SECTION 628 - SHOTCRETE

628.01 Description. This section describes furnishing and placing shotcrete (pneumatically applied mortar) for lining ditches and channels, paving slopes, constructing portions of structures, texturing concrete surfaces, encasing steel members, and other miscellaneous work. Shotcrete consists of pneumatically applied mortar using either the dry-mix or wet-mix process.

628.02 Materials.

Structural Concrete 601

Portland Cement 701.01

Welded Wire Fabric Reinforcement 709.01(C)

Water 712.01

Use fine aggregate conforming to Subsection 703.01 - Fine Aggregate for Concrete, except maximum percentage for material passing the No. 100 sieve shall be 15 percent. Use fine aggregate with minimum sand equivalent of 60.

If admixtures are proposed, submit type, quantity, and manner of admixture incorporation.

628.03 Construction. Use shotcrete only at locations indicated in the contract documents or ordered by the Engineer.

(A) Proportioning, Batching, and Mixing. Submit proposed mix design three weeks prior to start of work. Batch the quantity of water as specified in mix design accepted by the Engineer for the process used. Proportion mortar ingredients, except water, either by volume or by weight.

Batches requiring fractional sacks will not be allowed unless cement is weighed. Use mixtures within time requirements as specified in Section 601 - Structural Concrete.

(1) Dry-Mix Process. Thoroughly mix cement and fine aggregate before charging into delivery equipment. Maintain moisture content of fine aggregate between 3 to 6 percent, such that fine aggregate-cement mixture flows at a uniform rate (without slugs) through delivery hose.
(2) **Wet-Mix Process.** Mix material at central mixing plant or at project site. If mixing is done at project site, use mixer capable of thoroughly mixing specified materials in sufficient quantity to maintain continuous shotcrete placement.

**(B) Shotcrete Process - General.** Use either dry-mix or wet-mix shotcrete process as follows:

(1) **Dry-Mix Process.**

(a) Mix cement and fine aggregates thoroughly.

(b) Feed cement-fine aggregate mixture into special mechanical feeder (gun) or other delivery equipment accepted by the Engineer.

(c) Meter mixture into delivery hose by feed wheel or distributor.

(d) Convey mixture by compressed air through delivery hose to special nozzle. Fit nozzle with perforated manifold capable of introducing water under pressure and thoroughly mixing water with other ingredients.

(e) Jet mortar from nozzle at high velocity onto shotcrete-receiving surface.

(2) **Wet-Mix Process.**

(a) Mix ingredients thoroughly, as specified in Subsection 628.03(B)(1) – Dry-Mix Process, including water.

(b) Introduce mortar into delivery equipment chamber.

(c) Meter mortar into delivery hose and convey mortar to nozzle by compressed air or by other means.

(d) Inject additional air at nozzle to increase velocity and improve gunning pattern.

(e) Jet mortar from nozzle at high velocity onto the shotcrete-receiving surface.

**(C) Equipment.** Submit proposed equipment, manufacturer’s specifications, and operating instructions. Operate equipment in accordance with manufacturer’s recommendations.
(1) **Dry-Mix Process.** Provide mixing equipment that will mix ingredients thoroughly and continuously.

Discharge fine aggregate-cement mixture into delivery hose in a manner that ensures delivery of a continuous, smooth stream of uniformly mixed material at proper velocity to discharge nozzle.

Equip discharge nozzle with manually operated water injection system (water ring) for directing even distribution of water through fine aggregate-cement mixture. Provide water valve capable of adjusting quantity of water delivered to nozzle. Locate water valve to enable nozzle operator to instantaneously adjust water volume as necessary during shotcrete application.

Deliver conical discharge stream of uniform appearance. If stream distortion or nonuniform appearance is noted, suspend shotcrete application until uniform shotcrete discharge is restored.

Use adequate supply of clean air to maintain required nozzle velocity and simultaneous blowpipe operation for removing rebound.

Supply water at uniform pressure of at least 15 pounds per square inch greater than operating air pressure at the nozzle. Use water booster pump to provide required pressure if line water pressure is inadequate.

(2) **Wet-Mix Process.** Provide wet-mix delivery equipment of design and size that has produced satisfactory results in similar work. Use wet-mix equipment that has adequate capacity to deliver pre-mixed materials accurately, uniformly, and continuously through delivery hose. Follow manufacturer’s recommendations regarding:

(a) Type and size of nozzle.

(b) Cleaning equipment.

(c) Inspecting equipment.

(d) Maintaining equipment.

