

SHOTCRETE

**\*\*From Rockingham IM 091-1(57)**

- xx. DESCRIPTION. This work shall consist of installing shotcrete buttresses in the faces of rock slopes at the locations shown in the Plans and as directed by the Engineer and Agency Geologist (Geologist).

The work includes high-angle installation to be completed using industrial rope access methods.

- xx. GENERAL. This method of rock support consists of pneumatically applied shotcrete and required reinforcing elements to construct permanent shotcrete buttresses.

All shotcrete shall comply with the requirements of ACI 506.2-95 except as specified otherwise herein. The Contractor shall core and test shotcrete panels and inspect all shotcrete and rock nails for shotcrete placement in accordance with ACI 506.4R-94.

All workers, including foreman, nozzle men, finishers, and delivery equipment operators shall be fully qualified to perform the work. Qualification of the nozzle men shall be based on the results of test panels as required herein, unless approved otherwise by the Engineer and Geologist.

The Engineer and Geologist will provide design for rock nails for shotcrete buttresses to the Contractor prior to construction. Reinforcement may include installation of rock dowels for support, and will use rock dowel bars.

- xx. APPLICABLE STANDARDS AND SPECIFICATIONS. The most recent versions of the cited standards and specifications shall be used to govern the quality of work and materials.

ASTM A 36	Standard Specification for Structural Steel
ASTM A 123	Zinc (Hot-Dip Galvanized) Coatings for Iron and Steel Products
ASTM A 153	Zinc Coating (Hot-Dip Galvanized) on Iron and Steel Hardware
ASTM A 185/AASHTO M 55M/M 55	Standard Test Method for Air Content of Hydraulic Cement Mortar
ASTM A 615/AASHTO M 31M/M 31	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A 820	Standard Specification for Steel Fibers for Fiber-Reinforced Concrete

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ASTM C 33	Standard Specification for Concrete Aggregates
ASTM C 42/AASHTO T 24	Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 94/AASHTO M 157	Standard Specification for Ready-Mixed Concrete
ASTM C 150	Standard Specification for Portland Cement
ASTM C 260/AASHTO M 154	Standard Specification for Air-Entrained Mixtures for Concrete
ASTM C 618/AASHTO M 285M/ Ash M M 285 Pozzolan for	Standard Specification for Coal Fly and Raw or Calcined Natural Use in Concrete
ASTM C 1240	Standard Specification for Silig Fume Used in Cementitious Mixtures
AASHTO M 80	Standard Specification for Coarse Aggregate for Hydraulic Cement Concrete
AASHTO M 148	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
AASHTO M 171	Standard Specification for Sheet Materials for Curing Concrete
AASHTO T 260	Standard Method of Test for Sampling and Testing for Chloride Ion in Concrete and Raw Materials
xx. <u>MATERIALS.</u>	Materials shall conform to the following requirements:
(a) <u>Cement.</u>	Cement shall conform to ASTM C 150, Type I.
(b) <u>Fine and Coarse Aggregate.</u>	Fine and coarse aggregate shall conform to ASTM C33/AASHTO M 6.
(c) <u>Combined Aggregate Gradation.</u>	Combined aggregate gradation shall conform to ACI 506 R-90(95).
(d) <u>Water.</u>	Water shall be potable, clean, and free from substances deleterious to concrete and steel, or that would cause staining.
(e) <u>Accelerator.</u>	Accelerator shall be the fluid and non-chloride type, applied at the nozzle, and meet the requirements specified herein.

