



Note to User:

This section **contains macros** to aid the editing process. By default Microsoft Word **disables** macros for virus security reasons. When you open a file that has macros, the yellow message bar appears with a shield icon and the enable content button. To enable these macros, click the **Enable Content** button.



**SECTION 033713
SHOTCRETE**

(To View Hidden Text, Type CTRL-H)

PART 1 – GENERAL

1.1 SECTION INCLUDES

- A. Shotcrete applied by [dry-mix] [or] [wet-mix] process.

1.2 RELATED SECTIONS

- A. Section 0301 30 - Maintenance of Cast-in-Place Concrete:for examining and preparing shotcrete repairs of existing cast-in-place concrete.
- B. Section 03 30 00 - Cast-in-Place Concrete: for concrete requirements, including formwork, reinforcement, and concrete materials and mixes.
- C. Section 03 21 00 -Reinforcing Steel.
- D. Section 3120 00 - Earth Moving:for excavations and formed earth and rock surfaces to receive shotcrete.

1.3 REFERENCES

- A. American Concrete Institute (ACI):
 - 1. ACI 117R - Specifications for Tolerances for Concrete Construction and Materials.
 - 2. ACI 301 - Specifications for Structural Concrete.
 - 3. ACI 305R - Hot Weather Concreting.
 - 4. ACI 306.1 - Specification for Cold Weather Concreting.
 - 5. ACI 506R - Guide to Shotcrete.
 - 6. ACI 506.2 - Specification for Shotcrete.
- B. ASTM International (ASTM):
 - 1. ASTM A 36 - Specification for Carbon Structural Steel.
 - 2. ASTM A 82 - Specification for Steel Wire, Plain, for Concrete Reinforcement.
 - 3. ASTM A 153 - Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
 - 4. ASTM A 185 - Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.
 - 5. ASTM A 307 - Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.
 - 6. ASTM A 497 - Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
 - 7. ASTM A 615 - Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
 - 8. ASTM A 706 - Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
 - 9. ASTM A 767 - Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement.
 - 10. ASTM A 820 - Specification for Steel Fibers for Fiber Reinforced Concrete.
 - 11. ASTM C 33 - Specification for Concrete Aggregates.
 - 12. ASTM C 42 - Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.



13. ASTM C 150 - Specification for Portland Cement.
 14. ASTM C 171 - Specification for Sheet Materials for Curing Concrete.
 15. ASTM C 173 - Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.
 16. ASTM C 231 - Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
 17. ASTM C 260 - Specification for Air-Entraining Admixtures for Concrete.
 18. ASTM C 309 - Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
 19. ASTM C 494 - Specification for Chemical Admixtures for Concrete.
 20. ASTM C 618 - Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete.
 21. ASTM C 979 - Specification for Pigments for Integrally Colored Concrete.
 22. ASTM C 1064 - Test Method for Temperature of Freshly Mixed Portland Cement Concrete.
 23. ASTM C 1077 - Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation.
 24. ASTM C 1116 - Specification for Fiber-Reinforced Concrete and Shotcrete.
 25. ASTM C 1141 - Specification for Admixtures for Shotcrete.
 26. ASTM C 1240 - Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic Cement Concrete, Mortar, and Grout.
 27. ASTM D 1751 - Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types).
 28. ASTM D 1752 - Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.
 29. ASTM E 329 - Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.
- C. Concrete Reinforcing Steel Institute (CRSI):
1. Manual of Standard Practice.
 2. SSPC: The Society for Protective Coatings.
 3. SSPC-SP 6/NACE No. 3 2000 - Joint Surface Preparation Standard SSPC-SP 6/NACE No. 3: Commercial Blast Cleaning.

1.4 DEFINITIONS

- A. Shotcrete: Mortar or concrete pneumatically projected onto a surface at high velocity.
- B. Dry-Mix Shotcrete: Shotcrete with most of the water added at nozzle.
- C. Wet-Mix Shotcrete: Shotcrete with ingredients, including mixing water, mixed before introduction into delivery hose.

1.5 SUBMITTALS

- A. Submit under provisions of Section 01 33 00 - Submittal Procedures.
- B. Product Data: Submit for manufactured materials and products including reinforcement and forming accessories, shotcrete materials and curing compounds.
- C. Shop Drawings: Submit for details of fabricating, bending, and placing reinforcement. Include support and anchor details, number and location of splices, and special reinforcement required for openings through shotcrete structures.
- D. Samples: Approximately 24 by 24 by 2 inches, to illustrate quality of finishes, colors, and textures of exposed surfaces of shotcrete.
- E. Design Mixes: For each shotcrete mix.



