



Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)¹

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1. Scope

1.1 This test method permits detection within 16 days of the potential for deleterious alkali-silica reaction of aggregate in mortar bars.

1.2 The values stated in SI units are to be regarded as standard. The values in inch-pound units are shown in parentheses, and are for informational purposes only.

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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in 5.3.1.

2. Referenced Documents

2.1 ASTM Standards:

- C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)²
- C 150 Specification for Portland Cement^{3,2}
- C 151 Test Method for Autoclave Expansion of Portland Cement²
- C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)³
- C 295 Practice for Petrographic Examination of Aggregates for Concrete³
- C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency²
- C 490 Specification for Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete^{3,2}
- C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes^{3,2}
- C 856 Practice for Petrographic Examination of Hardened Concrete³

¹ This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

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

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

E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁴

D 1193 Specification for Reagent Water⁵

2.2 CSA Standards:

CAN/CSA-A23.2-14A-M90 Test Methods for Potential Expansion of Cement-Aggregate Combination (Concrete Prism Expansion Method)⁶

3. Significance and Use

3.1 This test method provides a means of detecting the potential of an aggregate intended for use in concrete for undergoing alkali-silica reaction resulting in potentially deleterious internal expansion. It is based on the NBRI Accelerated Test Method (1-4).⁷ It may be especially useful for aggregates that react slowly or produce expansion late in the reaction. However, it does not evaluate combinations of aggregates with cementitious materials nor are the test conditions representative of those encountered by concrete in service.

3.2 Because the specimens are exposed to a NaOH solution, the alkali content of the cement is not a significant factor in affecting expansions.

3.3 When excessive expansions (see appendix) Appendix X1 are developed, it is recommended that supplementary information be developed to confirm that the expansion is actually due to alkali-silica reaction. Sources of such supplementary information include: (1) petrographic examination of the aggregate (Practice C 295) to determine if known reactive constituents are present; (2) examination of the specimens after tests (Practice C 856) to identify the products of alkali reaction; and (3) where available, field service records can be used in the assessment of performance.

3.4 When it has been concluded from the results of tests performed using this test method and supplementary information that a given aggregate should be considered potentially deleteriously reactive, the use of mitigative measures such as low-alkali portland cement, mineral admixtures, or ground granulated blast-furnace slag should be evaluated (see last sentence of 3.1).

⁴ *Annual Book of ASTM Standards*, Vol 14.02.

⁵ *Annual Book of ASTM Standards*, Vol 11.01.

⁶ Available from National Standards of Canada, Canadian Standards Association, 178 Rexdale Blvd., Toronto, Ont. Canada M9W 1R3.

⁷ The boldface numbers in parentheses refer to a list of references at the end of the text.

4. Apparatus

4.1 The apparatus shall conform to Specification C 490, except as follows:

4.2 *Sieves*—Square hole, woven-wire cloth sieves, shall conform to Specification E 11.

4.3 *Mixer, Paddle, and Mixing Bowl*—Mixer, paddle, and mixing bowl shall conform to the requirements of Practice C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 5.1 ± 0.3 mm (0.20 ± 0.01 in.).

4.4 *Tamper and Trowel*—The tamper and trowel shall conform to Test Method C 109.

4.5 *Containers*—The containers must be of such a nature that the bars can be totally immersed in either the water or 1N NaOH solution. The containers must be made of material that can withstand prolonged exposure to 80°C (176°F) and must be inert to a 1N NaOH solution (see Note 1). The containers must be so constructed that when used for storing specimens, the loss or gain of moisture is prevented by tight-fitting covers, by sealing, or both (see Note 2). The bars in the solution must be placed and supported so that the solution has access to the whole of the bar; therefore, it should be ensured that the specimens do not touch the sides of the container or each other. The specimens, if stood upright in the solution, shall not be supported by the metal gage stud.

NOTE 1—The NaOH solution will corrode glass or metal containers.

NOTE 2—Some microwave-proof food storage containers made of polypropylene or high-density polyethylene have been found to be acceptable.

4.6 *Oven, or Water Bath*—A convection oven or water bath with temperature control maintaining $80 \pm 2.0^\circ\text{C}$ ($176 \pm 3.6^\circ\text{F}$).