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- (f) Water-Reducer and Superplasticizer. Water-reducer and superplasticizer shall conform to ASTM C 494/AASHTO M 194M/M 194, Type A, D, F, G.
- (g) Air-Entraining Agent. Air-entraining agent shall conform to ASTM C260/AASHTO M154.
- (h) Fly Ash. Fly ash shall conform to ASTM C 18/AASHTO M 295, Type F or G, with cement replacement up to 35% by weight of cement.
- (i) Silica Fume. Silica fume shall conform to ASTM C 1240, 90% minimum silicon dioxide solids content, not to exceed 12% by weight of cement.
- (j) Welded Wire Fabric. Welded wire fabric shall conform to ASTM A 185/AASHTO M 55M/M 55.
- (k) Rock Nails. Rock nails for shotcrete shall conform to ASTM A 615/AASHTO M 31M/M 31, Grade 75 (minimum). All rock nails for shotcrete details shall conform to ACI 315.
- (l) Curing Compound. Curing compound shall conform to AASHTO M 148, Type 1D or Type 2.
- (m) Film Protection. Film protection for curing shall conform to AASHTO M 171 or polyethylene film.
- (n) Steel Reinforcement. Steel fiber reinforcement shall conform to ASTM A 820 and consist of a deformed high strength, carbon steel fiber product. Steel fibers shall have a minimum ultimate tensile strength of 120,000 psi, with lengths between 1 inch and 1½ inches and an aspect ratio (length divided by minimum width or diameter) between 40 and 80.

Shotcrete admixtures shall not be used unless approved by the Engineer and Geologist. Admixtures used to entrain air, to reduce water-cement ratio, to retard or accelerate setting time, or to accelerate the development of strength, shall be thoroughly mixed into the shotcrete at the rate specified by the manufacturer, unless specified otherwise. Accelerating additives shall be compatible with the cement used, be non-corrosive to steel, and shall not promote other detrimental effects such as cracking or excessive shrinkage. The maximum allowable chloride ion content of all ingredients shall not exceed 0.10 percent when tested per AASHTO T 260.

Materials shall be delivered, stored, and handled to prevent contamination, segregation, corrosion, or damage. Liquid admixtures shall be stored to prevent evaporation and freezing.

Aggregates for shotcrete shall meet the strength and durability requirement of AASHTO M 80 and shall meet the following gradation requirements:

Sieve Size	Percent Passing by Weight	Sieve Size	Percent Passing by Weight
1/2 inch	100	No. 16	35-55
3/8 inch	90-100	No. 30	20-35
No. 4	70-85	No. 50	8-20
No. 8	50-70	No. 100	2-10

Cement content shall be a minimum of 600 lb/yd<sup>3</sup>. The water/cement ratio shall not be greater than 0.45.

Shotcrete shall be proportioned to attain a compressive strength of 2000 psi in 3 days, 2400 psi in 7 days, and 4000 psi in 28 days. The average compressive strength of each set of three cores extracted from test panels or wall face must be equal to or exceed 85%, with no individual core less than 75%, of the specified compressive strength in accordance with ACI 506.2. The boiled absorption of shotcrete, when tested in accordance with ASTM C 642 at 7 days, shall be less than 8%.

Aggregate and cement may be batched by weight or by volume in accordance with the requirements of ASTM C 94/AASHTO M 157. Mixing equipment shall be capable of thoroughly mixing the materials in sufficient quantity to maintain placing continuity. Ready-mix shotcrete shall be delivered and placed within 1 ½ hours of the batch time unless approved otherwise by the Engineer and Geologist.

Shotcrete should not be applied when ambient, substrate, and material temperatures are below 40°F or above 95°F, or during rainfall events. Shotcrete can be applied under a heated and covered work area, as approved by the Engineer and Geologist.

xx. SUBMITTALS.

(a) Qualifications. Not less than two weeks prior to beginning installation of shotcrete buttresses, the Contractor shall provide qualifications of Contractor's personnel in writing to the Engineer and Geologist. The shotcrete nozzleman shall have a minimum of five years of demonstrated experience in the installation of shotcrete. The shotcrete finishers and delivery equipment operators shall have a minimum of two years of demonstrated experience.

(b) Work Plan. Not less than two weeks prior to beginning installation of shotcrete buttresses, the Contractor shall submit a detailed work plan for the shotcrete buttresses. The plan shall include:

- (1) The proposed construction sequence and schedule.
- (2) The proposed rope access methods and safety plan.
- (3) The proposed shotcrete product specifications and material testing/data sheets.

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- (4) The proposed steel reinforcement, including rock nails for shotcrete used to support the buttresses during curing.
- (5) The proposed shotcrete application and curing methods, including alignment control, surface preparation, delivery/application, rock nails for shotcrete, and finishing methods.

Work shall not begin until the submittals have been approved in writing by the Engineer and Geologist.

