



Designation: **C593 – 06 (Reapproved 2011) C593 – 19**

## Standard Specification for Fly Ash and Other Pozzolans for Use With Lime for Soil Stabilization<sup>1</sup>

This standard is issued under the fixed designation C593; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 This specification covers the qualification of fly ash and other pozzolans for use with lime in plastic, nonplastic mixtures and other mixtures that affect lime pozzolanic reaction required by soil stabilization. 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 values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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, health, and ~~health~~ environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

[C25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime](#)

[C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens](#)

[E50/C50/C50M Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products](#)

[C51 Terminology Relating to Lime and Limestone \(as used by the Industry\)](#)

[C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars \(Using 2-in. or \[50-mm\] Cube Specimens\)](#)

[C110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone](#)

[C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency](#) [/astm-c593-19](#)

[E311/C311M Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete](#)

[C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials](#)

[C778 Specification for Standard Sand](#)

[C821 Specification for Lime for Use with Pozzolans](#)

[D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort \(56,000 ft-lbf/ft<sup>3</sup> \(2,700 kN-m/m<sup>3</sup>\)\)](#)

### 3. Terminology

3.1 For definitions of terms specific to this specification, see Terminology [C51](#).

### 4. Physical Properties

4.1 Pozzolans for use with lime in plastic mixtures, when tested in accordance with the procedures of Sections 7 – 9, shall conform to the requirements prescribed in [Table 1](#).

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee C07 on Lime and Limestone and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved June 1, 2011; Dec. 1, 2019. Published July 2011; December 2019. Originally approved in 1966. Last previous edition approved in 2006 as C593 – 06; C593 – 06 (2011). DOI: 10.1520/C0593-06R11; 10.1520/C0593-19.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard

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**.

**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- $\mu$ m) sieve, max, %	2.0
No. 200 (75- $\mu$ m) sieve, max, %	30.0
Lime-pozzolan strength, minimum compressive strength, psi (MPa):	
— At 7 days, 130 $\pm$ 3 $^{\circ}$ F (54 $\pm$ 2 $^{\circ}$ C)	600 (4.1)
— After additional 21 days, 73 $\pm$ 3 $^{\circ}$ F (23 $\pm$ 2 $^{\circ}$ C)	600 (4.1)
Compressive strength, min, psi (MPa)	400 (2.8)
Vacuum saturation strength, min, psi (MPa)	400 (2.8)

**TABLE 1 Physical Requirements**

Water-soluble fraction, max, %	10.0
Fineness, amount retained, when wet sieved:	
600- $\mu$ m (No. 30) sieve, max, %	2.0
75- $\mu$ m (No. 200) sieve, max, %	30.0
Lime-pozzolan strength, minimum compressive strength, MPa:	
At 7 days, 54 $\pm$ 2 $^{\circ}$ C	4.1
After additional 21 days, 23 $\pm$ 2 $^{\circ}$ C	4.1
Compressive strength, min, MPa	2.8
Vacuum saturation strength, min, MPa	2.8

## 5. Sampling

5.1 Sample pozzolan in accordance with the applicable provisions of Test Methods **C311/C311M**, except take one ~~10-lb (4.5-kg)~~ 4.5-kg sample from approximately each 400 tons (350 metric 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 sources of fly ash and other pozzolans to meet specified job or project criteria as related to soil stabilization.

### 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  $^{\circ}$ F (105 to 110  $^{\circ}$ C)) 105 to 110  $^{\circ}$ C in a 200-mL Erlenmeyer flask and add 100 mL of distilled water at 73  $\pm$  3  $^{\circ}$ F (23  $\pm$  2  $^{\circ}$ C) 23  $\pm$  2  $^{\circ}$ 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  $^{\circ}$ F (105  $^{\circ}$ C) 105  $^{\circ}$ 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 **C110**, 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 **C109/C109M** and Practice **C305**, 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 and shall meet the requirements of Specification **C821**.

9.3.2 *Sand*—The sand shall be graded standard sand as required by Test Method ~~C109/C109M~~ and meet the requirements of Specification ~~C109/C109M~~**C778**.

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*—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 **C305**, 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 ( $140 \pm 5$  rpm) for 30 s.”

9.6 *Determination of Flow*—Determine the flow in accordance with Test Method **C109/C109M**, 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 specimens in accordance with Test Method **C109/C109M**.

9.8 *Storage of Test Specimens*—When molding is completed, place the filled mold in the vapor immediately above water at  $54 \pm 3$  °F ( $54 \pm 2$  °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  $73 \pm 3$  °F ( $23 \pm 2$  °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  $73 \pm 3$  °F ( $23 \pm 2$  °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 and shall meet the applicable requirements of Specification **C821**. 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)~~ 19.0-mm sieve. If the aggregate fraction between the ~~¾-in. and No. 4 (4.75-mm)~~ 19.0-mm and 4.75-mm (No. 4) 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 **C109/C109M** 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 **D1557**, 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)) 102 by 117-mm cylinders (approximately 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