Designation: C 441 – 02

Standard Test Method for Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction[1]

This standard is issued under the fixed designation C 441; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the effectiveness of mineral admixtures or slag in preventing the excessive expansion caused by reaction between aggregates and alkalies in portland cement mixtures. The evaluation is based on the expansion developed in mortar bars by a combination of portland cement and a mineral admixture or slag, made with reactive aggregates (Pyrex glass), during storage under prescribed conditions of test.

1.2 *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 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 150 Specification for Portland Cement[3]

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)[2]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete[2]

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars[2]

C 1240 Specification for Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout[2]

C 1437 Test Method for Flow of Hydraulic Cement Mortar[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 125.

4. Significance and Use

4.1 This test method may be used as a preliminary or screening test to evaluate the relative effectiveness of a number of different materials being considered for use to prevent excessive expansion due to alkali-silica reaction.

4.2 This test method may also be used to evaluate materials proposed for use on a particular job to prevent excessive expansion due to alkali-silica reaction, by testing in the quantity and in combination with the cement or cements to be used on the job.

4.3 This test method does not assess the suitability of mineral admixtures or slag for use in concrete. These materials should comply with Specification C 618, Specification C 989 or Specification C 1240.

5. Apparatus

5.1 The apparatus shall be as described in Test Method C 227.

6. Materials

6.1 *Pyrex Glass* [4] —Crushed Pyrex Glass No. 7740 cullet or solid glass rod crushed and graded according to Table 1. After the Pyrex glass has been separated into the various sieve sizes, wash with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. Dry the portions retained on the various sieves and, unless used immediately, store each such portion individually in a clean container provided with a tight-fitting cover.

6.2 *High-Alkali Cement*—For the preparation of mortar bars for the preliminary or screening tests, use a blend of cement or cements that conform to Specification C 150 and contain between 0.95 and 1.05 % total alkalies as sodium oxide (Na_2O) calculated as % Na_2O + 0.658 × % potassium oxide (K_2O). If blending is needed, introduce the individual cements into the batch separately.

7. Proportioning and Consistency of Mortar

7.1 *Control Mixture*—The quantities of dry materials for the control mixture shall be 400 g of high-alkali cement and 900 g

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

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

[4] Pyrex Brand Glass No. 7740 is available as lump cullet from the Corning Glass Works, Corning, NY.

TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75-mm (No. 4)	2.36-mm (No. 8)	10
2.36-mm (No. 8)	1.18-mm (No. 16)	25
1.18-mm (No. 16)	600-µm (No. 30)	25
600-µm (No. 30)	300-µm (No. 50)	25
300-µm (No. 50)	150-µm (No. 100)	15

of Pyrex glass aggregate made by recombining the portions retained on the various sieves in the prescribed grading (Table 1). Test specimens made from the control mixture shall have a 14-day increase in length of at least 0.250 %.

7.2 *Test Mixture Using Mineral Admixtures*—The quantities of dry materials for the test mixture shall be 300 g of high-alkali cement, a mass of mineral admixture having an absolute volume equal to the absolute volume of 100 g of portland cement (100 × density of mineral admixture/3.15) and 900 g of Pyrex glass aggregate made as described for the control mixture.

7.3 *Test Mixture Using Slag*—The quantities of dry materials for this test mixture shall be 200 g of high-alkali cement, a mass of slag having an absolute volume of 200 g of portland cement (200 × density of slag/3.15) and 900 g of Pyrex glass made in accordance with 7.1.

7.4 A smaller quantity of the mineral admixture or slag and a proportionately large quantity of cement may be used if there is evidence that it is unusually effective in reducing expansion due to the alkali-silica reaction and that the use of a smaller quantity is likely to produce a large reduction of expansion of the test mixture as compared to that of the control mixture.

7.5 *Job Mixture*—The quantities of dry materials used for the job mixture shall be in accordance with the requirements given above, except that the cement or cements to be used on the job shall be used instead of the high-alkali cement. Also, the quantity of mineral admixture or slag, by mass, used with the portland cement shall be equivalent to that proposed for use on the job.

7.6 *Flow*—The amount of mixing water, measured in millilitres, shall be such as to produce a flow of between 100 and 115 as determined in accordance with Test Method C 1437.

8. Temperature and Humidity

8.1 The temperature of the dry materials, water, molding room, and moist cabinet and the humidity of the laboratory and moist cabinet shall conform to the requirements of Test Method C 227.

9. Test Specimen

9.1 *Preparation of Molds*—Prepare the molds as specified in Test Method C 227.

