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## Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction<sup>1</sup>

This standard is issued under the fixed designation C 1293; 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 test method covers the determination of the susceptibility of an aggregate or combination of an aggregate with pozzolan or slag for participation in expansive alkali-silica reaction by measurement of length change of concrete prisms.

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. (Warning—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.<sup>2</sup>)*

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound values in parentheses are for information only.

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>3</sup>

C 29/C 29M Test Method for Bulk Density (Unit Weight) and Voids in Aggregate

C 33 Specification for Concrete Aggregates

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

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

C 289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 856 Practice for Petrographic Examination of Hardened Concrete

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

C 1240 Specification for Silica Fume Used in Cementitious Mixtures

C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

D 75 Practice for Sampling Aggregates

#### 2.2 CSA Standards:<sup>4</sup>

<sup>1</sup> This test method is under the jurisdiction of Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

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<sup>2</sup> Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, <http://www.csa.ca>.

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

CSA A23.2-14A Potential Expansivity of Aggregates (Procedure for Length Change due to Alkali-Aggregate Reaction in Concrete Prisms at 38 °C)

CSA A23.2-27A Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete

CSA A23.2-28A Standard Practice for Laboratory Testing to Demonstrate the Effectiveness of Supplementary Cementing Materials and Lithium-Based Admixtures to Prevent Alkali-Silica Reaction in Concrete

### 3. Terminology

3.1 Terminology used in this standard is as given in Terminology C 125 or Descriptive Nomenclature C 294.

### 4. Significance and Use

4.1 Alkali-silica reaction is a chemical interaction between some siliceous constituents of concrete aggregates and hydroxyl ions (1).<sup>5</sup> The concentration of hydroxyl ion within the concrete is predominantly controlled by the concentration of sodium and potassium (2).

4.2 This test method is intended to evaluate the potential of an aggregate or combination of an aggregate with pozzolan or slag to expand deleteriously due to any form of alkali-silica reactivity (3,4).

4.3 When testing an aggregate with pozzolan or slag, the results are used to establish minimum amounts of the specific pozzolan or slag needed to prevent deleterious expansion. Pozzolan or slag from a specific source can be tested individually or in combination with pozzolan or slag from other sources.

4.4 When selecting a sample or deciding on the number of samples for test, it is important to recognize the variability in lithology of material from a given source, whether a deposit of sand, gravel, or a rock formation of any origin. For specific advice, see Guide C 295.

4.5 This test method is intended for evaluating the behavior of aggregates in portland cement concrete with an alkali (alkali metal oxide) content of 5.25 kg/m<sup>3</sup> (8.85 lb/yd<sup>3</sup>) or in concrete containing pozzolan or slag with an alkali content proportionally reduced from 5.25 kg/m<sup>3</sup> (8.85 lb/yd<sup>3</sup>) Na<sub>2</sub>O equivalent by the amount of pozzolan or slag replacing portland cement. This test method assesses the potential for deleterious expansion of concrete caused by alkali-silica reaction, of either coarse or fine aggregates, from tests performed under prescribed laboratory curing conditions that will probably differ from field conditions. Thus, actual field performance will not be duplicated due to differences in concrete alkali content, wetting and drying, temperature, other factors, or combinations of these (5).

4.6 Results of tests conducted on an aggregate as described herein should form a part of the basis for a decision as to whether precautions should be taken against excessive expansion due to alkali-silica reaction. Results of tests conducted on combinations of an aggregate with pozzolans or slag should form a part of the basis for a decision as to whether the specific pozzolan or slag, when used in the amount tested, was effective in preventing excessive expansion. These decisions should be made before a particular aggregate is used in concrete construction. Criteria to determine the potential deleteriousness of expansions measured in this test are given in Appendix X1.

4.7 When the expansions in this test method are greater than the limit shown in X1.2, the aggregate or combination of aggregate with the tested amount of pozzolan or slag is potentially alkali-reactive. Supplemental information should be developed to confirm that the expansion is actually due to alkali-silica reaction. Petrographic examination of the concrete prisms should be conducted after the test using Practice C 856 to confirm that known reactive constituents are present and to identify the products of alkali-silica reactivity. Confirmation of alkali-silica reaction is also derived from the results of the test methods this procedure supplements (see Appendix X1).

4.8 If the supplemental tests show that a given aggregate is potentially deleteriously reactive, additional studies may be appropriate to evaluate preventive measures in order to allow safe use of the aggregate. Preventive measures are mentioned in the Appendix to Specification C 33.

4.9 This test method does not address the general suitability of pozzolans 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 molds, the associated items for molding test specimens, and the length comparator for measuring length change shall conform to the applicable requirements of Test Method C 157/C 157M and Practice C 490, and shall have square cross sections of 75.0 ± 0.7 mm (3.00 ± 0.03 in.).

