

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.

45 **(2) Wet-Mix Process.** Mix material at central mixing plant or at
46 project site. If mixing is done at project site, use mixer capable of
47 thoroughly mixing specified materials in sufficient quantity to maintain
48 continuous shotcrete placement.

49
50 **(B) Shotcrete Process - General.** Use either dry-mix or wet-mix
51 shotcrete process as follows:

- 52
53 **(1) Dry-Mix Process.**
- 54 **(a)** Mix cement and fine aggregates thoroughly.
 - 55 **(b)** Feed cement-fine aggregate mixture into special
56 mechanical feeder (gun) or other delivery equipment accepted
57 by the Engineer.
 - 58 **(c)** Meter mixture into delivery hose by feed wheel or
59 distributor.
 - 60 **(d)** Convey mixture by compressed air through delivery
61 hose to special nozzle. Fit nozzle with perforated manifold
62 capable of introducing water under pressure and thoroughly
63 mixing water with other ingredients.
 - 64 **(e)** Jet mortar from nozzle at high velocity onto shotcrete-
65 receiving surface.

- 66
67 **(2) Wet-Mix Process.**
- 68 **(a)** Mix ingredients thoroughly, as specified in Subsection
69 628.03(B)(1) – Dry-Mix Process, including water.
 - 70 **(b)** Introduce mortar into delivery equipment chamber.
 - 71 **(c)** Meter mortar into delivery hose and convey mortar to
72 nozzle by compressed air or by other means.
 - 73 **(d)** Inject additional air at nozzle to increase velocity and
74 improve gunning pattern.
 - 75 **(e)** Jet mortar from nozzle at high velocity onto the
76 shotcrete-receiving surface.

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78 **(C) Equipment.** Submit proposed equipment, manufacturer's
79 specifications, and operating instructions. Operate equipment in accordance
80 with manufacturer's recommendations.

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92 **(1) Dry-Mix Process.** Provide mixing equipment that will mix
93 ingredients thoroughly and continuously.

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

98
99 Equip discharge nozzle with manually operated water injection
100 system (water ring) for directing even distribution of water through fine
101 aggregate-cement mixture. Provide water valve capable of adjusting
102 quantity of water delivered to nozzle. Locate water valve to enable
103 nozzle operator to instantaneously adjust water volume as necessary
104 during shotcrete application.

105
106 Deliver conical discharge stream of uniform appearance. If
107 stream distortion or nonuniform appearance is noted, suspend
108 shotcrete application until uniform shotcrete discharge is restored.

109
110 Use adequate supply of clean air to maintain required nozzle
111 velocity and simultaneous blowpipe operation for removing rebound.

112
113 Supply water at uniform pressure of at least 15 pounds per
114 square inch greater than operating air pressure at the nozzle. Use
115 water booster pump to provide required pressure if line water pressure
116 is inadequate.

117
118 **(2) Wet-Mix Process.** Provide wet-mix delivery equipment of
119 design and size that has produced satisfactory results in similar work.
120 Use wet-mix equipment that has adequate capacity to deliver
121 pre-mixed materials accurately, uniformly, and continuously through
122 delivery hose. Follow manufacturer's recommendations regarding:

123
124 **(a)** Type and size of nozzle.

125
126 **(b)** Cleaning equipment.

127
128 **(c)** Inspecting equipment.

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130 **(d)** Maintaining equipment.

131
132 Provide air compressor capable of performing as specified in
133 Subsection 628.03(C)(1) - Dry Mix Process and wet-mix equipment
134 manufacturer's recommendations.

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(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 \pm 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 $0.85f'_c$ with no individual core less than $0.75f'_c$. The mean of a set of three cubes shall equal or exceed f'_c with no individual cube less than $0.88f'_c$.

(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

182 continuous reinforcing steel are unacceptable. The surface
183 against the form or bond plane shall be sound, without sandy
184 texture or voids.

185
186 **(b) Grade 2.** Shotcrete specimens shall have no more than
187 two laminations or sandy areas with dimensions not to exceed
188 1/8 inch thick by 1 inch long. The height, width, and depth of
189 voids shall not exceed 3/8 inch. Porous areas behind
190 reinforcing steel shall not exceed 1/2 inch in any direction
191 except along length of reinforcing steel. The surface against
192 the form or bond plane shall be sound, without sandy texture or
193 voids.