5. Reagents

5.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used, provided the Na^+ and OH^- concentrations are shown by chemical analysis to lie between 0.99N and 1.01N.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

5.3 *Sodium Hydroxide Solution*—Each litre of solution shall contain 40.0 g of NaOH dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. The volume proportion of sodium hydroxide solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars. The volume of a mortar bar may be taken as 184 mL.

5.3.1 **Precaution**—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 manufacturer's Material Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves should be checked periodically for pin holes.

6. Conditioning

6.1 Maintain the temperature of the molding room and dry

materials at not less than 20°C (68°F) and not more than 27.5°C (81.5°F). The temperature of the mixing water, and of the moist closet or moist room, shall not vary from 23°C (73.4°F) by more than 1.7°C (3°F).

6.2 Maintain the relative humidity of the molding room at not less than 50 %. The moist closet or room shall conform to Specification C 511.

6.3 Maintain the storage oven or water bath in which the specimens are stored in the containers at a temperature of $80 \pm 2.0^\circ\text{C}$ ($176 \pm 3.6^\circ\text{F}$).

7. Sampling and Preparation of Test Specimens

7.1 *Selection of Aggregate*—Process materials proposed for use as fine aggregate in concrete as described in 7.2 with a minimum of crushing. Process materials proposed for use as coarse aggregate in concrete by crushing to produce as nearly as practical a graded product from which a sample can be obtained. Grade the sample as prescribed in 7.2. The sample shall represent the composition of the coarse aggregate as proposed for use.

7.1.1 When a given quarried material is proposed for use both as coarse and as fine aggregate, test it only by selection of an appropriate sample crushed to the fine aggregates sizes, unless there is reason to expect that the coarser size fractions have a different composition than the finer sizes and that these differences might significantly affect expansion due to reaction with the alkalis in cement. In this case test the coarser size fractions in a manner similar to that employed in testing the fine aggregate sizes.

7.2 *Preparation of Aggregate*—Grade all aggregates to which this test method is applied in accordance with the requirements prescribed in Table 1. Crush aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist until the required material has been produced. In the case of aggregates containing insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the grading specified in Table 1. When such procedures are required, make a special note thereof in the test report. After the aggregate has been separated into the various sieve sizes, wash each size 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.

7.3 *Selection and Preparation of Cement:*

7.3.1 *Reference Cement*—Use the portland cement meeting the requirements of Specification C 150. In addition, the

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

autoclave expansion in Test Method C 151 shall be less than 0.20 %.

NOTE 3—The alkali content of the cement has been found to have negligible (3) or minor (5) effects on expansion in this test.

7.3.2 *Preparation of Cement*—Pass cement for use in this test through an 850- μm (No. 20) sieve to remove lumps before use.

7.4 *Preparation of Test Specimens*:

7.4.1 *Number of Specimens*—Make at least three test specimens for each cement-aggregate combination.

7.4.2 *Preparation of Molds*—Prepare the specimen molds in accordance with the requirements of Specification C 490 except, the interior surfaces of the mold shall be covered with a release agent (see Note 4). A release agent will be acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 4—TFE-fluorocarbon (Teflon⁸) tape complies with the requirements for a mold release agent.

7.4.3 *Proportioning of Mortar*—Proportion the dry materials for the test mortar using 1 part of cement to 2.25 parts of graded aggregate by mass. The quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cement and 990 g of aggregate made up by recombining the portions retained on the various sieves (see 7.2) in the grading prescribed in Table 1. Use a water to cement ratio equal to 0.47 by mass (see Note 5).

NOTE 5—Ruggedness tests indicated that mortar bar expansions were less variable at a fixed water to cement ratio than when gaged to a constant flow (3).

7.4.4 *Mixing of Mortar*—Mix the mortar in accordance with the requirements of Practice C 305.

7.4.5 *Molding of Test Specimens*—Mold test specimens within a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the molds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mold and smooth the surface with a few strokes of the trowel.