Provide air compressor capable of performing as specified in Subsection 628.03(C)(1) - Dry Mix Process and wet-mix equipment manufacturer’s recommendations.
(D) Quality Control/Quality Assurance.

(1) Preconstruction Testing. Prepare and test preconstruction test panels in accordance with ASTM C 1140. Produce test panels for each proposed mix proportion, each anticipated shooting orientation, and each proposed nozzle operator. Make test panels at least 30 inches square with the same thickness as in the structure, but not less than 3 inches. In half of the test panels, provide reinforcement of the same size and spacing required for the work. Obtain six test specimens from each panel, three nonreinforced and three reinforced specimens.

Test nonreinforced specimens for conformance to specified physical properties in accordance with ASTM C 42. The Engineer will visually grade reinforced specimens for conformance to specified core grade as specified in Subsection 628.03(D)(3) - Shotcrete Core Grades.

Allow only nozzle operators with test panel mean core grade less than or equal to 2.5 to place job shotcrete. Require nozzle operator to shoot second test panel if first test panel is rejected. If nozzle operator’s second mean core grade is greater than 2.5, do not permit that nozzle operator to shoot on the project.

(2) Construction Testing. Produce material test panel for each mix and each workday or every 50 cubic yards placed, whichever is less. Keep test panels moist and at 70 degrees F ±10 degrees F until moved to test laboratory. Obtain test specimens either from job site material test panel or from in-place shotcrete. Test specimens from test panels in accordance with ASTM C 1140.

Test specimens from in-place shotcrete in accordance with ASTM C 42. The Engineer will grade cores that include reinforcement as specified in Subsection 628.03(D)(3) - Shotcrete Core Grades.

The mean compressive strength of a set of three cores shall equal or exceed 0.85\(f'_{c}\) with no individual core less than 0.75 \(f'_{c}\). The mean of a set of three cubes shall equal or exceed \(f'_{c}\) with no individual cube less than 0.88\(f'_{c}\).

(3) Shotcrete Core Grades.

(a) Grade 1. Shotcrete specimens are solid; there are no laminations, sandy areas or voids. Small air voids with maximum diameter of 1/8 inch and maximum length of 1/4 inch are normal and acceptable. Sand pockets or voids behind
continuous reinforcing steel are unacceptable. The surface against the form or bond plane shall be sound, without sandy texture or voids.

(b) Grade 2. Shotcrete specimens shall have no more than two laminations or sandy areas with dimensions not to exceed 1/8 inch thick by 1 inch long. The height, width, and depth of voids shall not exceed 3/8 inch. Porous areas behind reinforcing steel shall not exceed 1/2 inch in any direction except along length of reinforcing steel. The surface against the form or bond plane shall be sound, without sandy texture or voids.

(c) Grade 3. Shotcrete specimens shall have no more than two laminations or sandy areas with dimensions exceeding 3/16 inch thick by 1-1/4 inches long, or one major void, sand pocket, or lamination containing loosely bonded sand not to exceed 5/8 inch thick and 1-1/4 inches in width. The surface against the form or bond plane may be sandy, with voids containing overspray to a depth of 1/16 inch.

(d) Grade 4. Core shall meet, in general, requirements of Grade 3 cores, but may have two major flaws such as described for Grade 3, or may have one flaw with maximum dimension of 1 inch perpendicular to the face of the core, with maximum width of 1-1/2 inches. The end of the core that was shot against the form may be sandy, with voids containing overspray to a depth of 1/8 inch.

(e) Grade 5. Core that does not meet criteria of core grades 1 through 4, by being of poorer quality, shall be classified as Grade 5.

(f) Determine grade by computing the mean of a minimum of three test specimens. Accept mean grade of 2.5 or less. Reject individual shotcrete cores with grade greater than 3.

(g) The above core grades are based on cores with surface area of 50 square inches. For cores with greater or lesser area than 50 square inches, adjust allowable flaws relative to 50 square inches.

(4) Evaluation of In-Place Shotcrete. Remove and replace shotcrete that is delaminated, exhibits laminations, voids, or sand pockets exceeding limits for specified grade of shotcrete. Remove and replace shotcrete that does not comply with specified material properties.
Repair core holes in accordance with ACI 301 Chapter 9. Do not fill holes by shooting.

(5) **Acceptance.** The Engineer will accept shotcrete work that meets requirements of the contract documents. The Engineer will accept shotcrete work that has previously failed to meet one or more requirements, but which has been repaired to meet requirements of the contract documents.

Shotcrete work that fails to meet one or more requirements and that cannot be brought into compliance will be evaluated for acceptance by the Engineer. Modifications may be required to ensure remaining work complies with requirements of the contract documents.