- F. Quality Assurance/Control Submittals:
 - 1. Submit manufacturer's certificates that products meet or exceed specified requirements.
 - 2. Submit test results prepared by a qualified independent testing laboratory.

1.6 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Firm specializing in manufacture of shotcrete materials, with minimum 10 years' experience.
- B. Quality Assurance/Control Testing: Test Reports prepared by a qualified independent laboratory indicating compliance with the following performance requirements:
 - 1. ACI 301, Specifications for Structural Concrete.
 - 2. ACI 506.2, Specification for Shotcrete.
- C. Testing Agency Qualifications: An independent agency qualified according to ASTM C 1077 and ASTM E 329 for testing indicated.
- D. Mockups: Before installing shotcrete, construct mockups for each finish required and for each design mix, shooting orientation, and nozzle operator to demonstrate aesthetic effects and set quality standard for installation.
 - 1. Size: _____, maximum.
 - 2. Location: As directed by Architect.
 - 3. Location: As indicated on drawings.
 - 4. Approved mockups may become part of the completed Work if undamaged at time of Substantial Completion.
 - 5. When directed by Architect, dismantle and remove mock-ups from Project site.
- E. Pre-Installation Meeting: At least three weeks prior to commencing masonry work conduct a meeting at the project site to discuss contract requirements and job conditions; require the attendance of contractor, and installers of related materials; notify Architect in advance of meeting.

1.7 PROJECT CONDITIONS

- A. Cold-Weather Shotcreting: Protect shotcrete work from physical damage or reduced strength caused by frost, freezing, or low temperatures according to ACI 306.1 and as follows:
 - 1. Discontinue shotcreting when ambient temperature is 40 deg. F and falling. Uniformly heat water and pre-packaged materials before mixing to obtain a shotcrete shooting temperature of not less than 50 deg. F and not more than 90 deg. F.
 - 2. Do not use frozen materials or materials containing ice or snow.
 - 3. Do not place shotcrete on frozen surfaces or surfaces containing frozen materials.
 - 4. Do not use calcium chloride, salt, or other materials containing antifreeze agents.
- B. Hot-Weather Shotcreting: Mix, place, and protect shotcrete according to ACI 506R when hot weather conditions and high temperatures would seriously impair quality and strength of shotcrete, and as follows:
 - 1. Cool ingredients before mixing to maintain shotcrete temperature at time of placement below 100 deg. F for dry mix or 90 deg. F for wet mix.
 - 2. Reduce temperature of reinforcing steel and receiving surfaces below 100 deg. F before shotcreting.

PART 2 – PRODUCTS

2.1 FORM MATERIALS



- A. Forms: Form facing panels that will provide continuous, straight, smooth, concrete surfaces. Furnish panels in largest practicable sizes to minimize number of joints.

2.2 REINFORCING MATERIALS

- A. Reinforcing Bars: ASTM A 615, Grade 60 (Grade 420), deformed.
- B. Low-Alloy-Steel Reinforcing Bars: ASTM A 706, deformed.
- C. Galvanized Reinforcing Bars: ASTM A 767, Class II, zinc coated, hot-dip galvanized after fabrication and bending, as follows:
 - 1. Steel Reinforcement: [ASTM A 615, Grade 60 (Grade 420)] [ASTM A 706], deformed.
 - 2. Plain-Steel Wire: ASTM A 82, [as drawn] [galvanized].
- D. Plain-Steel-Welded Wire Fabric: ASTM A 185, fabricated from [as-drawn] [galvanized] steel wire into flat sheets.
- E. Deformed Steel Welded Wire Fabric: ASTM A 497, flat sheet.
- F. Supports: Bolsters, chairs, spacers, ties, and other devices for spacing, supporting, and fastening reinforcing steel in place according to CRSI's "Manual of Standard Practice" and as follows:
 - 1. For uncoated reinforcement, use [all-plastic] [CRSI Class 1, plastic-protected] [CRSI Class 2, stainless-steel] bar supports.
 - 2. For zinc-coated reinforcement, use [galvanized wire or dielectric-polymer-coated wire] [all-plastic] bar supports.
- G. Reinforcing Anchors: ASTM A 36, un-headed rods or ASTM A 307, Grade A, hex-head bolts; carbon steel; and carbon-steel nuts.
 - 1. Finish: [Plain, uncoated] [Hot-dip zinc coating, ASTM A 153, Class C].

