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Standard Specification for Fly Ash and Other Pozzolans for Use With Lime[1]

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1. Scope

1.1 This specification covers fly ash and other pozzolans for use with lime in plastic mortars, nonplastic mixtures and other mixtures that affect lime pozzolanic reaction. Evaluation of pozzolans containing available lime, such as Class C fly ash, is given consideration. Pozzolans covered include artificial pozzolans such as fly ash, and natural pozzolans, such as diatomite and pumicite, in either raw or calcined state.

1.2 The following precautionary caveat pertains only to the test method portion, Sections 5 and 10 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[3]

C 50 Practice for Sampling, Inspection, Packing, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (As Used by the Industry)[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

C 207 Specification for Hydrated Lime for Masonry Purposes[2]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[2]

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete[3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 821 Specification for Lime for Use With Pozzolans[2]

D 1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))[4]

D 5239 Practice for Characterizing Fly Ash for Use in Soil Stabilization[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *calcined pozzolans*—materials that are produced by calcination of natural siliceous or alumino-siliceous earths, such calcination being for the purpose of activation of pozzolanic properties.

3.1.2 *fly ash*—the finely divided residue that results from the combustion of ground or powdered coal and is transported from the boiler by flue gases. Additional methods for characterization of fly ash can be found in Practice D 5239.

3.1.2.1 *Discussion*—Section 12 provides guidance for determining the available lime index of fly ash, which may affect the desired proportions of fly ash with lime.

3.1.3 *lime*—all classes of quicklime and hydrated lime, both calcitic (high calcium) and dolomitic.

3.1.4 *natural pozzolans*—materials that, in the natural state, exhibit pozzolanic properties, such as some volcanic ash and lava deposits.

3.1.5 *pozzolan*—a siliceous or alumino-siliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties.

4. Physical Properties

4.1 Pozzolans for use with lime in plastic mortars, when tested in accordance with the procedures of Sections 7-9, shall conform to the requirements prescribed in Table 1.

4.2 Pozzolans for use with lime in nonplastic mixtures shall conform to the requirements of Table 1, except the lime-pozzolan strength requirement, and in addition shall be tested in accordance with the procedures of Section 10 and shall conform to the following requirements:

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[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.07 on Pozzolanic Materials.

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[2] *Annual Book of ASTM Standards,* Vol 04.01.

[3] *Annual Book of ASTM Standards,* Vol 04.02.

[4] *Annual Book of ASTM Standards,* Vol 04.08.

[5] *Annual Book of ASTM Standards,* Vol 04.09.

Compressive strength, min, psi (MPa)	400 (2.8)
Vacuum saturation strength, min, psi (MPa)	400 (2.8)

NOTE 1—If the minimum value of the vacuum saturation strength specified in 4.2 of this specification is reduced, sufficient documentation shall be provided to the user to enable the determination of a satisfactory minimum residual strength for the given material in its intended use. Such documentation should include at least the following: (*1*) determination of a minimum residual strength requirement that will enable the material to perform its structural function in the pavement system; and (*2*) a rational analysis, using actual climatic data, that will show the severity of exposure of the material to cyclic freeze-thaw action.

TABLE 1 Physical Requirements

Water-soluble fraction, max, %	10.0
Fineness, amount retained, when wet sieved:	
No. 30 (600-µm) sieve, max, %	2.0
No. 200 (75-µm) sieve, max, %	30.0
Lime-pozzolan strength, minimum compressive strength, psi (MPa):	
At 7 days, 130 ± 3°F (54 ± 2°C)	600 (4.1)
After additional 21 days, 73± 3°F (23 ± 2°C)	600 (4.1)

5. Sampling

5.1 Sample pozzolan in accordance with the applicable provisions of Test Methods C 311, except take one 10-lb (4.5-kg) sample from approximately each 400 tons (350 metric tons) of pozzolan.

5.2 The sampling procedures and techniques shall be consistent from original sample to project completion.

TEST METHODS

6. Significance and Use

6.1 This test method states various procedures that are recommended to quantify various aspects of the lime enhanced pozzolanic reaction. These tests are intended to qualify or quantify sources of fly ash and other pozzolans to meet specified job or project criteria.

