

TECHNICAL SPECIFICATIONS
FOR
PERMANENT SHOTCRETE FACING AND WALL DRAINAGE

1. Description

Shotcrete facing and wall drainage work consists of furnishing all materials and labor required for placing and securing geocomposite drainage material, connection pipes, footing drains, weepholes and horizontal drains, drainage ditch behind shotcrete wall, reinforcing steel and shotcrete for the permanent shotcrete facing and nail head bearing plates and nuts for the soil nail walls shown on the Plans. The Work shall include any preparatory trimming and cleaning of soil/rock surfaces and shotcrete cold joints to receive new shotcrete.

2. Materials

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

- a) Cement: All cement shall conform to ASTM C 150/AASHTO M85, Types I, II, III or V.
- b) Aggregates: Aggregate for shotcrete shall meet the strength and durability requirements of AASHTO M6/M80 and the following gradation requirements:

Sieve Size	Percent Passing by Weight
12.5 mm	100
9.50 mm	90-100
4.75 mm	70-85
2.36 mm	50-70
1.18 mm	35-55
0.60 mm	20-35
0.30 mm	8-20
0.15 mm	2-10

Fine aggregate shall conform to the requirements of AASHTO M6/ASTM C33 clean, natural.

Coarse aggregate shall conform to the requirements of AASHTO M80, Class B for quality.

- c) Water: AASHTO M157/ASTM C94, clean and potable.
- d) Admixtures: Do not use admixtures unless approved by the Engineer. Thoroughly mix admixtures into the shotcrete at the rate specified by the manufacturer. Accelerators (if used) shall be compatible with the cement used, be non-corrosive to steel and 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% when tested to AASHTO T260.

1. Chemical Admixtures
 - a. Accelerator: Shall be fluid type, applied at nozzle, and meet the requirements of AASHTO M194/ASTM C494/ASTM C1141.
 - b. Air-Entraining Agent: AASHTO M154/ASTM C260
 - c. Water-reducer and Superplasticizer: AASHTO M194/ASTM C494 Type A, C, D, E, F, or G
 - d. Retarders: AASHTO M194/ASTM C494 Type B or D
2. Mineral Admixtures
 - a. Fly Ash: AASHTO M295/ASTM C618 Type F or C, cement replacement up to 35 percent by weight of cement.
 - b. Silica Fume: ASTM C1240, 90 percent minimum silicon dioxide solids content, not to exceed 12 percent by weight of cement.
- e) Welded Wire Fabric: AASHTO M55/ASTM A185 or A497
- f) Reinforcing Bars for Shotcrete Facing: AASHTO M31/ASTM A615, Grade 420, deformed.
- g) Bearing Plates: AASHTO M183/ASTM A36
- h) Nuts: AASHTO M291, Grade B, hexagonal, fitted with beveled washer or spherical seat to provide uniform bearing.
- i) Curing Compounds: AASHTO M148, Type 1D or Type 2
- j) Prepackaged Shotcrete: ASTM C928
- k) Drainage Geotextile: Drainage geotextile shall be provided in rolls wrapped with a protective covering and stored in a manner which protects the fabric from mud, dirt, dust, debris, and shotcrete rebound. Protective wrapping shall not be removed until immediately before the geotextile is installed. Extended exposure to ultra-violet light shall be avoided. Each roll of geotextile in the shipment shall be labeled to identify the production run.
 1. For Wall Footing Drain: AASHTO M288 Class 2, Permittivity minimum 0.2 per second; AOS 0.25 mm maximum.
 2. For Drain Strip: AASHTO M288 Class 3, Permittivity minimum 0.2 per second; AOS 0.25 mm maximum.
- l) Drainage Aggregate: AASHTO M43/ASTM C33 No. 67 with no more than two percent passing the 0.075 mm sieve.
- m) Geocomposite Drain Strip: Geocomposite drain strips shall be provided in rolls wrapped with a protective covering and stored in a manner which protects the fabric from mud, dirt, dust, debris, and shotcrete rebound. Protective wrapping shall not be removed until immediately before the drain strip is installed. Extended exposure to ultra-violet light shall be avoided. Each roll of drain strip in the shipment shall be labeled to identify the production run.
Miradrain 6000, Amerdrain 500 or approved equal.
- n) Film Protection: Polyethylene films per AASHTO M-171.