2.3 SHOTCRETE MATERIAL MANUFACTURER

- A. Acceptable Manufacturer: SPEC MIX®, Inc., which is located at: 1230 Eagan Industrial Road, Suite 160, Eagan, MN 55121; Toll Free Tel: 888-SPEC-MIX (773-2649); Tel: 651-994-7120; Email: request_info@specmix.com; Web: www.specmix.com

2.4 SHOTCRETE MATERIALS

- A. **SPECSHOTShotcrete:** SPEC MIX SPECSHOTShotcrete is a pre-blended, high early strength, low permeability and low rebound cement based product containing Portland cement, aggregate, fly ash, silica fume, steel or synthetic fibers, and chemical admixtures, specifically designed for ground support shotcrete applications.
 - 1. Applicable Standards: ASTM A 820, ASTM C 33, ASTM C 150, ASTM C 260, ASTM C 494, ASTM C 618, ASTM C 1116, ASTM C 1141, ASTM C 1240, ACI 506.2.
- B. **SPECPATCHShotcrete:** SPEC MIX SPECPATCHShotcrete is a pre-blended, high early strength, cement-based shotcrete patching product containing Portland cement, aggregate, fly ash, silica fume, steel or synthetic fibers, and chemical admixtures specifically designed for concrete repair.
 - 1. Applicable Standards: ASTM A 820, ASTM C 33, ASTM C 150, ASTM C 260, ASTM C 494, ASTM C 618, ASTM C 1116, ASTM C 1141, ASTM C 1240, ACI 506.2.
- C. **SPECFINISHShotcrete:** SPEC MIX SPECFINISHShotcrete is a pre-blended, high early strength, cement based product finish shotcrete containing Portland cement, aggregate, fly ash, silica fume, steel or synthetic fibers, and chemical admixtures specifically designed for finishing rockscapes, sculptures or other architectural shotcrete applications.



SPEC MIX, Inc. – Guide Specification

1. Coloring Agent: ASTM C 979, synthetic mineral-oxide pigments or colored, water-reducing admixtures, color stable, nonfading, and resistant to lime and other alkalis.
 - a. Color: [As indicated by manufacturer's designation] [Match Architect's sample] [As selected by Architect from manufacturer's full range] <Insert color>.
 2. Applicable Standards: ASTM A 820, ASTM C 33, ASTM C 150, ASTM C 260, ASTM C 494, ASTM C 618, ASTM C 1116, ASTM C 1141, ASTM C 1240, ACI 506.2.
- D. **SPECNAILShotcrete:** SPEC MIXSPECNAILShotcrete is a pre-blended, high early strength, cement-based product containing Portland cement, aggregate, fly ash, silica fume, steel or synthetic fibers, and chemical admixtures specifically designed to stabilize natural soil slopes.
1. Applicable Standards: ASTM A 820, ASTM C 33, ASTM C 150, ASTM C 260, ASTM C 494, ASTM C 618, ASTM C 1116, ASTM C 1141, ASTM C 1240, ACI 506.2.
- E. **SPECPOOLShotcrete:** SPEC MIXSPECPOOLShotcrete is a pre-blended, high early strength, cement-based product containing Portland cement, aggregate (ACI Gradation 1, 2 or 3), fly ash, silica fume, steel or synthetic fibers, and chemical admixtures specifically designed for use in pool construction.
1. Coloring Agent: ASTM C 979, synthetic mineral-oxide pigments or colored, water-reducing admixtures, color stable, nonfading, and resistant to lime and other alkalis.
 - a. Color: [As indicated by manufacturer's designation] [Match Architect's sample] [As selected by Architect from manufacturer's full range] <Insert color>.
 2. Applicable Standards: ASTM A 820, ASTM C 33, ASTM C 150, ASTM C 260, ASTM C 494, ASTM C 618, ASTM C 1116, ASTM C 1141, ASTM C 1240, ACI 506.2.

2.5 ACCESSORY MATERIALS

- A. Water: Clean and free from deleterious acids, alkalis, and organic matter.
- B. Ground Wire: High-strength steel wire, 0.8 to 1 mm in diameter.
- C. Joint Filler Strips: ASTM D 1751, asphalt-saturated cellulosic fiber or ASTM D 1752, cork or self-expanding cork.