7. Water-Soluble Fraction

7.1 *Procedure*—Place 10 g of a dried pozzolan sample (dried to constant weight in an oven at 221 to 230°F (105 to 110°C)) in a 200-mL Erlenmeyer flask and add 100 mL of distilled water at 73 ± 3°F (23 ± 2°C). Shake well by hand until no lumps can be observed; then with a mechanical shaker or stirring device, agitate at laboratory room temperature for a period of 1 h. Pour the material into a weighed Gooch or sintered-glass crucible, and wash all residue from the flask into the crucible with distilled water from a wash bottle. Wash the residue in the crucible free of adhering solution by repeated washings with distilled water. Dry the crucible to constant weight in an oven at 221°F (105°C).

7.2 *Calculation*—Calculate the percentage of water-soluble fraction by multiplying the loss in weight in grams by 10.

8. Fineness

8.1 Test in accordance with Test Methods C 110, except that the sample shall be 100 g of the dried pozzolan.

9. Lime-Pozzolan Strength Development

9.1 Test the pozzolan in accordance with the applicable portions of Test Method C 109 and Practice C 305, and in accordance with the following:

9.2 *Apparatus*:

9.2.1 *Oven*, closed, vapor-type.

9.3 *Materials*:

9.3.1 *Hydrated Lime*—Where possible, the lime shall be the same as that to be used on the job or shall meet the requirements of Specification C 207.

9.3.2 *Sand*—The sand shall be graded standard sand as required by Test Method C 109.

9.4 *Number of Test Specimens*—Three specimens shall be prepared for each age at which a strength test is desired.

9.5 *Proportioning, Consistency, and Mixing of Mortars*—Batches shall be of a size sufficient to make six specimens and shall consist of proportions of dry materials as follows:

Hydrated lime	180 g
Pozzolan (dry basis)	360 g
Graded standard sand	1480 g

9.5.1 The amount of mixing water, measured in millilitres, shall be such as to produce a flow of 65 to 75 as determined in accordance with 9.6, and shall be expressed as weight percent of the combined lime and pozzolan. The lime and pozzolan shall be blended together in a closed container. Mixing shall be done in accordance with the procedure described in Practice C 305, except that it shall be amended to read "Add the blended lime and pozzolan to the water and allow it to stand for 1 min. Then start the mixer and mix at slow speed (140 ± 5 rpm) for 30 s."

9.6 *Determination of Flow*—Determine the flow in accordance with Test Method C 109, except that the number of drops of the flow table shall be 10 drops in 6 s instead of 25 drops in 15 s. If the flow is less than the specified limit, the material used for the flow test may be returned to the mixing bowl and additional water added, the batch mixed for 1½ min, and a new flow taken. This operation may be repeated until a flow within the specified range is obtained. If the flow exceeds the range specified, discard the batch and give a new batch a new trial until a flow within range is obtained.

9.7 *Molding Test Specimens*—Immediately after the completion of the flow test, mold mortar specimens in accordance with Test Method C 109.

9.8 *Storage of Test Specimens*—When molding is completed, place the filled mold in the vapor immediately above water at 130 ± 3°F (54 ± 2°C) in a closed vapor oven with the top surface protected from the drip. Allow the specimens in the molds to remain in the vapor for a period of 7 days, after which remove them from the vapor and cool to 73 ± 3°F (23 ± 2°C) in air saturated sufficiently that no drying takes place during the cooling. When the specimens are cool, remove them from the molds, and store them at 73 ± 3°F (23 ± 2°C) at 95 to 100 % relative humidity until time of the compressive strength test.

10. Compressive Strength Development and Freeze-Thaw Resistance of Nonplastic Mixtures

10.1 *Materials*:

10.1.1 *Hydrated Lime*—Where possible, the lime shall be the same as that to be used on the job, or shall meet the applicable requirements of Specification C 207, Type N. Prior to usage, the lime shall be stored in a sealed container to prevent carbonation.

10.1.2 *Pozzolan*—The pozzolan used in this test shall be the same as intended for use on the job.

10.1.3 *Aggregate*—Where possible, the aggregate used in this test shall be the same as intended for use on the job. When using job aggregates, discard the material, if any, retained on the ¾-in. (19.0-mm) sieve. If the aggregate fraction between the ¾-in. and No. 4 (4.75-mm) sieve does not contain free surface moisture, then that fraction of the aggregate shall be soaked for 24 h and towel dried to obtain a saturated surface dry condition. If job aggregates are not available, graded standard sand as specified in Test Method C 109 shall be used.