- (c) Field Reports. The Contractor shall submit a field report on a daily basis to the Engineer and Geologist for approval. The field report shall include the location of the shotcrete buttress, rock nails for shotcrete installed (type and amount), and volume of shotcrete applied (in cubic yards).

- xx. TEST PANEL. One shotcrete test panel will be required. The test panel shall not be disturbed or moved within the first 24 hours after shooting. The test panel shall be field cured under conditions similar to those anticipated for the work. Shotcreting and coring of the test panel shall be performed by qualified personnel in the presence of the Engineer and Geologist. The Contractor shall notify the Engineer and Geologist not less than 2 days prior to the shooting of the test panel.

Preconstruction test panels shall be 30 inches x 30 inches (minimum) in accordance with ACI 506.2-95 and the following:

- (a) The test panel shall be unreinforced, at least 6 inches thick and used for absorption and compressive strength testing.
- (b) The sides of the test panel shall be chamfered outward at 45 degrees over the full thickness of the panel.

Shotcrete will be accepted based on the 7-day strength of cores taken from the test panel. The frequency specified for test panels is approximate. A greater number of panels may be required by the Engineer and Geologist.

A minimum of nine cores shall be cut from the test panel for compressive strength and absorption testing. The cores shall be soaked in water for at least 40 hours in accordance with AASHTO T 24 or ACI 506.2. Cores shall be at least 3 inches in diameter and shall have a minimum length to diameter ratio of one. When the length of a core is less than twice the diameter, apply the correction factors given in ASTM C 42 to obtain the compressive strength of individual cores. Three cores shall be tested for compressive strength at 7 days, and three cores shall be tested for compressive strength at 28 days. Three core samples shall be tested at 7 days for absorption in accordance with ASTM C 642.

- xx. EXECUTION OF PRODUCTION SHOTCRETE WORK.

- (a) Surface Preparation. Prior to shotcreting the ungrouted zone above the rock dowel grout at the bedrock face (birds beak), the Contractor shall remove all loose materials from the surface of the grout.

The Contractor shall remove all loose materials and loose dried shotcrete from previous placement operations and from all receiving surfaces by methods acceptable to the Engineer and Geologist. The removal shall be accomplished in such a manner as not to loosen, crack, or shatter the surfaces to receive the shotcrete. Any surface material that, in the opinion of the Engineer and Geologist is so loosened or damaged shall be removed to sufficient depth to provide a base that is suitable to receive the shotcrete. Material that loosens as the shotcrete is applied shall be removed. Shotcrete shall not be placed on frozen surfaces.

- (b) Delivery and Application. A clean, dry, oil-free supply of compressed air sufficient for maintaining adequate nozzle velocity for all parts of the work and for simultaneous operation of a blow pipe for cleaning away rebound shall be maintained at all times. The equipment shall be capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose.

The shotcrete shall be applied from the lower part of the work area upwards to prevent accumulation of rebound on uncovered surfaces. Thickness, methods of support, air pressure, and rate of placement of shotcrete shall be controlled to prevent sagging or sloughing of freshly applied shotcrete. Where shotcrete is used to fill the bird's beak, the nozzle shall be positioned into the mouth of the drill hole to completely fill the void. Rebound shall not be worked back into the placement nor shall the rebound be salvaged. Rebound that does not fall clear of the working area shall be removed. The nozzle shall be held at a distance and at an angle approximately perpendicular to the working face so that rebound will be minimal and compaction will be maximized. The nozzle should be rotated steadily in a small circular pattern.

Shotcrete placement shall be by the bench gunning method when the thickness of the shotcrete layer is 6 inches or greater. The gunning method shall consist of building up a thick layer of shotcrete from the bottom of the lift and maintaining the top surface at approximately a 45 degree slope.

- (c) Visual Observation. The shotcreting procedure may be corrected by adjusting the nozzle distance and orientation perpendicular to the surface, adjusting the water content of the shotcrete mix, or other means acceptable to the Engineer and Geologist. All overspray and rebound shall be removed from the surface.