- o) PVC Connector and Drain Pipes
 - 1. Pipe: ASTM 1785 Schedule 40 PVC, solid and perforated wall, cell classification 12454-B or 12354-C, wall thickness SDR 35, with solvent weld or elastomeric gasket joints.
 - 2. Fittings: ASTM D3034, cell classification 12454-B or 12454-C, wall thickness SDR35, with solvent weld or elastomeric gasket joints.
- p) Solvent Cement: ASTM D2564
- q) Primer: ASTM F656

3. Shotcrete Mix Design

The Contractor must receive notification from the Engineer that the proposed mix design and method of placement are acceptable before shotcrete placement can begin.

- a) Proportioning

Proportion the shotcrete to be pumpable with the concrete pump furnished for the work, with a cementing materials content of at least 650 pounds per cubic yard and water/cement ratio not greater than 0.45.
- b) Air Entrainment

Air entrainment is required for wet-mix shotcrete. The air content measured at the truck shall be between 7 to 10 percent when tested in accordance with AASHTO T152/ASTM C231. Air entrainment is not required in dry-mix shotcrete.
- c) Strength and Durability Requirements

Provide a shotcrete mix capable of attaining 2000 psi compressive strength in 3 days and 4000 psi in 28 days. The average compressive strength of each set of three test cores extracted from test panels or wall face must equal or exceed 85 percent of specified compressive strength, with no individual core less than 75 percent of the specified compressive strength, in accordance with ACI 506.2. The boiled absorption of shotcrete, when tested in accordance with ASTM C642 at 7 days, shall not exceed 8.0 percent.
- d) Mixing and Batching

Aggregate and cement may be batched by weight or by volume in accordance with the requirements of ASTM C94 or AASHTO M241/ASTM C685. Mixing equipment shall thoroughly blend the materials in sufficient quantity to maintain placing continuity. Ready mix shotcrete shall comply with AASHTO M157. Shotcrete shall be batched, delivered, and placed within 90 minutes of mixing. The use of retarding admixtures may extend application time beyond 90 minutes if approved by the Engineer.

Premixed and packaged shotcrete mix may be provided for on-site mixing. The packages shall contain materials conforming to the Materials section of this specification. Placing time limit after mixing shall be per the manufacturers' recommendations.

4. Field Quality Control

Both preconstruction test panels (for nozzlemen without previous ACI certification) and production test panels or test cores from the wall facing are required. Qualified personnel in the presence of the Engineer shall perform Shotcreting and coring of test panels. The Contractor shall provide equipment, materials, and personnel as necessary to obtain shotcrete cores for testing including construction of test panel boxes, field curing requirements and coring. Compressive strength testing will be performed by the Engineer. Shotcrete final acceptance will be based on the 28-day strength.

Shotcrete production work may commence upon initial approval of the design mix and nozzlemen and continue if the specified strengths are obtained. The shotcrete work by a crew will be suspended if the test results for their work do not satisfy the strength requirements. The Contractor shall change all or some of the following: the mix, the crew, the equipment, or the procedures. Before resuming work, the crew must shoot additional test panels and demonstrate that the shotcrete in the panels satisfies the specified strength requirements. The cost of all work required to obtain satisfactory strength tests will be borne by the Contractor.

a) Preconstruction Test Panels

Each nozzleman without previous ACI certification shall furnish at least two preconstruction test panels for each proposed mixture being considered and for each shooting position to be encountered on the job. Preconstruction test panels shall be made prior to the commencement of production work using the same equipment, materials, mixture proportions and procedures proposed for the job.

