097.13 DPWH
05-15-2007

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

MAY 15 2007

DEPARTMENT ORDER)
No. 26)
Series of 2007 05-15-07)
X-X-X-X-X-X-X-X-X-X

SUBJECT: DPWH Standard Specifications for Shotcrete (Concrete Spray), Item 514

In line with the mandate of the Department in providing effective standard specifications to be used in the implementation of various infrastructure projects and in view of the need of setting standard specifications for shotcrete (concrete spray), the attached **DPWH Standard Specifications for Shotcrete (Concrete Spray), Item 514**, are hereby prescribed for the guidance and compliance of all concerned.

These specifications shall form part of the revised edition of the DPWH Standard Specifications (Volume II – Highways, Bridges and Airports).

This Order shall take effect immediately.

MANUEL M. BONOAN
Officer-In-Charge

WIN7U00194

DPWH STANDARD SPECIFICATION FOR

ITEM 514 – SHOTCRETE (CONCRETE SPRAY)

514.1 Description

This item shall consist of mixing and placing one or more courses of shotcrete on a prepared slope surface in accordance with this specification and in conformity with the lines, grades, dimensions and cross-sections shown on the plans or as established by the Engineer.

514.2 Material Requirements

514.2.1 Air-Entraining Admixtures (wet mix only)

Air-entraining admixtures shall conform to AASHTO M 154.

514.2.2 Chemical Admixtures (wet mix only)

Water-reducing, retarding, set-accelerating, and hydration stabilizing admixtures, or combinations thereof, shall conform to AASHTO M 194. Hydration stabilizing admixtures shall conform to AASHTO M 194, type B or D.

514.2.3 Concrete Coloring Agents

Concrete coloring agents shall conform to ASTM C 979. Coloring agents composed of synthetic or natural inorganic iron oxides shall only be used.

514.2.4 Curing Material

Curing Material shall conform to the following:

a)	Burlap cloth	AASHTO M 182
b)	Waterproof paper	AASHTO M 171
c)	Polyethylene film	AASHTO M 171
d)	Liquid membrane forming compounds	AASHTO M 148, type 1-D or 2

514.2.5 Hydraulic Cement

Hydraulic cement shall conform to the requirements of Item 700, Hydraulic Cement.

Cement brands or types shall not be mixed.

514.2.6 Penetrating Stain

Penetrating stain shall conform to the following:

a)	Weatherometer on base material, ASTM G 23	1000 h
b)	Acrylic dispersion	73.4% of nonvolatile vehicle
c)	Viscosity	58±2 Krebs units
d)	Solids volatile content	40.3

Stain shall be stored according to the manufacturer's recommendations.

514.2.7 Reinforcing Fibers

Deformed steel or fibrillated polypropylene fibers conforming to ASTM C 1116 shall be used.

514.2.8 Reinforcing Steel

Reinforcing steel shall conform to the requirements of Item 710, Reinforcing Steel and Wire Rope.

514.2.9 Shotcrete Aggregate

Fine aggregate shall be rounded particles conforming to AASHTO M 6, class B including the reactive aggregate supplementary requirement, except as amended or supplemented by the following:

a.	Material passing No. 200 sieve, AASHTO T 11	3% max.
b.	Sand equivalent value, AASHTO T 176, alternate method no. 2, reference method	75 min.

Lightweight fine aggregate shall conform to AASHTO M 195.

Coarse aggregate shall conform to AASHTO M 80, class B, except as amended or supplemented by the following:

a.	Los Angeles abrasion, AASHTO T 96	40% max.
b.	Adherent coating, ASTM D 5711	1% max.

Aggregates shall be combined to meet the designated gradation in Table 514-1.

Table 514 - 1
Shotcrete Gradation Limits for Combined Aggregates

Sieve Size	Percent by Mass Passing Designated Sieve (AASHTO T 27 & T 11)		
	Grading Designation		
	A	B	C
19 mm	-	-	100
12.5 mm	-	100	80-95
9.5 mm	100	90-100	70-90
4.75 mm	95-100	70-85	50-70
2.36 mm	80-100	50-70	35-55
1.18 mm	50-85	35-55	20-40
600 µm	25-60	20-35	10-30
300 µm	10-30	8-20	5-17
150 µm	2-10	2-10	2-10

514.2.10 Water

Water shall conform to the requirements of Item 714, Water.

514.2.11 Polyvinyl Chloride (PVC) Pipes

PVC drainpipes shall be furnished and installed including necessary fittings as shown on the drawings or as directed by the Engineer. The PVC drainpipes shall also be 40 mm diameter un-elasticized or as approved by the Engineer.