9.2 *Mixing of Mortar*—Mix the mortar as specified in Test Method C 227, except add the admixture or slag with the cement to the water.

9.3 *Molding Test Specimens*—Mold the specimens as specified in Test Method C 227.

9.4 *Dimensions and Number of Test Specimens*—Make three 1 by 1 by 11¼-in. or 25 by 25 by 285-mm test specimens having an effective gage length of 10 ± 0.1 in. or 254 ± 2.5 mm from each batch of each mortar mixture. One set of three specimens shall represent each test mixture or each job mixture. On the same day that the test specimens are made, make one set of three specimens representing the control mixture and store in the same container with the corresponding test specimens. Make all specimens stored in a given container on the same day. If more specimens from test or job mixtures, or both, are made on a given day than can be stored in a single container with the specimens from the control mixture made on that day, make additional control mixture specimens for each additional storage container used.

10. Procedure

10.1 Store and measure the test specimens in accordance with the applicable requirements of Test Method C 227.

11. Calculation

11.1 For tests of mixtures proportioned as prescribed, calculate the reduction of mortar expansion resulting from the use of a mineral admixture or slag and report the result to the nearest 0.1 % as follows.

$$R_e = (E_r - E_t) \times 100/E_r$$

where:

R_e = reduction of mortar expansion, %,
E_t = average increase in length of mortar bars from the test mixture, and
E_r = average increase in length of mortar bars from the control mixture.

11.2 For test mixtures proportioned in accordance with the job mixture procedure, report the average length increase of the mortar bars as the length increase of the combination proposed for use in the work. Indicate contraction (length decrease) by prefixing a minus sign to the value of the length change reported.

12. Interpretation

12.1 Information pertaining to this procedure and to the significance of the results obtained has been published[5,6,7,8] and should be reviewed before results of the test are used as a basis for conclusions and recommendations concerning the properties and use of mineral admixtures, or slag combinations for concrete.

12.2 Minimum values for the reduction of mortar expansion (R_e) have been selected for use in specifications as a basis for acceptance of mineral admixture or slag proposed for use in

[5] Moran, W. T., and Gilliland, J. L., "Summary of Methods for Determining Pozzolanic Activity," *Symposium on Use of Pozzolanic Materials in Mortars and Concretes, ASTM STP 99*, ASTM International, 1950, p. 109.

[6] Gilliland, J. L., and Bartley, T. R., "Water-Solubility of Alkalies in Portland Cement," *Journal of the American Concrete Institute*, American Concrete Institute, Vol 47, 1951, p. 153 (especially Fig. number 2 and Table number 3).

[7] Mielenz, R. C., Greene, K. T., Benton, E. J., and Geier, F. H., "Chemical Test for Alkali Reactivity of Pozzolans," *Proceedings*, ASTM International, Vol 52, 1952, p. 1128.

[8] Pepper, L., and Mather, B., "Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete Due to Alkali-Aggregate Reaction," *Proceedings*, ASTM International, Vol 59, 1959, p. 1178–1203.

combination with high-alkali cement and an aggregate known to be potentially deleteriously alkali reactive.

13. Report

13.1 Report the following information:

13.1.1 The type of portland cement used and its total alkali content as Na_2O in percent. If the test is applied to a cement-mineral admixture or cement-slag combination to be used in specific work, the type, brand, and manufacturing plant of the cement.

13.1.2 The type and proportion of mineral admixture or slag used. If the test is applied to a cement-mineral admixture or cement-slag combination to be used in specific work, the type, brand, source, proportion, and the nature of the mineral admixture or slag.

13.1.3 If the control mixture and the test mixture are prepared as specified, the average increase in length of the mortar bars prepared from the control mixture and the average increase in length of the mortar bars from the test mixture, in percent. Also, the reduction in mortar length change resulting from the use of the mineral admixture or slag (R_e), in percent.

13.1.4 The average increase in length of the mortar bars prepared from the job mixtures, in percent.

14. Precision and Bias

14.1 *Precision*—Repeatability shall be considered satisfactory if the percentage length increase of each specimen made from the same cement-aggregate combination is within 0.003 of the average, except that, if the average length increase exceeds 0.02 %, the repeatability shall be considered satisfactory if the percentage length increase of each specimen molded from the same cement-aggregate combination is within 15 % of the average.

14.2 *Bias*—This procedure has no bias because the effectiveness is defined in terms of this test method.

15. Keywords

15.1 alkali-silica reaction; concrete; expansion; fly ash; ground blast-furnace slag; mineral admixture; mortar; silica fume