8. Procedure

8.1 *Initial Storage and Reading*—Place each mold in the moist cabinet or room immediately after molds have been filled. The specimens shall remain in the molds for 24 ± 2 h. Remove the specimens from the molds and, while they are being protected from loss of moisture, properly identify and make an initial comparative reading. Make and record the initial and all subsequent readings to the nearest 0.002 mm. Place the specimens made with each aggregate sample in a storage container with sufficient tap water to totally immerse them. Seal and place the containers in an oven or water bath at $80 \pm 2.0^\circ\text{C}$ ($176 \pm 3.6^\circ\text{F}$) for a period of 24 h.

8.2 *Zero Readings*—Remove the containers from the oven or water bath one at a time. Remove other containers only after the bars in the first container have been measured and returned to the oven or water bath. Remove the bars one at a time from the water and dry their surface with a towel paying particular attention to the two metal gage studs. Take the zero reading (see Note 6) of each bar immediately after drying, and read as soon as the bar is in position. Complete the process of drying and reading within 15 ± 5 s of removing the specimen from the water. After readings, leave the specimen on a towel until comparative readings have been taken on the remainder of the bars. Place all specimens made with each aggregate sample in a container with sufficient 1N NaOH, at $80 \pm 1.0^\circ\text{C}$ ($176 \pm 3.6^\circ\text{F}$) for the samples to be totally immersed. Seal the container and return it to the oven or water bath.

NOTE 6—The reference bar should be read prior to each set of specimens since the heat from the mortar bars may cause the length of the comparator to change.

8.3 *Subsequent Storage and Measurement*—Make subsequent comparator readings of the specimens periodically, with at least three intermediate readings, for 14 days after the zero reading, at approximately the same time each day. If readings are continued beyond the 14-day period, take at least one reading per week. The procedure is identical to that described in 8.2 except that the specimens are returned to their own container after measurement.

9. Calculation

9.1 Calculate the difference between the zero comparative reading of the specimen and the reading at each period to the nearest 0.001 % of the effective gage length and record as the expansion of the specimen for that period. Report the average expansion of the three specimens of a given cement-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

10. Report

10.1 Report the following information:

10.1.1 Type and source of aggregate,

10.1.2 Type and source of portland cement,

10.1.3 Autoclave expansion and alkali content of cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent,

10.1.4 Average length change in percent at each reading of the specimens,

10.1.5 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 7.2,

10.1.6 Any significant features revealed by examination of the specimens during and after test,

10.1.7 Amount of mixing water expressed as mass percent of cement,

10.1.8 A graph of the length change data from the time of the zero reading to the end of the 16 day period.

11. Precision and Bias

11.1 *Precision*—The between-laboratory precision has been estimated from an interlaboratory study involving six laboratories, each testing three aggregates with three cements (5). For

⁸ Teflon is a registered trademark.

values of expansion greater than 0.015 %, the between-laboratory precision has been found to be 9.55 % (1s %). Therefore, the results of two properly conducted tests in two different laboratories should differ by no more than 27.0 % of the mean expansion.

11.2 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement on bias is being made.

APPENDIX

(Nonmandatory Information)

X1. INTERPRETATION OF TEST RESULTS

X1.1 There is good agreement in the published literature (1,2,6-9) for the following expansion limits:

X1.1.1 Expansions of less than 0.10 % at 16 days after casting are indicative of innocuous behavior in most cases (see Note X1.1).

X1.1.2 Expansions of more than 0.20 % at 16 days after casting are indicative of potentially deleterious expansion. (See 3.3.)

X1.1.3 Expansions between 0.10 and 0.20 % at 16 days after casting include both aggregates that are known to be

innocuous and deleterious in field performance. For these aggregates, it is particularly important to develop supplemental information as described in 3.3. In such a situation, it may also be useful to take comparator readings until 28 days (7,9).

NOTE X1.1—Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 % at 16 days after casting (9). With such aggregate, it is recommended that prior field performance be investigated. In the absence of field performance data, mitigative measures should be taken as discussed in 3.4.

REFERENCES

- (1) Oberholster, R. E., and Davies, G., “An Accelerated Method for Testing the Potential Alkali Reactivity of Siliceous Aggregates,” *Cement and Concrete Research*, Vol 16, 1986, pp. 181–189.
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