514.3 Construction Requirements

514.3.1 Composition (Shotcrete Mix Design).

Shotcrete mixtures shall be designed and produced conforming to Table 514-2.

Table 514-2
Composition of Shotcrete

Type of Shotcrete Process	Minimum Cement Content (Kg/m^3)	Maximum W/C Ratio	Air Content Range %	Minimum 28-Day Strength (Mpa)
Wet	325	0.55	NA	28
Dry	325	0.50	NA	28
Wet (Air-Entrained)	325	0.45	5 min.	28
Dry (Air-Entrained)	325	0.45	5 min.	28

Shotcrete mixtures shall also conform to the following ACI specifications:

a. ACI 506R Guide to Shotcrete

b. ACI 506.1 State of the Art Report on Fiber Reinforced Shotcrete

c. ACI 506.2 Specifications for Proportioning Application of Shotcrete

Mix design shall be verified with trial mixes prepared from the same source proposed for use. The following shall be submitted for acceptance before placing shotcrete:

1. Proposed shotcrete mix design with mix proportions. Dosage and type of any admixture shall be included with proposed mix design.

2. Results of shotcrete preconstruction testing.

3. Proposed method for applying shotcrete

4. Other information necessary to verify compliance with ACI 506.2.

5. Shotcrete materials certifications.

6. Fiber samples, if used.

7. Description of proposed equipment for mixing and placing shotcrete. Manufacturer's instructions, recommendations, literature, performance, and test data shall all be included. In addition to meeting equipment requirements in ACI 506, the following shall also be provided:

a. Water Supply System

For dry mix, a job site water storage tank shall be provided. It shall be provided with a positive displacement pump with a regulating valve that is accurately controlled to provide water at the required pressure and volume.

b. Mixing

Equipment capable of handling and applying shotcrete containing the specified maximum size aggregate and admixtures shall be used. An air hose and blow pipe shall be provided to clear dust and rebound during shotcrete application.

514.3.2 Hydration Stabilizing Admixtures

When hydration stabilizing admixtures are used to extend the allowable delivery time for shotcrete, admixtures shall be included in the shotcrete mix design. Dosage shall be based on the time needed to delay the initial set of the shotcrete for delivery and discharge on the job. Design discharge time limit shall be included in the dosage submittal. The maximum allowable design discharge time shall be 3.5 hours.

An approved and compatible hydration activator shall be used at the discharge site to ensure proper placement and testing.

Dosage required to stabilize shotcrete shall be determined using job site material and field trial mixtures. The extended-set admixture shall control the hydration of all cement minerals and gypsum.

When requested, the admixture manufacturer shall provide the service of a qualified person to assist in establishing the proper dose of extended-set admixture and shall make dosage adjustments required to meet changing job site conditions.

514.3.3 Preconstruction Testing

Preconstruction shotcrete field trials shall be conducted before starting shotcrete production.

1. Field Trials. Test panels shall be constructed from 600 millimeter by 600 millimeter by 150 millimeters wood forms. Each proposed nozzleman shall produced shotcrete panels on two vertical wood forms. The test panels shall be cured according to AASHTO T 23 except that the panels shall not be immersed in water or curing compound.

2. Coring. Six 75-millimeter diameter cores shall be taken from each test panel according to AASHTO T 24. The ends of the cores shall be trimmed according to AASHTO T 24 to make cores at least 75 millimeters long.

3. Compressive Strength Testing. The cores shall be soaked in water for 40 hours immediately before testing. Three cores from each test panel shall be tested four days after the field trial and the remaining three cores shall be tested 28 days after the field trial. Tests shall be performed according to AASHTO T 23.

4. Mix Design Acceptance. Test data and a visual description of each core shall be submitted. Details concerning presence of voids, sand pockets, lamination, and other inadequacies shall be included. Acceptance of the mix design shall be based on preconstruction field trials and test results. The visual quality of the cores shall not be lower than Grade 2 according to shotcrete grading requirements of ACI 506.2.

Field quality control test reports shall be submitted after performing the tests. The following information shall be included in the reports:

1. Sample identification including mix design and test panel number and orientation.

2. Date and time of sample preparation including curing conditions and sample dimensions.

3. Date, time, and type of test.

4. Complete test results including load and deformation data during testing, pictures of sample before and after testing, and any unusual occurrences observed.

