

BOARD OF WATER COMMISSIONERS  
DENVER, COLORADO

ADDENDUM NO. 2

TO THE CONTRACT DOCUMENTS

DILLON DAM OUTLET WORKS GATE REPAIRS

CONTRACT 13327A

December 23, 2011

**TO ALL PLAN-HOLDERS:**

This Addendum No. 2 consists of Pages AD2-1 to AD2-3. The following changes, additions, and/or deletions are hereby made part of the Contract Documents for Dillon Dam Outlet Works Gate Repairs, Contract 13327A, dated December, 2011, as fully and completely as if the same were fully set forth therein:

**FRONT END:**

1. **TABLE OF CONTENTS, PAGE TC-2:**

ADD: SECTION 03 37 13 SHOTCRETE 1-8

**SPECIFICATIONS:**

1. **SECTION 03 37 13 - SHOTCRETE:**

ADD: Add Specification Section in its entirety.

2. **SECTION 35 20 15 – OUTLET GATE REPAIRS, SUBPARAGRAPH 2.4.A (TABLE), PAGE 4:**

DELETE: "Type XI" from column "Repair Type" for "Control Gate No 3, Gate Leaf and Seats".

SUBSTITUTE: "Type XI" to column "Repair Type" for "Control Gate No 3, Frame Seats".

3. **SECTION 35 20 15 – OUTLET GATE REPAIRS, SUBPARAGRAPH 2.4.A (TABLE), PAGE 4:**

DELETE: "Type XI" from column "Repair Type" for "Guard Gate No 3, Gate Leaf and Seats".

**DRAWINGS:**

1. **DILLON DAM OUTLET WORKS IMPROVEMENTS DRAWINGS, TITLE BLOCK:**

ADD: "SHEET \_\_\_ OF 89 SHEETS" to entire set.

2. **DILLON DAM OUTLET WORKS IMPROVEMENTS DRAWINGS, TITLE BLOCK:**

DELETE: "C-930" to each drawing.

SUBSTITUTE: "C-0930H" to each drawing.

(BOARD OF WATER COMMISSIONERS )  
(DILLON DAM OUTLET WORKS )  
(GATE REPAIRS )  
(13327A ) AD2-1

3. **DRAWING G-1 – COVER SHEET, TITLE BLOCK:**  
ADD: "WATER DIVISION 5, WATER DISTRICT 36, SUMMIT COUNTY,  
DAM ID 3601040"
4. **DRAWING G-1 – COVER SHEET, TITLE BLOCK:**  
DELETE: "CONTRACT NO 13327A"  
SUBSTITUTE: "CONTRACT 13327A"
5. **DRAWING S-1 – STRUCTURAL INDEX SHEET, TITLE BLOCK:**  
DELETE: "CONTRACT NO 13327A"  
SUBSTITUTE: "CONTRACT 13327A"
6. **DRAWING C-1 – CIVIL INDEX SHEET, TITLE BLOCK:**  
DELETE: "CONTRACT NO 13327A"  
SUBSTITUTE: "CONTRACT 13327A"
7. **DRAWING M-1 – MECHANICAL INDEX SHEET, TITLE BLOCK:**  
DELETE: "CONTRACT NO 13327A"  
SUBSTITUTE: "CONTRACT 13327A"
8. **DRAWING E-1 – ELECTRICAL INDEX SHEET, TITLE BLOCK:**  
DELETE: "CONTRACT NO 13327A"  
SUBSTITUTE: "CONTRACT 13327A"
9. **DRAWING E-30 – GATE CONTROL PANEL PLC - SLOT 1 ANALOG INPUTS, TITLE BLOCK:**  
DELETE: "GATE CONTROL PLC - SLOT 1 ANALOG INPUTS"  
SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 1 ANALOG INPUTS"
10. **DRAWING E-31 – GATE CONTROL PANEL PLC - SLOT 2 ANALOG OUTPUTS, TITLE BLOCK:**  
DELETE: "GATE CONTROL PLC - SLOT 2 ANALOG OUTPUTS"  
SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 2 ANALOG OUTPUTS"
11. **DRAWING E-32 – GATE CONTROL PANEL PLC - SLOT 3 DIGITAL INPUTS, TITLE BLOCK:**  
DELETE: "GATE CONTROL PLC - SLOT 3 DIGITAL INPUTS"  
SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 3 DIGITAL INPUTS"

