honeycombing, or laminations, or contains dry patches, slugs, voids or sand pockets the Contractor shall remove and replace the defective shotcrete. The Engineer's concurrence in the extent of removal and replacement is required.
- B. Prior to starting significant removal and replacement work the Contractor shall obtain the Engineer's approval of their plan for making the repair. Such approval shall not be considered a waiver of the Contractor's responsibility to complete removal of defective work if the completed repair does not produce shotcrete of the required quality and appearance.
- C. Repair work shall be performed only when the Engineer is present.
- D. Repair shall be made with shotcrete conforming to this Specification. When removal of defective shotcrete is required, reinforcement damaged or destroyed shall be replaced prior to replacement of the shotcrete. At the edges of removed sections the sound shotcrete shall be carefully trimmed to the extent required to expose sufficient reinforcement for effecting competent

splices. The sound shotcrete at the edges of removed sections shall be trimmed to a slope of approximately 45 degrees with the surface of the work and shall be thoroughly moistened prior to placement of the new shotcrete.

- E. Any portions of the work having thickness less than those specified may be repaired by the placement of additional layers of shotcrete, provided that such repair is expressly approved by the Engineer.
- F. Surfaces of the work to which additional shotcrete is to be applied shall be prepared as required by this Specification.
- G. Curing as specified in Section 14 of this Specification shall be applied to repaired areas immediately after the repairs are completed.

4.04 – FORMS

Forms shall be incidental to this Item and shall meet the following requirements:

- A. Forms shall be structurally adequate and of such design that rebound or accumulated loose sand can freely escape or be readily removed.
- B. Shooting strips shall be used at corners, edges, and on surfaces where necessary to obtain true lines and proper thickness.
- C. Ground Wires - Where practicable, ground wires shall be installed as guides to accurately establish the specified contour of the finished surface of shotcrete.
 - 1. Ground wires shall be set and used as guides for templates in forming curved and molded surfaces.
 - 2. When shotcrete is to be placed on horizontal or sloping surfaces, headers and ground wires shall be provided to the extent necessary to insure control of slab thickness.
 - 3. Ground wires shall be tightened and kept taut, secure, and true to line and plane during placement of shotcrete and shall be removed when placement is completed.
- D. Header boards will be required where the drawings indicate a square edge and at required joints. Form surfaces shall be thoroughly cleaned and a form release agent applied before shotcrete is placed.

END OF SECTION