2.6 CURING MATERIALS

- A. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz./sq. yd. dry.
- B. Moisture-Retaining Cover: ASTM C 171, polyethylene film or white burlap-polyethylene sheet.
- C. Water: Clean and free from deleterious acids, alkalis, and organic matter.
- D. Clear, [Waterborne] [Solvent-Borne], Membrane-Forming Curing Compound: ASTM C 309, Type 1, Class B.

2.7 SHOTCRETE MIXTURES, GENERAL

- A. Prepare design mixes for each type and strength of shotcrete.
- B. Design-Mix Adjustments: Subject to compliance with requirements, shotcrete design-mix adjustments may be proposed when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant.

2.8 SHOTCRETE MIXTURES

- A. Mix pre-packaged shotcrete materials with water either in dry mix or wet mix process to provide shotcrete with the following properties:



1. Compressive Strength (28 Days): [5000 psi] [4500 psi] [4000 psi] [3500 psi] <Insert strength>.
2. If pre-packaged, air-entrained mixtures are selected, verify that normal-weight, wet-mix shotcrete has an air content before pumping of [7] [8] <Insert number> percent with a tolerance of plus or minus 1-1/2 percent.

2.9 SHOTCRETE EQUIPMENT

- A. Mixing Equipment: Capable of thoroughly mixing shotcrete materials in sufficient quantities to maintain continuous placement.
- B. Dry-Mix Delivery Equipment: Capable of discharging aggregate-cement mixture into delivery hose under close control and maintaining continuous stream of uniformly mixed materials at required velocity to discharge nozzle. Equip discharge nozzle with manually operated water-injection system for directing even distribution of water to aggregate-cement mixture.
 1. Provide uniform, steady supply of clean, compressed air to maintain constant nozzle velocity while simultaneously operating blow pipe for cleaning away rebound.
 2. Provide water supply with uniform pressure at discharge nozzle to ensure uniform mixing with aggregate-cement mix. Provide water pump to system if line water pressure is inadequate.
- C. Wet-Mix Delivery Equipment: Capable of discharging aggregate-cement-water mixture accurately, uniformly, and continuously.

2.10 MIXING

- A. Dry-Mix Process: Dampen pre-packaged shotcrete materials and thoroughly mix prior to use.
 1. Verify with manufacturer the water mix ratio at head to achieve specified mix design prior to application.
- B. Wet-Mix Process: Thoroughly mix clean water with pre-packaged shotcrete materials in batch mixer prior to use.
 1. Verify with manufacturer quantity of water to be added to batch to achieve specified mix design.

PART 3 – EXECUTION

3.1 PREPARATION

- A. Concrete or Masonry: Before applying shotcrete, remove unsound or loose materials and contaminants that may inhibit shotcrete bonding. Chip or scarify areas to be repaired to extent necessary to provide sound substrate. Cut edges square and 1/2 inch deep at perimeter of work, tapering remaining shoulder at 1:1 slope into cavity to eliminate square shoulders. Dampen surfaces before shotcreting.
 1. Abrasive blast or hydroblast existing surfaces that do not require chipping to remove paint, oil, grease, or other contaminants and to provide roughened surface for proper shotcrete bonding.
- B. Earth: Compact and trim to line and grade before placing shotcrete. Do not place shotcrete on frozen surfaces. Dampen surfaces before shotcreting.
- C. Rock: Clean rock surfaces of loose materials, mud, and other foreign matter that might weaken shotcrete bonding.
- D. Steel: Clean steel surfaces by abrasive blasting according to SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning."

3.2 FORMS



- A. General: Design, erect, support, brace, and maintain forms, according to ACI 301, to support shotcrete and construction loads and to facilitate shotcreting. Construct forms so shotcrete members and structures are secured to prevent excessive vibration or deflection during shotcreting.
 - 1. Fabricate forms to be readily removable without impact, shock, or damage to shotcrete surfaces and adjacent materials.
 - 2. Construct forms to required sizes, shapes, lines, and dimensions using ground wires and depth gages to obtain accurate alignment, location, and grades in finished structures. Construct forms to prevent leakage but permit escape of air and rebound during shotcreting. Provide for openings, offsets, blocking, screeds, anchorages, inserts, and other features required in the Work.
- B. Form openings, chases, recesses, bulkheads, keyways, and screeds in formwork. Determine sizes and locations from trades providing such items. Accurately place and securely support items built into forms.