12. **DRAWING E-33 – GATE CONTROL PANEL PLC - SLOT 4 DIGITAL INPUTS, TITLE BLOCK:**

DELETE: "GATE CONTROL PLC - SLOT 4 DIGITAL INPUTS"

SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 4 DIGITAL INPUTS"

13. **DRAWING E-34 – GATE CONTROL PANEL PLC - SLOT 5 DIGITAL INPUTS, TITLE BLOCK:**

DELETE: "GATE CONTROL PLC - SLOT 5 DIGITAL INPUTS"

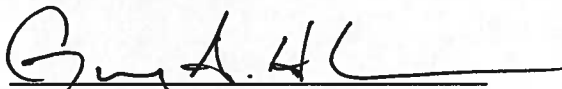
SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 5 DIGITAL INPUTS"

14. **DRAWING E-35 – GATE CONTROL PANEL PLC - SLOT 6 DIGITAL INPUTS, TITLE BLOCK:**

DELETE: "GATE CONTROL PLC - SLOT 6 DIGITAL INPUTS"

SUBSTITUTE: "GATE CONTROL PANEL PLC - SLOT 6 DIGITAL INPUTS"

All Bidders shall acknowledge receipt and acceptance of this Addendum No. 2 in the space provided on the Bid Form.



Greg Hempelman, P.E.  
Engineering Manager  
Denver Board of Water Commissioners

SECTION 03 37 13  
SHOTCRETE

PART 1 GENERAL

1.1 UNIT PRICES

A. Shotcrete

1. Payment
  - a. Payment will be made for all costs associated with furnishing, delivering, and placing shotcrete.
2. Measurement
  - a. Shotcrete will be measured for payment as specified in Section 01 29 00.
3. Unit of Measure
  - a. Unit of measure: Cubic yard.

1.2 REFERENCES

A. American Concrete Institute International (ACI):

1. CP-60 (2009) Craftsman Workbook for ACI Certification of Shotcrete Nozzleman

B. ASTM INTERNATIONAL (ASTM):

1. A 820/A 820M - Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
2. C 1077 - Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
3. C 1140 - Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels
4. C 1141/C 1141M - Standard Specification for Admixtures for Shotcrete
5. C 1240 - Standard Specification for Silica Fume Used in Cementitious Mixtures
6. C 1260 - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
7. C 136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
8. C 150/C 150M - Standard Specification for Portland Cement
9. C 1567 - Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
10. C 1609/C 1609M - Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
11. C 171 - Standard Specification for Sheet Materials for Curing Concrete
12. C 266 - Standard Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles
13. C 309 - Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
14. C 33/C 33M - Standard Specification for Concrete Aggregates
15. C 42/C 42M - Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
16. C 566 - Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
17. C 595/C 595M - Standard Specification for Blended Hydraulic Cements
18. C 618 - Standard Specification for Coal

**1.3 SYSTEM DESCRIPTION**

**A. Strength**

1. Final Acceptance of the shotcrete will be based on compressive strength results obtained from cores.

**B. Compressive Strength**

1. The required compressive strength of cores shall not be less than 5,500 psi at 28 days age when tested in accordance with ASTM C 42/C 42M. The average compressive strength of cores taken from the test panel, representing a shift or not more than 50 cubic yards of shotcrete tested at 28 days of age, shall equal or exceed the required compressive strength specified with no individual core less than 85 % of the required compressive strength.

**1.4 SUBMITTALS**

**A. Submit the following in accordance with Section 01 33 00:**

1. Product Data
  - a. Manufacturer's product data
  - b. Mixture proportions.

**1.5 QUALITY ASSURANCE**

**A. Qualifications**

1. Shotcrete will be produced by either the Dry or Wet Method. Submit a resume for each nozzleman certifying that each has not less than 1 years experience for the particular type of shotcrete to be applied. The resume shall include company name, address, and telephone number, name of supervisor, and detailed description of work performed. All nozzlemen shall be certified in accordance with ACI CP-60. Qualifications of additional nozzlemen throughout the job shall be similarly submitted for approval.

**B. Preconstruction Test Panels**

1. Specimens of the preconstruction test panels shall be made by each application crew using the equipment, materials, mixture proportions, and procedures for each mixture being considered, and for each shooting position to be encountered in the job. Submit cores taken from test panels and test them. Provide the same reinforcement as in the structure in at least one-half of the panel to test for proper embedment of reinforcing steel. Fabricate the test panels to the same thickness as the structure, but not less than 4 inches.