5.2 The storage container options required to maintain the prisms at a high relative humidity are described in 5.2.1.

5.2.1 *Recommended Container*—The recommended containers are 19 to 22-L (5 to 5.8-gal) polyethylene pails with airtight lids and approximate dimensions of 250- to 270-mm (9.8- to 10.6-in.) diameter at bottom, 290 to 310 mm (11.4 to 12.2 in.) at top, by 355 to 480 mm (14.0 to 18.9 in.) high. Prevent significant loss of enclosed moisture due to evaporation with airtight lid seal. Place a perforated rack in the bottom of the storage container so that the prisms are 30 to 40 mm (1.2-1.6 in.) above the bottom. Fill

<sup>5</sup> The boldface numbers in parentheses refer to the list of references at the end of this test method.

the container with water to a depth of  $20 \pm 5$  mm ( $0.8 \pm 0.2$  in.) above the bottom. A significant moisture loss is defined as a loss greater than 3 % of the original amount of water placed at the bottom of the pail. Place a wick of absorbent material around the inside wall of the container from the top so that the bottom of the wick extends into the water (See Note 1).

5.2.2 *Alternative Containers*—Alternative storage containers may be used. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.<sup>6</sup> The expansion efficiency is confirmed when expansions at one year obtained using the alternative container are within 10 % of those obtained using the recommended container. Alternative storage containers must contain the required depth of water. When reporting results, note the use of an alternative container, if one is used, together with documentation proving compliance with the above.

NOTE 1—Polypropylene geotextile fabric or blotting paper are suitable materials for use as the wick.

5.3 The storage environment necessary to maintain the  $38.0$  °C ( $100.4$  °F) reaction accelerating storage temperature consistently and homogeneously is described in 5.3.1.

5.3.1 *Recommended Environment*—The recommended storage environment is a sealed space insulated so as to minimize heat loss. Provide a fan for air circulation so the maximum variation in temperature measured within 250 mm (9.8 in.) of the top and bottom of the space does not exceed  $2.0$  °C ( $3.6$  °F). Provide an insulated entry door with adequate seals so as to minimize heat loss. Racks for storing containers within the space are not to be closer than 30 mm (1.2 in.) to the sides of the enclosure and are to be perforated so as to provide air flow. Provide an automatically controlled heat source to maintain the temperature at  $38.0 \pm 2.0$  °C ( $100.4 \pm 3.6$  °F) (see Note 2). Record the ambient temperature and its variation within the space to ensure compliance.

NOTE 2—It has been found to be good practice to monitor the efficiency of the storage environment by placing thermocouples inside dummy concrete specimens inside a dummy container within the storage area. The storage room described in Test Method C 227 generally will be satisfactory.

5.3.2 *Alternative Storage Environment*—Use of an alternative storage environment is permitted. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.<sup>6</sup> The expansion efficiency is confirmed when expansions at one year obtained using the alternative storage environment are within 10 % of those obtained using the recommended environment. When reporting the results, note the use of an alternative storage environment, if one is utilized, together with documentation proving compliance with the above.

## 6. Reagents

6.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used. (**Warning**—Before using NaOH, review: (1) the safety precautions for using NaOH; (2) first aid for burns; and (3) the emergency response to spills as described in the manufacturers Material Safety Data Sheet or other reliable safety literature. NaOH can cause severe burns and injury to unprotected skin and eyes. Always use suitable personal protective equipment including: full-face shields, rubber aprons, and gloves impervious to NaOH (Check periodically for pinholes).)

6.2 *Water:*

6.2.1 Use potable tap water for mixing and storage.

## 7. Materials

7.1 *Cement*—Use a cement meeting the requirements for a Type I Portland cement as specified in Specification C 150. The cement must have a total alkali content of  $0.9 \pm 0.1$  %  $\text{Na}_2\text{O}$  equivalent ( $\text{Na}_2\text{O}$  equivalent is calculated as percent  $\text{Na}_2\text{O} + 0.658 \times$  percent  $\text{K}_2\text{O}$ ). Determine the total alkali content of the cement either by analysis or by obtaining a mill run certificate from the cement manufacturer. Add NaOH to the concrete mixing water so as to increase the alkali content of the mixture, expressed as  $\text{Na}_2\text{O}$  equivalent, to 1.25 % by mass of cement (see Note 3).

NOTE 3—The value of 1.25 %  $\text{Na}_2\text{O}$  equivalent by mass of cement has been chosen to accelerate the process of expansion rather than to reproduce field conditions. At the  $420$  kg/m<sup>3</sup> ( $708$  lb/yd<sup>3</sup>) cement content, this corresponds to an alkali level of  $5.25$  kg/m<sup>3</sup> ( $8.85$  lb/yd<sup>3</sup>).

7.2 *Aggregates:*

7.2.1 To evaluate the reactivity of a coarse aggregate, use a nonreactive fine aggregate. A nonreactive fine aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar, (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.6 for interpretation of expansion data). Use a fine aggregate meeting Specification C 33 with a fineness modulus of  $2.7 \pm 0.2$ .

7.2.2 To evaluate the reactivity of a fine aggregate, use a nonreactive coarse aggregate. Prepare the nonreactive coarse aggregate according to 7.2.3.<sup>6</sup> A nonreactive coarse aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.6 for interpretation of expansion data). Use a coarse aggregate meeting Specification C 33. Test the fine aggregate using the grading as delivered to the laboratory.