Make preconstruction test panels with minimum dimensions of 2.5 feet square and at least 4 inches thick. Slope the sides of preconstruction and production test panels at 45 degrees over the full panel thickness to release rebound. One preconstruction test panel shall include the maximum anticipated reinforcing congestion shown on the Plans. Cores extracted from the test panel shall demonstrate encapsulation of the reinforcement in accordance with ACI 506.2 equal to core grade 2 or better. The other preconstruction test panel shall be constructed without reinforcement and have cores extracted for absorption and compressive strength testing.

b) Production Test Panels

Furnish at least one production test panel or, in lieu of production test panels, nine 3-inch diameter cores taken from the shotcrete facing, during the first production application of shotcrete and henceforth for every 5000 ft² of shotcrete placed. Construct the production test panels simultaneously with the shotcrete facing installation at times designated by the Engineer. Make production test panels with minimum full thickness dimensions of 1.5 feet square and at least 4 inches thick.

c) Test Panel Curing, Test Specimen Extraction and Testing

Immediately after shooting, field moist cure the test panels by covering and tightly wrapping with a sheet of material meeting the requirements of ASTM C171 until they are delivered to the testing lab or test specimens are extracted. Do not immerse the test panels in water. Do not further disturb test panels for the first 24 hours after shooting. Provide at least three 3-inch diameter core samples cut from each preconstruction test panel with reinforcement, for core grading. Provide

at least nine 3-inch diameter core samples cut from each unreinforced preconstruction and production test panel for absorption and compressive strength testing. Contractor has the option of extracting test specimens from test panels in the field or transporting to another location for extraction. Keep panels in their forms when transported. Do not take cores from the outer 6 inches of test panels measured in from the top outside edges of the panel form. Trim the ends of the compressive strength cores to provide test cylinders at least 3 inches long. Do not trim the ends of the cores to be tested for boiled absorption. If the Contractor chooses to take cores from the wall face in lieu of making production test panels, the Engineer will designate locations. Clearly mark the cores and container to identify the core locations and whether they are for preconstruction or production testing. If for production testing, mark the section of the wall represented by the cores on the cores and container. Immediately wrap cores in wet burlap or material meeting the requirements of ASTM C171 and seal in a plastic bag. Deliver cores to the testing lab within 48 hours of shooting the panels. The remainder of the panels will become the property of the Contractor. The Contractor shall perform compressive strength and boiled absorption tests. Upon delivery to the testing lab, samples will be placed in the moist room until the time of test. When the test length of a core is less than twice the diameter, the correction factors given in AASHTO T24/ASTM C42 will be applied to obtain the compressive strength of individual cores. Three cores will be tested at 3 days and three cores will be tested at 28 days for compressive strength per AASHTO T24/ASTM C42. Three cores will be tested at 7 days for boiled absorption per ASTM C642.

Fill core holes in the wall by dry packing with non-shrink patching mortar after the holes are cleaned and dampened. Do not fill core holes with shotcrete.

5. Construction Requirements

a) Wall Drainage Network

Install and secure all elements of the wall drainage network as shown on the Plans, specified herein, or as required by the Engineer to suit the site conditions. The drainage network shall consist of installing geocomposite drain strips, PVC connection pipes and wall footing drains as shown on the Plans or as directed by the Engineer. Exclusive of the wall footing drains, all elements of the drainage network shall be installed prior to shotcreting.

Unanticipated subsurface drainage features exposed in the excavation cut face shall be captured independently of the wall drainage network and shall be mitigated prior to shotcrete application. Costs due to the required mitigation will be paid for as Extra Work.

1. Geocomposite Drain Strips

Install geocomposite drain strips centered between the columns of nails as shown on the Plans. The drain strips shall be at least 12 inches wide and placed with the geotextile side against the ground. Secure the strips to the excavation face and prevent shotcrete from contaminating the groundside of the geotextile. Drain strips will be continuous. Splices shall be made with a 1-foot minimum overlap such that the flow of water is not impeded.

Repair damage to the geocomposite drain strip, which may interrupt the flow of water.

2. Footing Drains

Install footing drains at the bottom of each wall as shown on the Plans. The drainage geotextile shall envelope the footing drain aggregate and pipe and conform to the dimensions of the trench. Overlap the drainage geotextile on top of the drainage aggregate as shown on the Plans. Replace or repair damaged or defective drainage geotextile.