**PART 2 PRODUCTS**

**2.1 MATERIALS**

**A. Cementitious Materials: Portland cement, blended hydraulic cement, Portland cement in combination with pozzolan, slag cement, or Portland cement in combination with silica fume conforming to appropriate specifications listed below:**

1. Portland Cement:
  - a. Portland cement shall meet the requirements of ASTM C 150/C 150M Type I or II. Submit certificate of compliance with all specification requirements.

2. Pozzolan Other Than Silica Fume:
    - a. Pozzolans shall conform to ASTM C 618, Class C or F. Submit certificate of compliance for fly ash and other pozzolans with all specification requirements.
  3. Slag Cement:
    - a. Slag cement shall conform to ASTM C 989.
  4. Silica Fume:
    - a. Silica may be furnished as a dry, densified material or as a slurry. Silica fume, unprocessed, or before processing into a slurry or a densified material, shall conform to ASTM C 1240. Submit certificate of compliance for silica fume with all specification requirements.
- B. Aggregates**
1. Submit Supplier's test reports for aggregates showing the materials meet the requirements of this specification.
- C. Water**
1. Use fresh, clean, potable mixing water or non-potable water which meets the requirements of COE CRD-C 400.
- D. Curing Materials**
1. Submit certificate of compliance for curing materials with all specification requirements. Curing materials shall meet the following requirements:
  2. Impervious Sheet Materials
    - a. ASTM C 171, type optional except polyethylene film, if used, shall be white opaque.
  3. Membrane-Forming Curing Compound
    - a. ASTM C 309, Type 1-D or Type 2.
- E. Reinforcement**
1. Steel Fiber Reinforcement
    - a. Steel fiber reinforcement shall meet the requirements of ASTM A820/A820M. Submit certificate of compliance for fiber reinforcement with all specification requirements.
- F. Air Content**
1. Air-entraining admixture shall be used in such proportion that the air content of the shotcrete prior to gunning shall be 5% plus or minus ( $\pm$ ) 1.0 % as determined by ASTM C231/C231M.
- G. Air Supply**
1. Provide a supply of clean, dry air adequate for maintaining sufficient nozzle velocity for all parts of the work and, if required, for simultaneous operation of a suitable blowpipe for clearing away rebound.

## **2.2 MIXTURE PROPORTIONS**

- A.** Mixture proportions and test data from prior experience within 2 years, if available, may be submitted for approval. If test data from experience are not available or accepted, specimens shall be made and tested from mixtures having three or more different proportions. The recommended mixture proportions, sources of materials, and all test results shall be submitted for acceptance. Submit the recommended mixture proportions, sources of materials, and all test results, for approval.

## 2.3 EQUIPMENT

### A. Wet Mix Batching and Mixing

1. Batching and mixing shall be accomplished in accordance with the applicable provisions of ASTM C 94/C 94M. If volumetric batching and mixing are used, the materials shall be batched and mixed in accordance with the applicable provisions of ASTM C 685/C 685M. The mixing equipment shall be capable of thoroughly mixing the specified materials in sufficient quantity to maintain continuous placing. Ready-mix shotcrete complying with ASTM C 94/C 94M may be used.

### B. Delivery Equipment for Wet Mix

1. The equipment shall be capable of delivering the premixed materials accurately, uniformly, and continuously through the delivery hose. Recommendations of the equipment manufacturer shall be followed on the type and size of nozzle to be used and on cleaning, inspection, and maintenance of the equipment.

## PART 3 EXECUTION

### 3.1 PREPARATION OF SURFACES

#### A. Existing Concrete

1. All unsound and loose materials shall be removed by sandblasting, grinding, or high-pressure water jets before applying shotcrete. Any area to be repaired shall be chipped off or scarified to remove offsets which would cause an abrupt change in thickness without suitable reinforcement. Edges shall be tapered to leave no square shoulders at the perimeter of a cavity. The surface shall be dampened but without visible free water.

#### B. Rock

1. Rock surfaces shall be cleaned to remove loose or drummy material, mud, running water, and other foreign matter that will prevent bond of the shotcrete. The rock surface shall be dampened prior to placement of shotcrete.

#### C. Construction Joints

1. Unless otherwise specified, construction joints shall be tapered to a shallow edge form, about 1 inch thick. If non-tapered joints are specified, take special care to avoid or remove trapped rebound at the joint. The entire joint shall be thoroughly cleaned and wetted prior to the application of additional shotcrete.