<sup>6</sup> The sole source of supply of non-reactive aggregates and alkali-silica reactive aggregates of known expansion characteristics (6) known to the committee at this time is The Petrographer, Engineering Materials Office, Ministry of Transportation, 1201 Wilson Ave., Downsview, Ontario, Canada, M3M1J8.. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

7.2.3 Sieve all coarse aggregates to which this test method is applied and grade in accordance with the requirements in Table 1. Coarse aggregate fractions larger than 19.0-mm (¾-in.) sieve are not to be tested as such. When petrographic examination using Guide C 295 reveals that the material making up the size fraction larger than the 19.0-mm (¾-in.) sieve is of such a composition and lithology that no difference should be expected compared with the smaller size material, then no further attention need be paid to the larger sizes. If petrographic examination suggests the larger size material to be more reactive, the material should be studied for its effect in concrete according to one ~~or~~ of the other alternative procedures described herein:

7.2.3.1 *Proportional Testing*—Crush material larger than the 19.0-mm (¾-in.) sieve to pass the 19.0-mm (¾-in.) sieve. Grade the material passing the 19.0-mm (¾-in.) sieve as per the Table 1 grading, and proportionally add back to the original minus 19.0-mm (¾-in.) grading so as to include the oversized material in a mass proportion equal to its original grading percentage.

7.2.3.2 *Separated Size Testing*—Crush material larger than the 19.0-mm (¾-in.) sieve to pass the 19.0-mm (¾-in.) sieve, grade that material as per Table 1 and test in concrete as a separate aggregate.

7.3 *Concrete Mixture Proportions*—Proportion the concrete mixture to the following requirements:

7.3.1 *Cementitious Materials Content*—  $420 \pm 10 \text{ kg/m}^3$  ( $708 \pm 17 \text{ lb/ yd}^3$ ).

7.3.1.1 When evaluating the susceptibility of an aggregate to expansive alkali-silica reaction, use cement as 100 % of the cementitious material.

7.3.1.2 When evaluating combinations of aggregate with pozzolan or slag, replace cement with the desired amount of pozzolan or slag on a percent by mass basis.

7.3.2 *Volume of Coarse Aggregate Per Unit of Volume of Concrete*—Use a coarse aggregate oven-dry-rodded unit volume of  $70 \pm 0.2\%$  for all classes of aggregates (for example, low density, normal, and high density).

7.3.2 *Coarse Aggregate Content*—Use a dry mass of coarse aggregate per unit volume of concrete equal to  $0.70 \pm 0.02$  of its dry-rodded bulk density as determined by Test Method C 29/C 29M for all classes of aggregates (for example, low density, normal, and high density).

7.3.3 *Water-Cementitious Materials Ratio (w/cm)*—Maintain w/cm in the range of 0.42 to 0.45 by mass. Adjust the w/cm within this range to give sufficient workability to permit satisfactory compaction of the concrete in the molds. If necessary to obtain sufficient workability within the specified w/cm range, use of a high-range water reducer (HRWR), meeting the requirements of Specification C 494/C 494M Type F is permitted. If, within the specified w/cm range, specimens representative of the concrete mixture cannot be fabricated due to excessive bleeding or segregation, the use of a viscosity-modifying admixture (VMA) is permitted. Report the w/cm ratio used and the amount, if any, of HRWR or VMA.

7.3.4 *Admixture (NaOH)*—Dissolve in the mixing water and add as required to bring the alkali content of the concrete mixture, expressed as  $\text{Na}_2\text{O}_e = \% \text{Na}_2\text{O} + 0.658 \times \% \text{K}_2\text{O}$ , up to 1.25 % by mass of cement (see Note 4). Use no other admixture in the concrete except as permitted in the section on *Water-Cementitious Materials Ratio*.

NOTE 4—Example calculations for determining the amount of NaOH to be added to the mixing water to increase the alkali content of the cement from 0.90 % to 1.25 %:

Example A (Cement Only)

Cementitious materials content of 1 m <sup>3</sup> concrete	= 420 kg
Cement content of concrete	= 420 kg
Amount of alkali in the concrete	= 420 kg × 0.90 % = 3.78 kg
Specified amount of alkali in concrete	= 420 kg × 1.25 % = 5.25 kg
Amount of alkali to be added to concrete	= 5.25 kg – 3.78 kg = 1.47 kg

The difference (1.47 kg) is the amount of alkali, expressed as Na<sub>2</sub>O equivalent, to be added to the mix water. Factor to convert Na<sub>2</sub>O to NaOH: since



Compound	Molecular Weight
Na <sub>2</sub> O	61.98
NaOH	39.997

Conversion factor:

$$2 \times 39.997/61.98 = 1.291; \tag{1}$$

Amount of NaOH required in Example A:

$$1.47 \times 1.291 = 1.898 \text{ kg/m}^3 \tag{2}$$

**TABLE 1 Grading Requirement**

Sieve Size		Mass (%)
Passing	Retained	
19.0-mm (¾-in.)	12.5-mm (½-in.)	33
12.5-mm (½-in.)	9.5-mm (¾-in.)	33
9.5-mm (¾-in.)	4.75-mm (No. 4)	33