3. Connection Pipes and Weepholes

Install connection pipes as shown on the Plans. Connection pipes are lengths of solid PVC pipe installed to direct water from the geocomposite drain strips into a footing drain or to the exposed face of the wall. Connect the connection pipes to the drain strips using either prefabricated drain grates as shown on the Plans or using the alternate connection method described below. Install the drain grate per the manufacturer's recommendations. The joint between the drain grate and the drain strip and the discharge end of the connector pipe shall be sealed to prevent shotcrete intrusion. Connection pipes that end at the footing drain shall be extended to the edge of the drain. Do not puncture the drainage fabric around the footing drain.

The alternative acceptable method for connection of the connector pipe to the drain strip involves cutting a hole slightly larger than the diameter of the pipe into the strip plastic core but not through the geotextile. Wrap both ends of the connection pipe in geotextile in a manner that prevents migration of fines through the pipe. Tape or seal the inlet end of the pipe where it penetrates the drain strip and the discharge end of the connector pipe in a manner that prevents penetration of shotcrete into the drain strip or pipe. To assure passage of groundwater from the drain strip into the connector pipe, slot the inlet end of the connector pipe at every 45 degrees around the perimeter of the pipe to a depth of 6 mm.

Weepholes, if required, shall be provided through the shotcrete facing to drain water from behind the facing. Install as shown on the Plans. Use PVC pipe to form the weephole through the shotcrete. Cover the end of the pipe contacting the soil with a drainage geotextile. Prevent shotcrete intrusion into the discharge end of the pipe.

b) Permanent Shotcrete Facing

1. Shotcrete Alignment and Thickness Control

Ensure that the thickness of shotcrete satisfies the minimum requirements shown on the Plans using shooting wires, thickness control pins, or other devices acceptable to the Engineer. Install thickness control devices normal to the surface such that they protrude the required shotcrete thickness outside the surface and maintain a plane surface. The maximum distance between the wires on any surface shall be equal to the vertical nail spacing. Ensure that the alignment wires are tight, true to line, and placed to allow further tightening. Remove shooting wires after

completion of shotcreting and/or screeding. Ensure that the front face of the shotcrete does not extend beyond the limits shown on the Plans.

2. Surface Preparation

Clean the face of the excavation and other surfaces to be shotcreted of loose materials, mud, rebound, overspray or other foreign matter that could prevent or reduce shotcrete bond. Protect adjacent surfaces from overspray during shooting. Avoid loosening, cracking, or shattering the ground during excavation and cleaning. Remove any surface material that is so loosened or damaged, to a sufficient depth to provide a base that is suitable to receive the shotcrete. Remove material that loosens as the shotcrete is applied. Cost of additional shotcrete is incidental to the work. Divert water flow and remove standing water so that shotcrete placement will not be detrimentally affected by standing water. Do not place shotcrete on frozen surfaces.

3. Delivery and Applications

Maintain at all times a clean, dry, oil-free supply of compressed air sufficient for maintaining adequate nozzle velocity and for simultaneous operation of a blowpipe for cleaning away rebound. The equipment shall be capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose. Control shotcrete application thickness, nozzle technique, air pressure, and rate of shotcrete placement to prevent sagging or sloughing of freshly applied shotcrete.

Apply the shotcrete from the lower part of the area upwards to prevent accumulation of rebound. Orient nozzle at a distance and approximately perpendicular to the working face so that rebound will be minimal and compaction will be maximized. Pay special attention to encapsulating reinforcement. Care shall be taken while encasing reinforcing steel and mesh to keep the front face of the reinforcement clean during shooting operations, so that shotcrete builds up from behind, to encase the reinforcement and prevent voids and sand pockets from forming. Use a blowpipe to remove rebound and overspray immediately ahead of the nozzle. Do not work rebound back into the construction. Remove rebound that does not fall clear of the working area. Hardened rebound and hardened overspray shall be removed prior to application of additional shotcrete, using abrasive blast cleaning, chipping hammers, high pressure water blasting or other suitable techniques. When the thickness of an individual shotcrete layer is 6 inches or greater, or when shotcreting is conducted through two curtains of reinforcement, place shotcrete by the bench gunning method. The bench 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. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, position the nozzle into the mouth of the drillhole to completely fill the void.