### 3.2 PLACEMENT OF SHOTCRETE

#### A. General

1. Place shotcrete using suitable delivery equipment and procedures. The area to which shotcrete is to be applied shall be clean and free of rebound or overspray.

#### B. Placement Techniques

1. Placement Control
  - a. Thickness, method of support, air pressure, and water content of shotcrete shall be controlled to preclude sagging or sloughing off. Shotcreting shall be discontinued or suitable means shall be provided to screen the nozzle stream if wind or air currents cause separation of the nozzle stream during placement.

2. Corners
  - a. Horizontal and vertical corners and any area where rebound cannot escape or be blown free shall be filled first.

**C. Placement Around Reinforcement**

1. The nozzle shall be held at such distance and angle to place material behind reinforcement before any material is allowed to accumulate on the face of the reinforcement. In the dry-mix process, additional water may be added to the mixture when encasing reinforcement to facilitate a smooth flow of material behind the bars. Shotcrete shall not be placed through more than one layer of reinforcing steel rods or mesh in one application unless demonstrated by preconstruction tests that steel is properly encased.

**D. Cover of Reinforcement**

1. The minimum cover shall be 3 inches.

**E. Placement Precautions**

1. The following precautions shall be taken during placement.
  - a. Placement shall be stopped if drying or stiffening of the mixture takes place at any time prior to delivery to the nozzle.
  - b. Rebound or previously expended material shall not be used in the shotcrete mixture.

**3.3 REPAIR OF DEFECTS**

**A. Defects**

1. Defective areas larger than 48 square inches or 2 inches deep shall be removed and replaced with fresh shotcrete. These defects include honeycombing, lamination, dry patches, voids, or sand pockets. Defective areas shall be removed in accordance with the procedures described in paragraph EXISTING CONCRETE and replaced with fresh shotcrete.
  - a. Repairs
    - 1) All repairs shall be made within 1 week of the time the deficiency is discovered. All unacceptable materials shall be removed and repaired by the procedures described in the following two paragraphs. Voids and holes left by the removal of tie rods in all permanently exposed surfaces not to be backfilled and in surfaces to be exposed to water shall be reamed and completely filled with dry-patching mortar as specified below.
  - b. Minor Patching
    - 1) Minor patching may be accomplished with a dry-pack mixture, or with materials as approved by the Contracting Officer. Patches that exceed 0.1 cubic foot in volume shall receive a brush coat of approved epoxy resin meeting ASTM C 881/C 881M, Type II, as a prime coat. Care shall be taken not to spill epoxy or overcoat the repair surface so that the epoxy runs or is squeezed out onto the surface which will remain exposed to view. Epoxy resin shall be used in strict conformance with manufacturer's recommendations with special attention paid to pot life, safety, and thin film tack time.

**B. Core Holes**

1. Core holes shall not be repaired with shotcrete. Instead, they shall be filled solid with a dry-pack mixture after being cleaned and thoroughly dampened.

**3.4 FINISHING**

**A. Natural Gun Finish**

1. Unless otherwise specified, provide undisturbed final layer of shotcrete as applied from nozzle without hand finishing.

**B. Cutting Screed**

1. After the surface has taken its initial set (crumbling slightly when cut), excess material outside the forms and ground wires shall be sliced off with a downward cutting motion using a sharp-edged cutting screed.

**C. Flash Coat**

1. A thin coat of shotcrete containing finer sand applied from a distance greater than normal shall be applied to the surface as soon as possible after the screeding.

**D. Float and Trowel Finish**

1. Final surface finish shall be provided using steel trowel. Troweling of thin sections of shotcrete shall be avoided unless both troweling and commencement of moisture curing take place within a relatively short period after placement of shotcrete.

**E. Fiber-Reinforced Shotcrete**

1. Finish the outer surface of the structure with a layer of nonfiber-reinforced shotcrete and provide an appropriate finish as denoted.

**3.5 CURING AND PROTECTION**

**A. Initial Curing**

1. Immediately after finishing, shotcrete shall be kept continuously moist for at least 3 days. One of the following materials or methods shall be used:
  - a. Ponding or continuous sprinkling.
  - b. Absorptive mat or fabric, sand, or other covering kept continuously wet.
  - c. Curing Compounds:
    - 1) On natural gun or flash finishes, use the coverage application requirement of 100 square feet/gallon or twice the manufacturer's requirement, whichever is less. Curing compounds shall not be used on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded unless positive measures, such as sandblasting, are taken to completely remove curing compounds prior to the application of such additional materials.