5. Location of steel reinforcement, if used, covered by shotcrete.

514.3.4 Shotcrete Construction

Shotcrete application shall be according to ACI 506R and the following:

1. Surface Preparation.

For earth surfaces, all loose rock sharp protruding edges as well as dirt, grease, oil scale and other contaminations shall be carefully removed. Any seepage water entering shall be dealt with by suitable means, such as drainage boring with grouted pipe nipples connected to pipe, sealing measures, etc which shall be approved by the Engineer. Installation of weepholes shall follow the locations shown on the plans or as directed by the Engineer.

For previously placed shotcrete surfaces, curing compound shall be removed by sandblasting. Approved depth gauges to indicate the thickness of

the shotcrete layers shall be installed. Depth gauges shall be installed on 2-meter centers longitudinally and transversely with no less than two gauges per increment of surface area to receive the shotcrete. All surfaces shall be moistened.

2. Temperature and Weather Conditions.

The temperature of the shotcrete mix shall be maintained between 10 ^{0}C and 30 ^{0}C. Shotcrete shall be placed when the surface and ambient temperature is at least 5 ^{0}C and rising. Shotcrete operations shall not be performed during high winds and heavy rains.

3. Mixing

Thorough mixing of aggregates, cement, admixtures and water shall be ensured for all shotcrete mix.

4. Deliveries and Sampling

Sampling and testing requirements shall conform to Table 514-3.

All equipment shall be furnished and the temperature, unit mass, air content, slump, and other tests to verity specification compliance shall be performed before and during each placement operation.

If hydration stabilizing admixtures is used, the slump shall be determined before placement. Concrete with a slump loss of more than 50 mm as compared to the slump recorded at the batch plant shall not be used

Sample shall be taken from every batch of shotcrete mixture after at least 0.20 m^3 are discharge and before placing any of the batches. When continuous mixing is used, take sample from approximately every 7.5 m^3. The air content shall be tested according to AASHTO T 152 or T 196.

A single compressive strength test result is the average result from 2 cylinders cast from the same load and tested at 28 days. Remove and replace concrete if the compressive strength test results are less than 90 percent of specified design strength at the specified test age.

If three (3) successive samples are tested and compliance with the specifications is indicated, screening tests may be reduced to an approved frequency. Initial testing frequency shall be resumed if a test shows a failing temperature, air content, slump or when directed by the Engineer.

5. Shotcrete Application.

a. Shotcrete shall be applied within 45 minutes of adding cement to the mixture.

b. Layer thickness of each shotcrete application shall be limited to 50 millimeters. Thicker applications may be approved if the Contractor can demonstrate that no sloughing or sagging is occurring. If additional thickness is required, the applied surface shall be broomed or scarified and allow the layer to harden. The surface shall be dampened before applying an additional layer. Shooting shall be discontinued or shield the nozzle stream if wind causes separation of ingredients during shooting.

c. Laitance, loose material, and rebound shall be removed. Rebound shall be promptly removed from the work area.

d. Construction joints shall be tapered to a thin edge over a distance of at least 300 millimeters. Joint surface shall be wetted before placing additional shotcrete on the joint. Square construction joints shall not be used.

e. Shotcrete shall be finished as specified on the plan. The quantities of shotcrete mix to be discharged at the nozzle shall be determined based on the dimensions shown on the plans or as required by the Engineer. The surface of existing structures shall be protected before shooting of shotcrete mix. Rebound and hardened overspray shall be removed from final shotcrete surfaces and from areas not intended for shotcrete placement.

f. Minimum slump of wet-mix shotcrete shall be 25 mm.

514.3.5 Curing Shotcrete

Curing the surface shall immediately begin after the free surface water has evaporated and the finishing is completed. If the surface of the shotcrete begins to dry before the selected curing method can be implemented, shotcrete surface shall be kept moist using a fog spray without damaging the surface.

Surfaces to be rubbed shall be kept moist after forms are removed. It shall be cured immediately following the first rub.

All shotcrete shall be cured uninterrupted for at least 7 days.

For intermediate shotcrete surfaces or if a stained or finished final surface is required, the shotcrete surface shall be kept continuously wet by ponding, spraying, or covering with material that is kept continuously and thoroughly wet. Covering material may consist of cotton mats, multiple layers of burlap, or other approved material that does not discolor or otherwise damage the shotcrete and thereafter shall be covered with a waterproof sheet material that prevents moisture loss from the shotcrete. The widest sheets practical shall be used. Adjacent sheets shall be lapped at least 150 mm, and shall tightly seal all seams with pressure sensitive tape, mastic, glue, or other approved methods. All materials shall be secured so that wind does not displace them. Sheets that are broken or damaged shall be immediately repaired.

