
Standard Method of Test for

**Determination of Alkali Threshold
for Alkali–Silica Reactivity in
Aggregates Used in Concrete (ATT)**

AASHTO Designation: T 416-24¹

First Published: 2024

Technical Subcommittee: 1c, Aggregates



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1. SCOPE

- 1.1. This test method allows for the detection of the alkali threshold of aggregates susceptible to alkali-silica reaction (ASR) within 21 days. The alkali threshold of an aggregate used in a concrete mix refers to the safe limit of alkali loading of the concrete prepared using the specific aggregates below which ASR will not occur. The alkali threshold is determined by measuring the reactivity index (RI) of the aggregate under varying alkali loadings (ranging from 1.05 to 6.51 Na₂O_{eq} kg/m³). This standard describes the methodology to determine the alkali threshold for either coarse or fine aggregates alone or as a specific combination as will be used in a concrete mix. This information will be useful to design concrete mixtures with minimal risk to develop ASR.
- 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 may involve hazardous materials, operations, and equipment. This standard does not purport to address all safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*
- 1.4. *The quality of the results produced by this standard is dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. AASHTO Standards:
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - R 76, Standard Practice for Reducing Samples of Aggregate to Testing Size
 - R 90, Standard Practice for Sampling Aggregate Products
 - T 255, Standard Method of Test for Total Evaporable Moisture Content of Aggregate by Drying

- T 303, Standard Method of Test for Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction
- T 380, Standard Method of Test for Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT)
- TP 144, Standard Method of Test for Determining the Potential Alkali-Silica Reactivity of Coarse Aggregates (TFHRC T-FAST)

2.2. *ASTM Standards:*

- C1260, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- C1293, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
- E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.3. *Other Documents:*

- Kim, T., and J. Olek. Effects of Sample Preparation and Interpretation of Thermogravimetric Curves on Calcium Hydroxide in Hydrated Pastes and Mortars. In *Transportation Research Record 2290*. Transportation Research Board, National Research Council, Washington, DC, No. 1, pp. 10–18, 2012. Available from <https://doi.org/10.3141/2290-02>
- Muñoz, J. F., C. Balachandran, and T. S. Arnold. New Turner-Fairbank Alkali-Silica Reaction Susceptibility Test for Aggregate Evaluation. In *Transportation Research Record 2675*. Transportation Research Board, National Research Council, Washington, DC, No. 9, pp. 798–808, 2021a. Available from <https://doi.org/10.1177/03611981211004584>
- Muñoz, J. F., C. Balachandran, M. Beyene, and T. S. Arnold. A Novel Approach for the Assessment of ASR Susceptibility of Concrete Mixtures in Airfield Pavements and Infrastructure. FHWA-HRT-21-103. Office of Research, Development, and Technology, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2021b.

3. TERMINOLOGY

3.1. *Definitions of Terms Specific to This Standard:*

- 3.1.1. *Buchner funnel*—A ceramic funnel for the support of filter media used in vacuum filtration.
- 3.1.2. *inductively coupled plasma (ICP)*—A spectroscopic analytical technique for the accurate quantitative analysis of chemical elements present in aqueous solutions.
- 3.1.3. *polytetrafluoroethylene (PTFE)*—A plastic polymer inert to reaction with the alkalis used in the test.
- 3.1.4. *reactivity index (RI)*—The ratio of the concentrations in millimoles per liter of silicon divided by the concentrations of calcium plus aluminum.

4. SUMMARY OF TEST METHOD

- 4.1. The test method involves exposing individual coarse or fine aggregates, or a combination of both in specific concrete mix proportions under different $\text{Na}_2\text{O}_{\text{eq}}$ concentrations (alkali loadings) at a fixed quantity of calcium oxide and temperature of 55°C inside PTFE tubes for a duration of 21 days. The range of $\text{Na}_2\text{O}_{\text{eq}}$ concentrations to which the aggregates are exposed varies between 1.01 to 6.51 $\text{Na}_2\text{O}_{\text{eq}}$ kg/m^3 . Coarse aggregates are crushed to a specific gradation prior to testing while fine aggregates are tested in the gradation “as received”. After 21 days, the tubes are

removed from the oven and left to cool down after which their contents are homogenized. Vacuum filtration is performed to separate the liquid phase which is then analyzed for silicon, aluminum, and calcium ion concentrations. An RI is calculated for each alkali concentration condition by dividing the concentration of silicon by the sum of the concentrations of calcium and aluminum in the liquid fraction.

- 4.2. The alkali content of each tube (x-axis) is plotted against the reactivity index (y-axis) calculated for each tube. The alkali content point where the resulting curve crosses a specific critical RI line is defined as the alkali threshold. The value of the critical RI line varies depending on the type of aggregate sample analyzed. A value of 0.45 is used for the critical RI line to calculate the alkali threshold of individual coarse aggregates or a combination of coarse and fine aggregates as in a concrete mixture. A value of 1 is used for the RI line to calculate the alkali threshold of individual fine aggregates.