**B. Final Curing**

1. Additional curing shall be provided immediately following the initial curing and before the shotcrete has dried. One of the following materials or methods shall be used:
  - a. Continue the method used in initial curing.
  - b. Application of impervious sheet material conforming to ASTM C 171.

**C. Formed Surface**

1. If forms are to be removed during curing period, one of the curing materials or methods listed in paragraph INITIAL CURING shall be used immediately. Such curing shall be continued for the remainder of the curing period.

**D. Duration of Curing**

1. Curing shall be continued for the first 7 days after shotcreting or until the specified compressive strength of the in-place shotcrete as determined by specimens obtained and tested in accordance with ASTM C 42/C 42M is achieved.

**E. Temperature Considerations**

1. The air temperature in contact with the shotcrete shall be continuously maintained at a temperature above 40° F for at least 3 days after placement. No shotcrete shall be applied when the concrete surface or air in contact with the concrete surface is below 40° F.

**3.6 TESTS**

**A. Strength Testing**

1. Test specimens shall be initially cured onsite, then shall be transported in an approved manner to an approved testing laboratory meeting the requirements of ASTM C 1077 within 48 hours of scheduled testing time.
  - a. Test Panel
    - 1) One test panel shall be made for every 50 cubic yards of shotcrete placed but not less than one per each shift during which any shotcrete is placed. Panels shall have minimum dimensions of 18 by 18 by 4 inches and shall be gunned in the same positions as the work represented during the course of the work by the Contractor's regular nozzleman. Panels shall be field cured in the same manner as in the job. Three 2-inch diameter cores shall be drilled from each panel at least 40 hours prior to testing and tested in accordance with ASTM C 1140.
  - b. Test Cores
    - 1) Test cores shall be drilled from the structure at least 40 hours prior to testing and tested in accordance with ASTM C 1140. A set of three cores shall be taken not less than once each shift that shotcrete is placed nor less than once for each 50 cubic yards of shotcrete placed through the nozzle. The diameter of core specimens shall be determined in accordance with ASTM C 42/C 42M.
  - c. Average Compressive Strength
    - 1) The compressive strength of the shotcrete shall be determined from the average of three cores obtained from a test panel representing a specific volume of shotcrete and tested on the 7th day after panel fabrication.

**B. Thickness**

1. The minimum shotcrete thickness shall be as shown in the drawings. The unhardened shotcrete shall be checked for thickness using a probe by the nozzleman or laborer at the time of placement. These thickness checks shall be at 15-minute intervals and all low or thin areas shall be corrected by applying additional shotcrete.

**C. Mixture Proportions**

1. Record and check mixture proportions at least once per shift for weigh batching. Record and check mixture proportions as recommended by ASTM C 685/C 685M at least once per shift for volumetric batching and continuous mixing plants.

**D. Preparations**

1. Prior to each placement of shotcrete, the Contractor's inspector shall certify in writing or by an approved checkout form that cleanup and preparations are in accordance with the plans and specifications.

**E. Air Content**

1. Air content tests shall be conducted on wet-mix shotcrete according to ASTM C231/C231M with a frequency of not less than once each shift nor less than once for each 50 cubic yards of shotcrete placed through the nozzle. Tests shall be conducted on samples taken as the wet shotcrete mixture is placed in the delivery equipment.

**END OF SECTION**

SECTION 03 37 13  
SHOTCRETE

PART 1 GENERAL

1.1 UNIT PRICES

A. Shotcrete

1. Payment
  - a. Payment will be made for all costs associated with furnishing, delivering, and placing shotcrete.
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**1.3 SYSTEM DESCRIPTION**

**A. Strength**

1. Final Acceptance of the shotcrete will be based on compressive strength results obtained from cores.

**B. Compressive Strength**

1. The required compressive strength of cores shall not be less than 5,500 psi at 28 days age when tested in accordance with ASTM C 42/C 42M. The average compressive strength of cores taken from the test panel, representing a shift or not more than 50 cubic yards of shotcrete tested at 28 days of age, shall equal or exceed the required compressive strength specified with no individual core less than 85 % of the required compressive strength.