3.3 STEEL REINFORCEMENT

- A. General: Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.
- B. Clean reinforcement of loose rust and mill scale, earth, ice, and other materials that weaken shotcrete bonding.
- C. Securely embed reinforcing anchors into existing substrates, located as required.
- D. Accurately position, support, and rigidly secure reinforcement against displacement by formwork, construction, or shotcreting. Locate and support reinforcement by metal chairs, runners, bolsters, spacers, and hangers, as required.
- E. Place reinforcement to obtain minimum coverage for shotcrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during shotcreting. Set wire ties with ends directed into shotcrete, not toward exposed shotcrete surfaces.
- F. Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.

3.4 JOINTS

- A. Construction Joints: Locate and install construction joints tapered to a 1:1 slope where joint is not subject to compression loads and square where joint is perpendicular to main reinforcement. Continue reinforcement through construction joints, unless otherwise indicated.
- B. Contraction Joints: Construct contraction joints in shotcrete using saw cuts 1/8-inch wide by 1/3 slab depth or joint-filler strips 1/4-inch wide by 1/3 shotcrete depth, unless otherwise indicated.
 - 1. After shotcrete has cured, remove strip inserts and clean groove of loose debris.
 - 2. Space joints at [15 feet o.c.] [centers indicated] <Insert spacing> horizontally and vertically.
 - 3. Tool edges round on each side of strip inserts if floated or troweled finishes are required.

3.5 ALIGNMENT CONTROL

- A. Ground Wires: Install ground wires to establish thickness and planes of shotcrete surfaces. Install ground wires at corners and offsets not established by forms. Pull ground wires taut and position adjustment devices to permit additional tightening.

3.6 EMBEDDED ITEMS



- A. Place and secure anchorage devices and other embedded items required for adjoining work that is attached to or supported by shotcrete. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

3.7 APPLICATION

- A. Apply temporary protective coverings and protect adjacent surfaces against deposit of rebound and overspray or impact from nozzle stream.
- B. Moisten substrate immediately before placing shotcrete.
 - 1. Moisten wood forms immediately before placing shotcrete where form coatings are not used.
- C. Apply shotcrete according to ACI 506.2.
- D. Apply [dry-mix shotcrete materials within 45 minutes after pre-dampening] [and] [wet-mix shotcrete materials within 90 minutes after batching].
- E. Deposit shotcrete continuously in multiple passes, to required thickness, without cold joints and laminations developing. Place shotcrete with nozzle held perpendicular to receiving surface. Begin shotcreting in corners and recesses.
 - 1. Remove and dispose of rebound and overspray materials during shotcreting to maintain clean surfaces and to prevent rebound entrapment.
- F. Maintain reinforcement in position during shotcreting. Place shotcrete to completely encase reinforcement and other embedded items. Maintain steel reinforcement free of overspray and prevent buildup against front face during shotcreting.
- G. Do not place subsequent lifts until previous lift of shotcrete is capable of supporting new shotcrete.
- H. Do not permit shotcrete to sag, slough, or dislodge.
- I. Remove hardened overspray, rebound, and laitance from shotcrete surfaces to receive additional layers of shotcrete; dampen surfaces before shotcreting.
- J. Do not disturb shotcrete surfaces before beginning finishing operations.
- K. Remove ground wires or other alignment control devices after shotcrete placement.
- L. Installation Tolerances: Place shotcrete without exceeding installation tolerances permitted by ACI 117R, increased by a factor of 2.

3.8 SURFACE FINISHES

- A. General: Finish shotcrete according to descriptions in ACI 506R for the following finishes:
- B. Natural Finish:
 - 1. Gun Finish: Natural undisturbed finish.
 - 2. Rod Finish: Rough-textured finish obtained by cutting or screeding exposed face of shotcrete to plane by rod or straightedge after initial set[, and wood-float finished] [, and steel-trowel finished].
 - 3. Broom Finish: Rough-textured finish obtained by screeding exposed face of shotcrete to required plane by rod, cutting screed, or trowel, and brooming after initial set.
- C. Flash-Coat Finish: After screeding and rodding surface, apply up to 1/4-inch coat of shotcrete using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve to provide a finely textured finish.