Surface defects shall be repaired as soon as possible after initial placement of shotcrete. All shotcrete that lacks uniformity, exhibits segregation, sagging, honeycombing, or lamination, or contains any voids or sand pockets, shall be removed and replaced with fresh shotcrete by the Contractor to the satisfaction of the Engineer and Geologist.

- (d) Attachment of Rock Dowel Head Connection Hardware. For bearing plate connections, the plate shall be wet-set while the shotcrete is plastic to ensure full shotcrete bearing behind the plate. However, the retention nut shall only be hand tightened such that full bearing is achieved without excessively squeezing fresh shotcrete out from under the plate.

For embedded plate connections, the embedments shall be located within the shotcrete such that the proper shotcrete cover is provided as shown on the Plans. In addition, the plate, washer, and nut shall be pulled up flush together by wiring to the reinforcement or other means necessary to ensure adequate contact between these parts.

- (e) Finishing and Curing Requirements. The shotcrete shall be protected from loss of moisture for at least 7 days after placement. When shotcrete is being protected from low temperatures, curing shall be terminated no sooner than one day after the removal of low temperature protection. Curing of shotcrete shall be by methods that will keep shotcrete surfaces adequately wet and protected during the specified period. Curing shall commence within one hour of shotcrete application. When the ambient temperature exceeds 80°F, the Contractor shall plan the work such that curing can commence immediately after finishing. The curing shall be completed using water, membrane, or film curing methods in accordance with the following requirements:

- (1) For water curing, the rate of water application shall be regulated to provide complete surface coverage with a minimum of runoff.
- (2) For membrane curing, curing compounds shall not be used on any surfaces against which additional shotcrete or other finishing materials are to be bonded, unless the surface is sandblasted in a manner acceptable to the Engineer and Geologist. Membrane curing compounds shall be spray applied as quickly as practical after initial shotcrete set at a coverage rate of not less than 40 ft<sup>2</sup>/gal.
- (3) For film curing, polyethylene sheeting may be used to supplement water curing on shotcrete that will be covered later with additional shotcrete or concrete. The sheeting shall completely cover all surfaces, and have edges overlapped for proper sealing and anchorages.

- (f) Weather Limitations. Unless adequately protected, shotcrete shall not be placed in cold weather when the ambient temperature is below 40°F and falling, as measured on site with a thermometer, and/or when the shotcrete is likely to be subjected to freezing temperatures before reaching a minimum strength of 750 psi. Cold weather protection shall be maintained until the strength of the shotcrete is greater than 750 psi. Cold weather protection shall include heating under tents, blankets, or other means acceptable to the Engineer and Geologist. The temperature of the shotcrete when placed shall be not less than 50°F and not more than 80°F. The air in contact with shotcrete surfaces shall be maintained at temperatures above 32°F for a minimum of 7 days, or as authorized by the Engineer and Geologist. The Contractor shall monitor local weather conditions and forecasts issued for the project site area, such as those issued at nearby airports. The Contractor shall note that weather and temperature conditions may vary, and ambient air temperatures may vary by 5 to 10°F up or down at the project site as compared to nearby weather stations.

Shotcrete application shall also be suspended during high winds and heavy rains when in the opinion of the Engineer and Geologist the quality of the application is not acceptable. Newly-placed shotcrete exposed to rain that washes out cement, or otherwise makes the shotcrete unacceptable to the Engineer and Geologist, shall be removed and replaced. The Contractor shall provide adequately secured polyethylene sheeting or equivalent when adverse exposure to weather is anticipated.

- xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Shotcrete) to be measured for payment will be the number of cubic meters (cubic yards) placed in the complete and accepted work.

The quantity of Special Provision (Rock Nail for Shotcrete) to be measured for payment will be the number of meters (linear feet) of rock nail placed in the complete and accepted work.

- xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Shotcrete) will be paid for at the Contract unit price per cubic meter (cubic yard). Payment will be full compensation for placing the material specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Special Provision (Rock Nail for Shotcrete) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for furnishing, drilling, installing, and grouting the rock nail, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for preparing and making required submittals will not be made separately, but will considered incidental to the work under this Section.

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Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.608 Special Provision (Shotcrete)	Cubic Meter (Cubic Yard)
900.640 Special Provision (Rock Nail for Shotcrete)	Meter (Linear Foot)