**1.4 SUBMITTALS**

**A. Submit the following in accordance with Section 01 33 00:**

1. Product Date
  - a. Manufacturer's product data
  - b. Mixture proportions.

**1.5 QUALITY ASSURANCE**

**A. Qualifications**

1. Shotcrete will be produced by either the Dry or Wet Method. Submit a resume for each nozzleman certifying that each has not less than 1 years experience for the particular type of shotcrete to be applied. The resume shall include company name, address, and telephone number, name of supervisor, and detailed description of work performed. All nozzle men shall be certified in accordance with ACI CP-60. Qualifications of additional nozzle men throughout the job shall be similarly submitted for approval.

**B. Preconstruction Test Panels**

1. Specimens of the preconstruction test panels shall be made by each application crew using the equipment, materials, mixture proportions, and procedures for each mixture being considered, and for each shooting position to be encountered in the job. Submit cores taken from test panels and test them. Provide the same reinforcement as in the structure in at least one-half of the panel to test for proper embedment of reinforcing steel. Fabricate the test panels to the same thickness as the structure, but not less than 4 inches.

**PART 2 PRODUCTS**

**2.1 MATERIALS**

**A. Cementitious Materials: Portland cement, blended hydraulic cement, Portland cement in combination with pozzolan, slag cement, or Portland cement in combination with silica fume conforming to appropriate specifications listed below:**

1. Portland Cement:
  - a. Portland cement shall meet the requirements of ASTM C 150/C 150M Type I or II. Submit certificate of compliance with all specification requirements.

2. Pozzolan Other Than Silica Fume:
    - a. Pozzolans shall conform to ASTM C 618, Class C or F. Submit certificate of compliance for fly ash and other pozzolans with all specification requirements.
  3. Slag Cement:
    - a. Slag cement shall conform to ASTM C 989.
  4. Silica Fume:
    - a. Silica may be furnished as a dry, densified material or as a slurry. Silica fume, unprocessed, or before processing into a slurry or a densified material, shall conform to ASTM C 1240. Submit certificate of compliance for silica fume with all specification requirements.
- B. Aggregates
1. Submit Supplier's test reports for aggregates showing the materials meet the requirements of this specification.
- C. Water
1. Use fresh, clean, potable mixing water or non-potable water which meets the requirements of COE CRD-C 400.
- D. Curing Materials
1. Submit certificate of compliance for curing materials with all specification requirements. Curing materials shall meet the following requirements:
  2. Impervious Sheet Materials
    - a. ASTM C 171, type optional except polyethylene film, if used, shall be white opaque.
  3. Membrane-Forming Curing Compound
    - a. ASTM C 309, Type 1-D or Type 2.
- E. Reinforcement
1. Steel Fiber Reinforcement
    - a. Steel fiber reinforcement shall meet the requirements of ASTM A820/A820M. Submit certificate of compliance for fiber reinforcement with all specification requirements.
- F. Air Content
1. Air-entraining admixture shall be used in such proportion that the air content of the shotcrete prior to gunning shall be 5% plus or minus ( $\pm$ ) 1.0 % as determined by ASTM C231/C231M.
- G. Air Supply
1. Provide a supply of clean, dry air adequate for maintaining sufficient nozzle velocity for all parts of the work and, if required, for simultaneous operation of a suitable blowpipe for clearing away rebound.

## 2.2 MIXTURE PROPORTIONS

- A. Mixture proportions and test data from prior experience within 2 years, if available, may be submitted for approval. If test data from experience are not available or accepted, specimens shall be made and tested from mixtures having three or more different proportions. The recommended mixture proportions, sources of materials, and all test results shall be submitted for acceptance. Submit the recommended mixture proportions, sources of materials, and all test results, for approval.

## 2.3 EQUIPMENT

### A. Wet Mix Batching and Mixing

1. Batching and mixing shall be accomplished in accordance with the applicable provisions of ASTM C 94/C 94M. If volumetric batching and mixing are used, the materials shall be batched and mixed in accordance with the applicable provisions of ASTM C 685/C 685M. The mixing equipment shall be capable of thoroughly mixing the specified materials in sufficient quantity to maintain continuous placing. Ready-mix shotcrete complying with ASTM C 94/C 94M may be used.

### B. Delivery Equipment for Wet Mix

1. The equipment shall be capable of delivering the premixed materials accurately, uniformly, and continuously through the delivery hose. Recommendations of the equipment manufacturer shall be followed on the type and size of nozzle to be used and on cleaning, inspection, and maintenance of the equipment.