10.2 *Number of Specimens*—Three specimens shall constitute one test for the compressive strength test with three additional specimens for the freeze-thaw test.

10.3 *Proportioning*—The proportion of dry materials by weight shall be, where possible, the same proportions as intended for use on the job. If graded standard sand is used as the aggregate, the proportions of dry materials by weight shall be as follows:

Hydrated lime	4 %
Pozzolan	24 %
Graded standard sand	72 %

The amount of mixing water shall be the optimum moisture content as determined by Method C of Test Methods D 1557, except that the 5-lift requirement is replaced with 3 lifts and Note 1 is not to be used. In determining the moisture-density relationship, mix dry materials in a Lancaster PC Mixer, or its equivalent, for 1 min, or until the mixture is uniform in color and texture, plus an additional 3 min after the water is added in order to obtain the first point on the moisture-density curve. The original sample may be reused for subsequent trials. The batch shall be mixed for an additional minute after the water has been added for each subsequent trial.

10.4 *Mixing and Molding Test Specimens*— After the optimum moisture content is obtained by the above procedure, a batch large enough to make three 4.0 by 4.6-in. (102 by 117-mm) cylinders (approximately 15 lb (7 kg)) shall be mixed in the following manner: Mix the dry materials in a Lancaster PC Mixer, or its equivalent, for 1 min or until the mixture is uniform in color and texture, followed by the addition of water that will give optimum moisture content and an additional 3 min of mixing. Mold the specimens immediately in accordance with Method C of Test Methods D 1557, except as previously noted. Each layer should be scarified to a depth of ¼ in. (6 mm) before the next layer is compacted in order to assure a good bond between the layers. Weigh a representative sample of the mixture, using a container with a tight lid to assure that no moisture is lost while determining the weight of the sample. Dry to constant weight and calculate the actual moisture content of the sample. After molding, weigh each sample in the mold to determine the uniformity of molded weights of the specimens and then carefully remove from the mold by the use of a sample extruded, such as a jack or lever frame.

10.5 *Curing of Test Specimens*—Immediately after the specimens are removed from the mold, reweigh the specimens and place in a sealed container (½-gal (2-L) or 1-gal (4-L) can with double friction lids) to prevent loss of moisture. Place the specimens in the sealed containers carefully in a room or cabinet with forced-air circulation maintained at 100 ± 3°F (38 ± 2°C) for a 7-day period. After this period, remove the specimens from the container, reweigh, and allow to cool to room temperature. Submerge the specimens for compressive strength testing in water for 4 h, remove, allow to drain on a nonabsorbent surface, and cap and test within 1 h of the time of removal from the water.

10.6 *Number of Test Specimens*:

10.6.1 Three specimens shall be tested in accordance with Test Method C 39; no *l*/*d* correction will be considered in the computation of the compressive strength.

10.6.2 Three specimens shall be tested for freeze-thaw resistance after being cured in accordance with 10.5 (without the 4-h soaking period) by means of the vacuum saturation strength testing procedure described in Section 11.

11. Vacuum Saturation Strength Testing Procedure

11.1 *Equipment*:

11.1.1 *Vacuum Saturation Chamber*—The vacuum saturation chamber is a 12-in. (305-mm) high by 12-in. inside diameter stainless steel cylindrical section welded to a ½-in. (12.7-mm) thick by 14-in. (356-mm) diameter stainless steel base plate. The wall thickness of the cylindrical section is ⅜ in. (9.5 mm). The lid of the vacuum saturation chamber is a poly(methylmethacrylate) (PMMA) plate 1 in. (13 mm) thick and 14 in. in diameter. Both the PMMA lid and top of the vacuum cylinder are grooved for a ¼-in. (6.4-mm) circular O-ring seal having an inside diameter of 12⅛ in. (308 mm). The lid is fastened to the chamber by six equally spaced threaded ¼-in. rods which pass along the outside wall of the cylindrical section and thread into the base plate.

11.1.1.1 A sketch of the vacuum saturation chamber described above is shown in Fig. 1. A vacuum saturation chamber of equivalent size and capability is permitted under this specification. Vacuum desiccators can also be used for this purpose.

11.1.1.2 A ¼-in. (6.4-mm) vacuum line connection is located 1 in. (13 mm) below the top of the vacuum chamber and a ⅜-in. (9.5-mm) water line connection with control valve is located at the base of the vacuum chamber. The vacuum line is connected to a commercial vacuum pump and the water line is connected to a reservoir of desired water. The vacuum is controlled by a pressure valve at the vacuum pump.