If stained or finished surface is not required, curing compound shall be applied to the final exposed shotcrete surface. The liquid membrane method shall not be used on surfaces that will receive a rubbed finish. Use on construction joint surfaces shall be permitted only if the compound is removed by sandblasting before placement of shotcrete against the joint. Only Type 2, white-pigmented, liquid membrane shall be used on surfaces not exposed to view in the completed work. Type 1 or 1-D clear curing compounds shall be used on other surfaces. Membrane curing solutions containing pigments shall be mixed before use. It shall be continuously agitated during application. Equipment capable of producing a fine spray shall be used. The curing compound shall be applied at a minimum rate of 0.25 liter per square meter in one or two uniform applications. If the solution is applied in 2 applications, the first application shall be followed with the second application within 30 minutes, and shall be applied at right angles to the first application. If the membrane is damaged by rain or other means during the curing period, a new coat shall be applied immediately over the damaged areas.

Shotcrete shall be maintained at a temperature above 5^0 C until shotcrete has achieved a minimum compressive strength of 5.2 MPa.

514.3.6 Production Report.

The contractor shall prepare and submit a written report of shotcrete production and application for each shift. The following information shall be included in the report:

1. Quantity and location of shotcrete applied including pictures of areas where shotcrete was placed.

2. Observations of success or problems of equipment operation, application, final product condition, and any other relevant issues during production and application.

3. Batch number/s if applicable.

514.4 Acceptance

Materials for shotcrete shall be evaluated by visual inspection and by a certification from the manufacturer. Material accepted by certification may be sampled and tested at any time. If found not in conformance with the contract, the material shall be rejected whether in place or not.

The shotcrete placement system, mixtures air content and unit mass shall all be evaluated by visual inspection and by the results of measurements and testing.

Compressive strength shall be evaluated by test results.

514.5 Method of Measurement

The area to be paid for under this Item shall be the number of surface square meters (m^2) of shotcrete placed and accepted in the completed slope. In computing the quantity, the dimensions shall be those as measured in place and completed based on the preceding requirements.

514.6 Basis of Payment

The accepted quantity, measured as prescribed in Section 514.5, shall be paid for at the contract unit price for shotcrete, which price and payment shall be full compensation for preparation of slope, furnishing all materials, for mixing, placing, sampling and testing, finishing and curing all shotcrete, and for furnishing all labor, equipment, tools and incidentals necessary to complete the Item.

Payment will be made under:

Pay Item Number	Description	Unit of Measurement
514 (1)	Shotcrete (with reinforcing steel)	m^2
514 (2)	Shotcrete (with reinforcing fibers)	m^2

References:

1. American Standards for Testing Materials (ASTM)
2. American Association of State Highways and Transportation Officials (AASHTO)
3. Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-03, Metric Units), U.S. Department of Transportation Federal Highway Administration
4. Specification for Shotcrete (ACI 506.2-95)
5. Technical Specifications for Baguio – Aritao Road Improvement Project, Contract Package II
6. DPWH Standard Specifications for Highways, Bridges and Airport, Volume II, 2004 Edition

TABLE 514-3
Sampling and Testing Requirements

Material or Product	Characteristic	Test Methods or Specifications	Sample Frequency	Point of Sampling	Split Sample	Reporting Time
Aggregate source quality	Quality	AASHTO M 80	1 per material type	Source of material	Yes	Before producing
Shotcrete Composition (mix design)	All	Subsection 514.3.1	1 per mix design	Source of material	Yes	Before producing
Production aggregate (fine & course)	Gradation	AASHTO T 27 & T 11	1 per material type	Flowing aggregate stream (bin, belt, discharge conveyor belt, or stockpile)	Yes, when requested	Before batching
	Fineness modulus	"	"	"	"	"
Shotcrete	Unit mass	AASHTO T 121	1 per load	Truck mixer or agitator (1)	–	Upon completing tests
	Air content	AASHTO T 152 or T 196	"	"	–	"
	Compressive strength	AASHTO T 24	1 set per 25 m^3 but not less than 1 per day	Production test panels	Note 3	Note 2

(1) Sample according to AASHTO T 141.
(2) Prepare production test panels according to Subsection 514.3.5. Obtain two 75-millimeter diameter core specimens from each panel according to AASHTO T 24. A single compressive strength test result is the average result from two 75-millimeter diameter core specimens from the same test panel tested according to AASHTO T 23 at 28 days.
(3) Deliver cores to designated laboratory for testing.