## **PART 3 EXECUTION**

### 3.1 PREPARATION OF SURFACES

#### A. Existing Concrete

1. All unsound and loose materials shall be removed by sandblasting, grinding, or high-pressure water jets before applying shotcrete. Any area to be repaired shall be chipped off or scarified to remove offsets which would cause an abrupt change in thickness without suitable reinforcement. Edges shall be tapered to leave no square shoulders at the perimeter of a cavity. The surface shall be dampened but without visible free water.

#### B. Rock

1. Rock surfaces shall be cleaned to remove loose or drummy material, mud, running water, and other foreign matter that will prevent bond of the shotcrete. The rock surface shall be dampened prior to placement of shotcrete.

#### C. Construction Joints

1. Unless otherwise specified, construction joints shall be tapered to a shallow edge form, about 1 inch thick. If non-tapered joints are specified, take special care to avoid or remove trapped rebound at the joint. The entire joint shall be thoroughly cleaned and wetted prior to the application of additional shotcrete.

### 3.2 PLACEMENT OF SHOTCRETE

#### A. General

1. Place shotcrete using suitable delivery equipment and procedures. The area to which shotcrete is to be applied shall be clean and free of rebound or overspray.

#### B. Placement Techniques

1. Placement Control
  - a. Thickness, method of support, air pressure, and water content of shotcrete shall be controlled to preclude sagging or sloughing off. Shotcreting shall be discontinued or suitable means shall be provided to screen the nozzle stream if wind or air currents cause separation of the nozzle stream during placement.

2. Corners
  - a. Horizontal and vertical corners and any area where rebound cannot escape or be blown free shall be filled first.
- C. Placement Around Reinforcement
  1. The nozzle shall be held at such distance and angle to place material behind reinforcement before any material is allowed to accumulate on the face of the reinforcement. In the dry-mix process, additional water may be added to the mixture when encasing reinforcement to facilitate a smooth flow of material behind the bars. Shotcrete shall not be placed through more than one layer of reinforcing steel rods or mesh in one application unless demonstrated by preconstruction tests that steel is properly encased.
- D. Cover of Reinforcement
  1. The minimum cover shall be 3 inches.
- E. Placement Precautions
  1. The following precautions shall be taken during placement.
    - a. Placement shall be stopped if drying or stiffening of the mixture takes place at any time prior to delivery to the nozzle.
    - b. Rebound or previously expended material shall not be used in the shotcrete mixture.

### 3.3 REPAIR OF DEFECTS

- A. Defects
  1. Defective areas larger than 48 square inches or 2 inches deep shall be removed and replaced with fresh shotcrete. These defects include honeycombing, lamination, dry patches, voids, or sand pockets. Defective areas shall be removed in accordance with the procedures described in paragraph EXISTING CONCRETE and replaced with fresh shotcrete.
    - a. Repairs
      - 1) All repairs shall be made within 1 week of the time the deficiency is discovered. All unacceptable materials shall be removed and repaired by the procedures described in the following two paragraphs. Voids and holes left by the removal of tie rods in all permanently exposed surfaces not to be backfilled and in surfaces to be exposed to water shall be reamed and completely filled with dry-patching mortar as specified below.
    - b. Minor Patching
      - 1) Minor patching may be accomplished with a dry-pack mixture, or with materials as approved by the Contracting Officer. Patches that exceed 0.1 cubic foot in volume shall receive a brush coat of approved epoxy resin meeting ASTM C 881/C 881M, Type II, as a prime coat. Care shall be taken not to spill epoxy or overcoat the repair surface so that the epoxy runs or is squeezed out onto the surface which will remain exposed to view. Epoxy resin shall be used in strict conformance with manufacturer's recommendations with special attention paid to pot life, safety, and thin film tack time.

- B. Core Holes
  - 1. Core holes shall not be repaired with shotcrete. Instead, they shall be filled solid with a dry-pack mixture after being cleaned and thoroughly dampened.

### 3.4 FINISHING

- A. Natural Gun Finish
  - 1. Unless otherwise specified, provide undisturbed final layer of shotcrete as applied from nozzle without hand finishing.
- B. Cutting Screed
  - 1. After the surface has taken its initial set (crumbling slightly when cut), excess material outside the forms and ground wires shall be sliced off with a downward cutting motion using a sharp-edged cutting screed.
- C. Flash Coat
  - 1. A thin coat of shotcrete containing finer sand applied from a distance greater than normal shall be applied to the surface as soon as possible after the screeding.
- D. Float and Trowel Finish
  - 1. Final surface finish shall be provided using steel trowel. Troweling of thin sections of shotcrete shall be avoided unless both troweling and commencement of moisture curing take place within a relatively short period after placement of shotcrete.
- E. Fiber-Reinforced Shotcrete
  - 1. Finish the outer surface of the structure with a layer of nonfiber-reinforced shotcrete and provide an appropriate finish as denoted.

