Tech Brief

National Concrete Pavement Technology Center

Tech Center

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ALKALI-SILICA REACTION

Alkali-silica reaction (ASR) is a ubiquitous deleterious mechanism of concrete transportation infrastructure that involves the reaction between certain siliceous mineral phases within the aggregates and alkalis typically from the cementitious material. Some ASR products, under the presence of moisture, expand and induce cracking in concrete.

WHAT IS ALKALI THRESHOLD?

For ASR to occur in concrete, both alkali-silica reactive minerals and sufficient alkalis must be present. Alkali threshold (AT) is defined as the minimum alkali loading (AL) necessary to trigger the ASR of a particular aggregate or combination of aggregates used in a concrete mixture. The concept of AT, which has been known for more than 40 years, has always been recognized as an important prescriptive tool for preventing ASR from occurring in the field, since ASR in concrete can be prevented if the AL remains below the AT of the aggregates.

ALKALI THRESHOLD TESTING

A POWERFUL TOOL FOR ASSESSING ALKALI–SILICA REACTIVITY IN AGGREGATES

CLASSIFICATION OF AT BASED ON MEASUREMENT METHOD

AT can be measured using either chemical or physical methods:

- Chemical AT: The minimum AL needed to trigger ASR gel formation.
- Physical AT: The minimum AL required to produce enough ASR gel to cause expansion above 0.04%, which is the accepted limit according to ASTM C1293. Above this limit, the risk of cracking in unreinforced concrete increases.

Since each method captures different phenomena, chemical AT is typically lower than physical AT and therefore offers a more conservative approach to ASR management.

CLASSIFICATION OF AT BASED ON TYPE OF AGGREGATE SAMPLE

AT can be measured on two types of aggregate samples:

- AT_{Ag}: AT as measured on an individual aggregate alone.
- AT_{Mx}: AT as measured on a combination of coarse and fine aggregates under specific concrete mixture proportions.

The information conveyed by AT_{Ag} and AT_{Mx} differs, in that the former provides information regarding the ASR susceptibility of a particular aggregate while the latter gives similar information about an aggregate combination in a given mixture.

ATT: A NEW STANDARD FOR MEASURING AT

AASHTO T 416 describes the Alkali Threshold Test (ATT), a standardized test procedure used to measure AT. ATT measures chemical AT and can be used to determine either AT_{Ag} or AT_{Mx}. The testing protocol involves exposing individual coarse or fine aggregates, or a combination of both in specific concrete mix proportions, to different alkali contents at a fixed quantity of calcium oxide. Samples are kept inside test tubes at a temperature of 55°C for a duration of 21 days (Figure 1). The alkali threshold of the aggregate is determined by measuring an indicator to predict the potential for the formation of ASR gel products based on changes in the concentration of ASR-critical chemical elements in the test solution under varying alkali contents.

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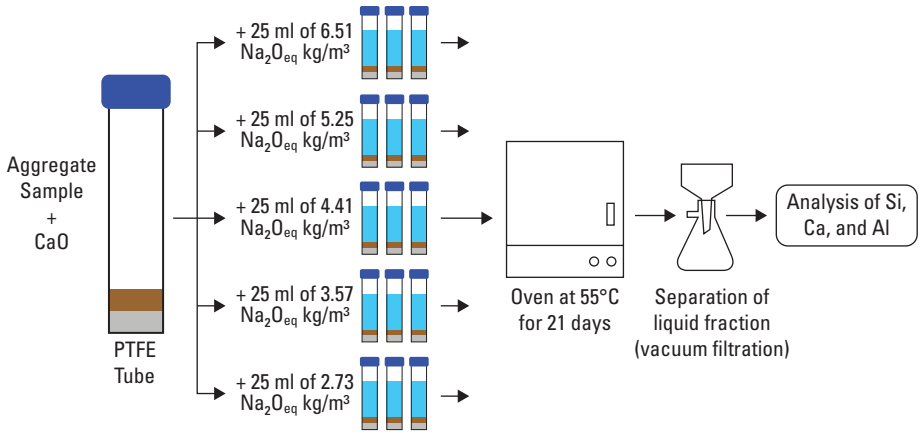

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Figure 1. ATT protocol for preparing, testing, and analyzing aggregate samples

WHY IS AT USEFUL?

Understanding the fundamental relationship between the AL of a concrete mixture and the AT of the aggregates used in that mixture is crucial to effective ASR management. ASR in concrete can be prevented if the AL remains below the AT_{Mx} of the aggregates. Combining AT_{Mx} measurement with the precise identification of alkali-silica reactive phases in aggregates, as explained in a tech brief on the T-FAST testing method, offers deeper insights into a concrete mixture's susceptibility to ASR. For example, after asserting the reactivity of the aggregates using T-FAST and determining the AT_{Mx} of the aggregates using ATT, the AL of a concrete mixture can be used to assess the associated ASR risk and optimize the mix design for effective ASR management.

RESOURCES

Muñoz, J. F., C. Balachandran, A. Shastry, R. Mulcahy, J. M. Robertson, and T. S. Arnold. 2023. Alkali-silica reaction evaluation of coarse aggregates from Massachusetts using accelerated tests. *ACI Materials Journal*, Vol. 120, No. 6, pp. 129–139. https://doi.org/10.14359/51739152.

Munoz, J. F., C. Balachandran, F. Zerai, R. Mulcahy, and T. S. Arnold. 2025. Combination of alkali threshold of aggregates and alkali loading of concrete as predictive tool of alkali-silica reactivity in the field. *Journal of Materials in Civil Engineering*, Vol. 37, No. 4, 04025028.

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