A clearly defined pattern of continuous horizontal or vertical ridges or depressions at the reinforcing elements after they are covered with

shotcrete will be considered an indication of insufficient reinforcement cover or poor nozzle techniques. In this case the application of shotcrete shall be immediately suspended and the Contractor shall implement corrective measures before resuming the shotcrete operations. The shotcreting procedure may be corrected by adjusting the nozzle distance and orientation, by insuring adequate cover over the reinforcement, by adjusting the water content of the shotcrete mix or other means. Adjustment in water content of wet-mix will require requalifying the shotcrete mix.

When using multiple layer shotcrete construction, the surface of the receiving layer shall be prepared before application of a subsequent layer, by either: (a) Brooming the stiffening layer with a stiff bristle broom to remove all loose material, rebound, overspray or glaze, prior to the shotcrete attaining initial set: or (b) If the shotcrete has set, surface preparation shall be delayed at least 24 hours, at which time the surface shall be prepared by sandblasting or high pressure water blasting, to remove all loose material, rebound, hardened overspray, glaze, or other material that may prevent adequate bond.

4. Defective Shotcrete

The Engineer shall have authority to accept or reject the shotcrete work. Shotcrete that does not conform to the project Specifications may be rejected either during the shotcrete application process, or on the basis of tests on the test panels or completed work. Repair shotcrete surface defects as soon as possible after placement. Remove and replace shotcrete that exhibits segregation, honeycombing, lamination, voids, or sand pockets. In-place shotcrete determined not to meet the specified strength requirement will be subject to remediation as determined by the Engineer. Possible remediation options include placement of additional shotcrete thickness or removal and replacement, at the Contractor's cost.

5. Construction Joints

Taper construction joints uniformly toward the excavation face over a minimum distance equal to the thickness of the shotcrete layer. Square joints are not permitted. The surface of the joints shall be rough, clean, and sound. Provide a minimum reinforcement overlap at reinforcement splice joints as shown on the Plans. Clean and wet the surface of a joint before adjacent shotcrete is applied. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, to the maximum extent practical, clean and dampen the upper grout surface to receive shotcrete, similar to a construction joint.

6. Final Face Finish

Shotcrete finish shall be either an undisturbed gun finish as applied from the nozzle or a rod, broom, wood float, rubber float, steel trowel or rough screeded finish as shown on the Plans or specified herein.

7. Attachment of Nail Head Bearing Plate and Nut

Attach a bearing plate and nut to each nail head as shown on the Plans. While the shotcrete is still plastic and before its initial set, uniformly seat the plate on the shotcrete by hand wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, set the plate in a bed of grout. After grout has set for 24 hours, hand wrench tighten the nut. Embed the bearing plate and nut in the wall as shown on the Plans. Ensure full shotcrete encapsulation of the bearing plate and nut free of any voids or pockets behind the plate. Ensure bearing plates with headed studs are located within the tolerances shown on the Plans or specified herein.

8. Weather Limitations

Protect the shotcrete if it must be placed when the ambient temperature is below 5°C and falling or when it is likely to be subjected to freezing temperatures before gaining sufficient strength. Maintain cold weather protection until the in-place compressive strength of the shotcrete is greater than 750 psi. Cold weather protection includes blankets, heating under tents, or other means acceptable to the Engineer. The temperature of the shotcrete mix, when deposited, shall be not less than 10° C or more than 35° C. Maintain the air in contact with shotcrete surfaces at temperatures above 0° C for a minimum of 7 days shall.