- D. Flash-Coat and Final Finish: After screeding and rodding surface, apply up to 1/4-inch coat of shotcrete using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve and apply [wood-float] [rubber-float] [brush-float] [steel-trowel] finish.
- E. Finish-Coat Finish: After screeding and rodding surface, apply shotcrete finish coat, 1/4 to 1 inch thick, using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve to provide a finish of uniform texture and appearance.
- F. Finish-Coat and Final Finish: After screeding and rodding surface, apply shotcrete finish coat, 1/4 to 1 inch thick, using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve and apply [wood-float] [rubber-float] [brush-float] [steel-trowel] finish.

3.9 CURING

- A. Protect freshly placed shotcrete from premature drying and excessive cold or hot temperatures.
- B. Start initial curing as soon as free water has disappeared from shotcrete surface after placing and finishing.
- C. Curing Exposed Surfaces: Cure shotcrete by one of the following methods:
 - 1. Moisture Curing: Keep surfaces continuously moist for at least seven days with water, continuous water-fog spray, water-saturated absorptive covers, or moisture-retaining covers. Lap and seal sides and ends of covers.
 - 2. Curing Compound: Apply curing compound uniformly in continuous operation by power spray according to manufacturer's written instructions. Recoat areas subjected to heavy rainfall within three hours after initial application. Maintain continuity of coating and repair damage during curing period.
 - a. Apply curing compound to natural or gun-finished shotcrete at rate of 1 gal./100 sq. ft.
- D. Curing Formed Surfaces: Cure formed shotcrete surfaces by moist curing with forms in place for full curing period or until forms are removed. If forms are removed, continue curing by methods specified above, as applicable.

3.10 FORM REMOVAL

- A. Forms not supporting weight of shotcrete may be removed after curing at not less than 50 deg. F for 24 consecutive hours after gunning, provided shotcrete is hard enough not to be damaged by form-removal operations and provided curing and protecting operations are maintained.
 - 1. Leave forms supporting weight of shotcrete in place until shotcrete has attained design compressive strength. Determine compressive strength of in-place shotcrete by testing representative field-cured specimens of shotcrete.
 - 2. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.
- B. Clean and repair surfaces of forms to be reused in the Work. Split, frayed, delaminated, or otherwise damaged form facing materials are unacceptable for exposed surfaces. Apply new form coating compound as specified for new formwork.

3.11 FIELD QUALITY CONTROL

- A. Testing Laboratory: Independent of the Owner, Architect and Contractor; the testing laboratory, in addition to meeting requirements of ASTM E-329, and must be an approved laboratory competent to perform concrete physical testing. All tests must be performed in strict accordance with the applicable ASTM standard.



- B. Distribution of Results of Tests: Within 24 hours of results of tests, copies of the results shall be submitted to the Architect, Contractor and the supplier if applicable.
- C. Shotcrete Testing:
 - 1. Air Content: ASTM C 173, volumetric method or ASTM C 231, pressure method; 1 test for each compressive-strength test for each mix of air-entrained, wet-mix shotcrete measured before pumping.
 - 2. Shotcrete Temperature: ASTM C 1064; 1 test hourly when air temperature is 40 deg. F and below and when 80 deg. F and above, and 1 test for each set of compressive-strength specimens.
 - 3. In-Place Shotcrete: Take a set of 3 unreinforced cores for each mix and for each workday or for every 50 cu. yd. of shotcrete placed; whichever is less. Test cores for compressive strength according to ACI 506.2 and ASTM C 42. Do not cut steel reinforcement.
 - a. Strength of shotcrete will be considered satisfactory when mean compressive strength of each set of 3 unreinforced cores equals or exceeds 85 percent of specified compressive strength, with no individual core less than 75 percent of specified compressive strength.

3.12 REPAIRS

- A. Remove and replace shotcrete that is delaminated or exhibits laminations, voids, or sand/rock pockets exceeding limits for specified core grade of shotcrete.
 - 1. Remove unsound or loose materials and contaminants that may inhibit bond of shotcrete repairs. Chip or scarify areas to be repaired to extent necessary to provide sound substrate. Cut edges square and 1/2 inch deep at perimeter of work, tapering remaining shoulder at 1:1 slope into cavity to eliminate square shoulders. Dampen surfaces and apply new shotcrete.
- B. Repair core holes from in-place testing according to repair provisions in ACI 301 and match adjacent finish, texture, and color.

3.13 CLEANING

- A. Remove and dispose of rebound and overspray materials from final shotcrete surfaces and areas not intended for shotcrete placement.

END OF SECTION