5. SIGNIFICANCE AND USE

- 5.1. ASR is the reaction between ionic species in the pore solution of concrete, principally hydroxyl (OH^-), sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}) ions which are present in the portland cement, and the silica present in the aggregate.
- 5.2. This standard describes the methodology to determine the alkali threshold for either coarse or fine aggregates, alone or as a specific combination of coarse and fine aggregate that will be used in a concrete mixture. The test method in its current form is not applicable to characterize aggregates that leach low amounts of aluminum, as typified by certain dolomitic aggregates. This shall be addressed in a future version of this test method.
- 5.3. The test method to determine the alkali threshold was developed using the experimental setup of TP 144 (referred to as T-FAST) to determine ASR reactivity of aggregates. The sealed environment of the experimental setup in T-FAST does not have the problem of progressive leaching of alkalis from the specimens as in the case of traditional mortar- and concrete-accelerated methods and can thus be used for reliable measurements of aggregate-alkali thresholds (Muñoz et al, 2021a and 2021b). The alkali thresholds are calculated based on the mix design proportions of ASTM C1293, that is, concrete prisms made with 420 kg/m³ of a standard M 85, Type I/II cement containing an average portlandite content of 0.16 g of $\text{Ca}(\text{OH})_2$ /g of dry paste and 0.45 water to cementitious materials ratio (Kim and Olek, 2012).
- 5.4. The aim of determining the alkali threshold of a specific combination of coarse and fine aggregate is to establish the maximum allowable alkali content of the mix. The aim of determining the alkali threshold for aggregates alone is to guide the user towards making appropriate choices for the combination of coarse and fine aggregates or for selecting the most effective supplementary cementitious materials (SCM) to minimize the risk of ASR in the concrete mix.
- 5.5. It is suggested to test the aggregate under evaluation using T-FAST first in order to gain some understanding of the level of ASR reactivity of the aggregate before determining its alkali threshold.

6. APPARATUS

- 6.1. *Crushing Equipment for Reducing the Size of Coarse Aggregates*—The crusher must be able to crush coarse aggregates to produce two fractions: finer fraction passing the No. 50 (300 μm) and retained on the No. 100 (150 μm) sieve (referred to as aggregate fraction retained on the No. 100); and coarser fraction passing the No. 30 (600 μm) and retained on the No. 50 (300 μm) sieve (referred to as aggregate fraction retained on the No. 50). It is important that the crushing

equipment does not contaminate the aggregate being crushed. The use of a mechanical sieve shaker is recommended to produce the required aggregate fractions.

- 6.2. *Test Tubes*—50-mL capacity test tubes with flat bottoms made of polytetrafluoroethylene (PTFE) properly sealed with a corresponding screw cap. If caps of polyethylene or other plastic are used, using duct tape to ensure proper sealing is recommended. Caps of material other than PTFE are at risk of cracking during the experiment due to differences in thermal expansion coefficients. It is important to seal the tubes properly to avoid the risk of evaporation.

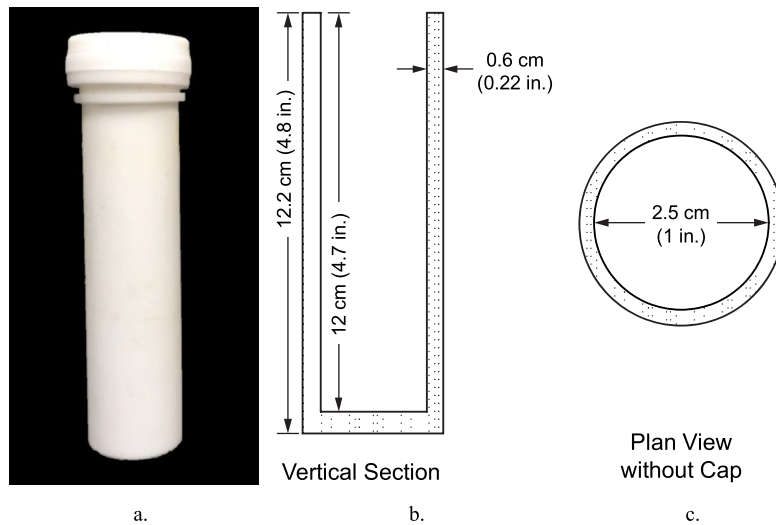


Figure 1—PTFE Test Tube and Cap (50-mL Capacity) (FHWA)

- 6.3. *Sieves*—19-mm ($3/4$ -in.), 12.5-mm ($1/2$ -in.), 2.38-mm (No. 8), 1.19-mm (No. 16), 600- μ m (No. 30), 300- μ m (No. 50), and 150- μ m (No. 100) size sieves, conforming to ASTM E11.
- 6.4. *Sample Storage Tubes*—25-mL capacity self-standing polypropylene (PP) tubes sealed with corresponding screw cap.
- 6.5. *Analytical Balance*—With sensitivity of 0.001 g.
- 6.6. *Automatic Pipette*—25-mL capacity.
- 6.7. *Oven*—Set at temperatures of $55.0 \pm 2^\circ\text{C}$ ($131.0 \pm 3.6^\circ\text{F}$).
- 6.8. *Spectrometer*—A spectrometer capable of accurately measuring concentrations of silicon, calcium, and aluminum ions in aqueous solutions. Inductively coupled plasma atomic emission spectroscopy (ICP-AES) and wavelength dispersive X-ray fluorescence spectroscopy (WDXRF) are recommended analytical techniques.
- Note 1**—It is theoretically possible to use other techniques such as atomic absorption (AA), although this technique has not yet been evaluated.
- 6.9. *Spatula*.
- 6.10. *Vacuum Filtration Set-Up:*
- 6.10.1. Buchner funnel;