(E) **Surface Preparation.**

(1) **Earth.** Grade area accurately to elevations and dimensions specified. Dampen surface immediately before shooting with sufficient moisture to provide firm foundation and to prevent absorption of water from the mortar, but without free surface water.

(2) **Concrete, Masonry, and Shotcrete.** When bonding is required, remove all deteriorated, loose, unsound material, or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Taper edges to eliminate square shoulders at perimeter of a cavity. Sandblast surface to clean rust from exposed reinforcing steel and to produce a clean, rough-textured surface. Maintain surface saturated, surface-dry immediately before applying shotcrete.

(3) **Steel.** Remove loose mill scale, rust, oil, paint, or other contaminants by sandblasting or other methods. Prepare surface in accordance with SSPC-SP6.6. If high-pressure water blasting is used, remove all freestanding water before applying shotcrete.

(4) **Rock.** Remove loose material, mud, or other foreign material that will prevent bonding. Clean and prewet surface immediately before applying shotcrete.

(5) **Forms.** If forms are to be removed after use, apply form-releasing coating material on forms. Use coating material that does not alter shotcrete properties or interfere with bond of subsequent shotcrete layers. Secure forms to minimize effects of vibration. Construct forms to allow escape of placement air and rebound.

(F) **Crew Qualifications.** Use nozzle operators with at least two years of experience in this type of work. Nozzle operator may be apprentice with at
least six months of experience if supervised by foreman in charge with at
least two years of nozzle operator experience.

(G) **Alignment Control.** Provide joints, side forms, headers, and shooting
strips for backing or paneling. Place in a manner that minimizes trapping of
rebound.

Install ground wires as guides to establish thicknesses, surface
planes, and finish lines. Maintain wires taut and true to line at all times during
shotcreting application.

(H) **Gunning.** Place shotcrete first in corners, recesses, and other areas
where rebound or overspray cannot escape easily. Place shotcrete with
nozzle held approximately perpendicular to receiving surface. In corners,
direct nozzle at approximately 45-degree angle or bisect corner angle.

Construct ditch lining in non-sagging layers. Build each layer by
making several passes of the nozzle over specified surface. Apply shotcrete
from nozzle in steady, uninterrupted flow. Should flow become intermittent,
direct flow away from work area until steady, uninterrupted flow is restored.

In gunning walls, apply mortar beginning at the bottom. Build first
layer up to thickness that will embed reinforcement, without sagging.
Remove slugs, sand spots, and wet sloughs. Resurface affected areas as
the work progresses.

Allow each layer ample time to set. Remove rebound material from
each layer before applying next layer. If final set has taken place, wet down
area before next application.

Suspend gunning if high winds prevent nozzle operator from properly
applying shotcrete or if rain washes out or causes shotcrete to slough.

(I) **Rebound.** Remove rebound or overspray from previously prepared
surfaces prior to shotcrete placement. Reuse of rebound or overspray will
not be allowed.

(J) **Construction Joints.** Form construction joints by tapering to a 1-inch
dge over a distance of 12 inches, where joints are not subject to
ression loads. Use square construction joints in areas subject to
ression loads. Clean construction joints thoroughly and saturate
urface of construction joints surface dry immediately before applying
shcrete.

(K) **Finishing.** Provide gun finish for ditch linings. Finish gutter surfaces
as specified in Subsection 638.03(C)(2) - Placing. Round exposed edges
with edging tool. For other surfaces provide finishes in accordance with the
contract documents.
Curing. Immediately after finishing, cure shotcrete continuously by maintaining in moist condition for 7 days, or until specified strength is attained, or until succeeding shotcrete layers are placed. Curing materials shall conform to Subsection 711.01 – Curing Materials.

Cure by one of the following methods:

(1) Ponding or continuous sprinkling.

(2) Covering with an absorptive mat.

(3) Covering with impervious sheet material.

(4) Curing compounds. If curing compounds are used and additional layers of concrete are to be applied, remove curing material by either water blasting or sand blasting.

Measurement. Shotcrete will be paid on a lump sum basis. Measurement for payment will not apply.

Payment. The Engineer will pay for the accepted shotcrete on a contract lump sum basis. Payment will be full compensation for the work prescribed in this section and the contract documents.

The Engineer will pay for the following pay item when included in the proposal schedule:

Pay Item

Shotcrete for ________________ Lump Sum

The Engineer will pay for reinforcing steel in accordance with and under Section 602 - Reinforcing Steel.

END OF SECTION 628