11.1.1.3 The specimen support plate inside of the chamber is constructed of ½-in. (12.7-mm) thick PMMA which is 11½ in. (292 mm) in diameter. The support plate sits on three 1½-in. (38.1-mm) long legs which elevate it off of the bottom of the chamber. The specimen support plate is perforated (approximately ten ⅛-in. (3.2-mm) diameter holes per square inch) so as to allow complete access of water to the specimens during saturation. For an equivalent size vacuum saturation chamber, a specimen support plate similar to that described above must be provided.

11.1.1.4 The vacuum saturation chamber must be of sufficient size to hold the same number of Proctor-sized specimens for vacuum saturation testing as the number of specimens tested for compressive strength.

11.1.2 *Vacuum System*—A system capable of maintaining a

FIG. 1 Pictorial View of Vacuum Saturation Equipment

vacuum of 24 in. Hg (11.8 psi) for a minimum of 30 min is required.

11.2 *Procedure*:

11.2.1 At the end of the curing period, remove the specimens from the curing room and allow approximately 2 h to reach equilibrium with room temperature. The specimens should remain sealed in the containers during this 2-h equilibration period in order to prevent moisture loss.

11.2.2 Place the cured specimens in an upright position on the specimen support plate within the vacuum chamber. Place the lid on the vacuum chamber and evacuate the chamber to a pressure of 24 in. Hg gradually over a period of not less than 45 s and hold for 30 min in order to remove air from the voids in the specimens. After the 30-min de-airing period, flood the vacuum chamber with water at room temperature to a depth sufficient to cover the specimens. Remove the vacuum and then soak the specimens for 1 h at atmospheric pressure.

11.2.3 At the end of the soaking period, remove the specimens from the water and allow to drain for approximately 2 min on a nonabsorptive surface. After the free surface water has drained, immediately test the specimens for unconfined compressive strength in accordance with Test Method C 39.

11.3 *Report*—Report of the compressive strength and vacuum saturation strength tests shall include the following:

11.3.1 Identification of each material used in the preparation of the specimens,

11.3.2 Percentage by dry weight of each of the constituents,

11.3.3 Actual percentage moisture content of mixture,

11.3.4 Actual dry unit weight of each specimen, nearest lb/ft^3 or g/cm^3,

11.3.5 Percentage of maximum dry unit weight of each specimen,

11.3.6 Cross-sectional area of each specimen, in. ^{2} or cm^2,

11.3.7 Maximum failure load of each specimen, lbf or N,

11.3.8 Compressive strength of each specimen, to nearest 5 psi or 50 kPa, and

11.3.9 Vacuum saturation strength of each specimen, to nearest 5 psi or 50 kPa.

11.3.10 The average compressive strength of the three specimens tested shall be designated as the test value for evaluation by this specification. The average vacuum saturation strength of the three specimens tested shall be designated as the test value for evaluation by this specification.

12. Available Lime Index of Fly Ash

12.1 The available lime index may be determined using the Available Lime Index Method of Test Methods C 25 (Hydrated Lime Procedure). See also Practice C 50, Terminology C 51, and Specification C 821.

12.2 The precision for pulverized coal fly ash, using the procedure of 12.1, is as follows:

12.2.1 The single operator standard deviation has been found to be 0.095 %.[6] Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.268 %.[6]

12.2.2 The multilaboratory standard deviation has been found to be 0.264 %.[6] Therefore, results of two properly conducted tests from two different laboratories on identical samples should not differ by more than 0.75 %.[6]

13. Storage and Inspection

13.1 Pozzolans shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment. Reasonable facilities shall be provided the purchaser for careful sampling and inspection either at the source or at the site of the work, as may be specified by the purchaser.

14. Rejection

14.1 Pozzolan may be rejected if it fails to meet any of the

[6] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

requirements of this specification.

14.2 Packages varying more than 5 % from the stated weight may be rejected; and if the average weight of the packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

15. Packaging and Package Marking

15.1 When pozzolan is delivered in packages, the name and brand and the weight of material contained therein shall be plainly marked on each package. Similar information shall be provided in shipping invoices accompanying the shipment of packaged or bulk pozzolans.

16. Keywords

16.1 fly ash; freeze-thaw resistance; lime; nonplastic mixture; pozzolan; plastic mortar; strength development