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195 **(c) Grade 3.** Shotcrete specimens shall have no more than
196 two laminations or sandy areas with dimensions exceeding
197 3/16 inch thick by 1-1/4 inches long, or one major void, sand
198 pocket, or lamination containing loosely bonded sand not to
199 exceed 5/8 inch thick and 1-1/4 inches in width. The surface
200 against the form or bond plane may be sandy, with voids
201 containing overspray to a depth of 1/16 inch.

202
203 **(d) Grade 4.** Core shall meet, in general, requirements of
204 Grade 3 cores, but may have two major flaws such as
205 described for Grade 3, or may have one flaw with maximum
206 dimension of 1 inch perpendicular to the face of the core, with
207 maximum width of 1-1/2 inches. The end of the core that was
208 shot against the form may be sandy, with voids containing
209 overspray to a depth of 1/8 inch.

210
211 **(e) Grade 5.** Core that does not meet criteria of core
212 grades 1 through 4, by being of poorer quality, shall be
213 classified as Grade 5.

214
215 **(f)** Determine grade by computing the mean of a minimum
216 of three test specimens. Accept mean grade of 2.5 or less.
217 Reject individual shotcrete cores with grade greater than 3.

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

223
224 **(4) Evaluation of In-Place Shotcrete.** Remove and replace
225 shotcrete that is delaminated, exhibits laminations, voids, or sand
226 pockets exceeding limits for specified grade of shotcrete. Remove
227 and replace shotcrete that does not comply with specified material
228 properties.

229

230 Repair core holes in accordance with ACI 301 Chapter 9. Do
231 not fill holes by shooting.

232
233 **(5) Acceptance.** The Engineer will accept shotcrete work that
234 meets requirements of the contract documents. The Engineer will
235 accept shotcrete work that has previously failed to meet one or more
236 requirements, but which has been repaired to meet requirements of
237 the contract documents.

238
239 Shotcrete work that fails to meet one or more requirements and
240 that cannot be brought into compliance will be evaluated for
241 acceptance by the Engineer. Modifications may be required to ensure
242 remaining work complies with requirements of the contract
243 documents.

244
245 **(E) Surface Preparation.**

246
247 **(1) Earth.** Grade area accurately to elevations and dimensions
248 specified. Dampen surface immediately before shooting with
249 sufficient moisture to provide firm foundation and to prevent
250 absorption of water from the mortar, but without free surface water.

251
252 **(2) Concrete, Masonry, and Shotcrete.** When bonding is
253 required, remove all deteriorated, loose, unsound material, or
254 contaminants that may inhibit bonding. Chip areas to be repaired to
255 remove offsets causing abrupt changes in thickness. Taper edges to
256 eliminate square shoulders at perimeter of a cavity. Sandblast
257 surface to clean rust from exposed reinforcing steel and to produce a
258 clean, rough-textured surface. Maintain surface saturated, surface-
259 dry immediately before applying shotcrete.

260
261 **(3) Steel.** Remove loose mill scale, rust, oil, paint, or other
262 contaminants by sandblasting or other methods. Prepare surface in
263 accordance with SSPC-SP6.6. If high-pressure water blasting is
264 used, remove all freestanding water before applying shotcrete.

265
266 **(4) Rock.** Remove loose material, mud, or other foreign material
267 that will prevent bonding. Clean and prewet surface immediately
268 before applying shotcrete.

269
270 **(5) Forms.** If forms are to be removed after use, apply form-
271 releasing coating material on forms. Use coating material that does
272 not alter shotcrete properties or interfere with bond of subsequent
273 shotcrete layers. Secure forms to minimize effects of vibration.
274 Construct forms to allow escape of placement air and rebound.

275
276 **(F) Crew Qualifications.** Use nozzle operators with at least two years of
277 experience in this type of work. Nozzle operator may be apprentice with at

278 least six months of experience if supervised by foreman in charge with at
279 least two years of nozzle operator experience.

280

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

284

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

288

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

293

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

298

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

303

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

307

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

310

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

314

315 **(J) Construction Joints.** Form construction joints by tapering to a 1-inch
316 edge over a distance of 12 inches, where joints are not subject to
317 compression loads. Use square construction joints in areas subject to
318 compression loads. Clean construction joints thoroughly and saturate
319 surface of construction joints surface dry immediately before applying
320 shotcrete.

321

322 **(K) Finishing.** Provide gun finish for ditch linings. Finish gutter surfaces
323 as specified in Subsection 638.03(C)(2) - Placing. Round exposed edges
324 with edging tool. For other surfaces provide finishes in accordance with the
325 contract documents.

628.03

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(L) 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.

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

628.05 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	Pay Unit
Shotcrete for _____	Lump Sum

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

END OF SECTION 628