### 3.5 CURING AND PROTECTION

- A. Initial Curing
  - 1. Immediately after finishing, shotcrete shall be kept continuously moist for at least 3 days. One of the following materials or methods shall be used:
    - a. Ponding or continuous sprinkling.
    - b. Absorptive mat or fabric, sand, or other covering kept continuously wet.
    - c. Curing Compounds:
      - 1) On natural gun or flash finishes, use the coverage application requirement of 100 square feet/gallon or twice the manufacturer's requirement, whichever is less. Curing compounds shall not be used on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded unless positive measures, such as sandblasting, are taken to completely remove curing compounds prior to the application of such additional materials.
- B. Final Curing
  - 1. Additional curing shall be provided immediately following the initial curing and before the shotcrete has dried. One of the following materials or methods shall be used:
    - a. Continue the method used in initial curing.
    - b. Application of impervious sheet material conforming to ASTM C 171.

- C. Formed Surface
  - 1. If forms are to be removed during curing period, one of the curing materials or methods listed in paragraph INITIAL CURING shall be used immediately. Such curing shall be continued for the remainder of the curing period.
- D. Duration of Curing
  - 1. Curing shall be continued for the first 7 days after shotcreting or until the specified compressive strength of the in-place shotcrete as determined by specimens obtained and tested in accordance with ASTM C 42/C 42M is achieved.
- E. Temperature Considerations
  - 1. The air temperature in contact with the shotcrete shall be continuously maintained at a temperature above 40° F for at least 3 days after placement. No shotcrete shall be applied when the concrete surface or air in contact with the concrete surface is below 40° F.

### 3.6 TESTS

- A. Strength Testing
  - 1. Test specimens shall be initially cured onsite, then shall be transported in an approved manner to an approved testing laboratory meeting the requirements of ASTM C 1077 within 48 hours of scheduled testing time.
    - a. Test Panel
      - 1) One test panel shall be made for every 50 cubic yards of shotcrete placed but not less than one per each shift during which any shotcrete is placed. Panels shall have minimum dimensions of 18 by 18 by 4 inches and shall be gunned in the same positions as the work represented during the course of the work by the Contractor's regular nozzleman. Panels shall be field cured in the same manner as in the job. Three 2-inch diameter cores shall be drilled from each panel at least 40 hours prior to testing and tested in accordance with ASTM C 1140.
    - b. Test Cores
      - 1) Test cores shall be drilled from the structure at least 40 hours prior to testing and tested in accordance with ASTM C 1140. A set of three cores shall be taken not less than once each shift that shotcrete is placed nor less than once for each 50 cubic yards of shotcrete placed through the nozzle. The diameter of core specimens shall be determined in accordance with ASTM C 42/C 42M.
    - c. Average Compressive Strength
      - 1) The compressive strength of the shotcrete shall be determined from the average of three cores obtained from a test panel representing a specific volume of shotcrete and tested on the 7th day after panel fabrication.
- B. Thickness
  - 1. The minimum shotcrete thickness shall be as shown in the drawings. The unhardened shotcrete shall be checked for thickness using a probe by the nozzleman or laborer at the time of placement. These thickness checks shall be at 15-minute intervals and all low or thin areas shall be corrected by applying additional shotcrete.

- C. Mixture Proportions
  - 1. Record and check mixture proportions at least once per shift for weigh batching. Record and check mixture proportions as recommended by ASTM C 685/C 685M at least once per shift for volumetric batching and continuous mixing plants.
- D. Preparations
  - 1. Prior to each placement of shotcrete, the Contractor's inspector shall certify in writing or by an approved checkout form that cleanup and preparations are in accordance with the plans and specifications.
- E. Air Content
  - 1. Air content tests shall be conducted on wet-mix shotcrete according to ASTM C231/C231M with a frequency of not less than once each shift nor less than once for each 50 cubic yards of shotcrete placed through the nozzle. Tests shall be conducted on samples taken as the wet shotcrete mixture is placed in the delivery equipment.

**END OF SECTION**