If the prevailing ambient conditions (relative humidity, wind speed, air temperature and direct exposure to sunlight) are such that the shotcrete develops plastic shrinkage and/or early drying shrinkage cracking, shotcrete application shall be suspended. The Contractor shall: (a) reschedule the work to a time when more favorable ambient conditions prevail; and/or (b) adopt corrective measures, such as installation of sun-screens, wind breaks or fogging devices, to protect the work. Remove and replace newly placed shotcrete exposed to rain that washes out cement or otherwise makes the shotcrete unacceptable.

a. Curing

Protect permanent shotcrete from loss of moisture for at least 7 days after placement. Cure shotcrete by methods that will keep the shotcrete surfaces adequately wet and protected during the specified curing period. Commence curing within 1 hour of shotcrete application. When the ambient temperature exceeds 27° C, plan the Work such that curing can commence immediately after finishing. Complete curing in accordance with the following requirements.

b. Water Curing

Regulate the rate of water application to keep the surface continuously wet and to provide complete surface coverage with a minimum of runoff. The use of intermittent wetting procedures that allow the shotcrete to undergo wetting and drying during the curing period is prohibited.

c. Membrane Curing

Do not use curing compounds on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded unless the surface is thoroughly sandblasted in a manner acceptable to the Engineer. Membrane curing compounds are to be spray applied as quickly as practical after initial shotcrete set at a coverage of not less than 2.5 m²/liter.

d. Film Curing

Film curing with polyethylene sheeting may be used to supplement water curing on shotcrete that will be covered later with additional shotcrete or concrete. Spray the shotcrete surface with water immediately prior to installation of the polyethylene sheeting. Polyethylene sheeting shall completely cover the surfaces. Overlap the sheeting edges for proper sealing and anchorage. Joints between sheets shall be sealed. Promptly repair any tears, holes, and other damage. Anchor sheeting as necessary to prevent billowing.

9. Permanent Shotcrete Facing Tolerances

Construction tolerances for the permanent shotcrete facing are as follows:

Horizontal Location of Wire Mesh; Rebar; Headed Studs on Bearing Plates, from Plan location; + or - 5/8 inches

Headed studs location on bearing plate, from plan location: 1/4 inch

Spacing between reinforcing bars, from plan dimension: 1 inch

Reinforcing lap, from specified dimension: - 1 inch

Complete thickness of shotcrete, from plan dimension:

If troweled or screeded: - 1/2 inch

If left as shot: - 1 inch

Planeness of finish face surface-gap under 10 foot straightedge-any direction:

If troweled or screeded: 1/2 inch

If left as shot: 1 inch

Nail head bearing plate, deviation from parallel to wall face: 10 degrees

c) Backfilling Behind Wall Facing Upper Cantilever

Compact backfill within 3 feet behind the wall facing upper cantilever using light mechanical tampers.

d) Safety Requirements

Nozzlemen and helpers shall be equipped with gloves, eye protection, and adequate protective clothing during the application of shotcrete. The Contractor is responsible for meeting all federal, state and local safety code requirements.

6. Method of Measurement

The shotcrete facing will be measured in square feet of the shotcrete area completed and accepted in the final work. The net area lying in a plane of the outside front face of the structure as shown on the Plans will be measured. No measurement or payment will be made for additional shotcrete or Shotcrete permanent facing needed to fill voids created by irregularities in the cut face, excavation overbreak or inadvertent excavation beyond the plan final wall face excavation line, or failure to construct the facing to the specified line and grade and tolerances. The final pay quantity shall include all structural shotcrete, admixtures, reinforcement, welded wire mesh, wire holding devices, wall drainage materials, bearing plates and nuts, test panels and all sampling, testing and reporting required by the Plans and this Specification. The final pay quantity shall be the design quantity increased or decreased by any changes authorized by the Engineer.

7. Basis of Payment

- a) The accepted quantity measured as provided above will be paid for at the Contract unit price per square foot.
- b) Payment will be full compensation for furnishing all equipment, materials, labor, tools and incidentals necessary to complete the work as specified and as detailed on the Plans, including the work required to provide the proper shotcrete facing alignment and thickness control.
- c) All wall drainage materials including geocomposite drain strips, connection pipes, drain grates, drain aggregate and geotextile, fittings, and accessories are considered incidental to the shotcrete facing and will not be paid separately.