Alkali Silica Reactions

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Alkali silica reaction (ASR) is a concrete durability problem whereby certain forms of silica in aggregates react in high alkaline pore solutions in concrete to form a reaction product that expands in the presence of moisture and results in deleterious cracking of concrete. Soluble alkali salts, typically sodium and potassium, exist in concrete ingredient materials, primarily from the portland cement. It is important to note that the problem occurs only when the concrete element is exposed to a source of moisture. ASR has gained more prominence in the last 10 to 20 years as visible evidence of cracked structures emerged and due to changing characteristics of concrete ingredient materials. In most cases, the use of supplementary cementitious materials such as fly ash or slag and lithium-based chemical admixtures have been effective means of controlling the deleterious expansions. Less practical solutions often stated are to use a non-reactive aggregate and/or a low alkali cement as these may not be economically justified in certain regions.

Significant research and efforts have gone toward establishing tests and criteria that would qualify a certain combination of concrete materials for a reduced potential for deleterious expansions due to ASR. Two very popular tests to evaluate the potential reactivity of aggregates are the mortar bar test (ASTM C 1260) and concrete prism test (ASTM C 1293). The mortar bar test takes only 16 days whereas the concrete prism test takes one year and hence many engineering agencies such as state DOTs invoke the mortar bar test in specifications as a means to qualify aggregates for their alkali silica reactivity. The problem with this scenario is that many studies, including one conducted by NRMCA, have found that more than 75 percent of the existing aggregate sources fail the mortar bar test. The concrete prism test is considered to be a better test that correlates with the field performance of an aggregate in concrete. However, it is not known exactly what percentage of the aggregate sources in the U.S. will fail that test. If it is assumed that 50 percent of all aggregate sources fail the concrete prism test, the reality is that we do not see this frequency of concrete failures due to ASR in existing structures. Does this mean that the concrete prism test is also not reliable? This question was posed to an expert in ASR and concrete durability. He first stated that no one knows exactly what percentage of all aggregate sources fail the concrete prism test. He was convinced that an aggregate that failed the concrete prism test will fail in the field (without using mitigative measures) provided there is more than 6 lbs/yd^3 of alkalis present in the system.

Designed to obtain reliable results in a reasonable time frame, the concrete prism test exposes concrete test specimens (3 x 3 x 10 inch prisms) to a severe set of exposure

Reactivity Level	Aggregate Expansion, C 1293, 1-year %	
	Equal to or greater than	Less than
Very Highly Reactive (VHR)	0.20	-
Highly Reactive (HR)	0.12	0.20
Moderately Reactive (MR)	0.04	0.12

conditions. The concrete mixture contains 8.85 lbs/yd³ of alkali (1.25 percent alkali by mass of cement and 708 lbs/yd³ of portland cement) and the test specimens are placed in an environment at a high temperature (80ºF) and relative humidity (~100%). Based on controlled studies correlating concrete prism test results to larger block specimens placed in the field, the general observation is that field specimens will see deleterious expansive cracking with reactive aggregates when the alkali content of the concrete is greater than 6 lb./yd³. Based on this, specifications in Canada and Europe have adopted limits such as 5 lb/yd³ or lower on the total alkali content in concrete.

This brings up the question as to whether this level of protection is necessary regardless of the degree of reactivity of the aggregates. For instance, will certain aggregate sources in the U.S. that are highly reactive be benign with a concrete alkali level at 5 lb/yd³? Alternatively, is this level of mitigation necessary for aggregates that barely exceed the expansion limit of the ASTM C 1293 test?

This brings us to the issue of classification of aggregates and establishing levels of prevention based on the degree of reactivity. The greatest mitigation measures can be adopted for the highly reactive aggregates while lesser mitigation measures are more appropriate for moderately reactive aggregates. This will improve the current situation where all aggregates that fail the C 1293 test are treated with the greatest mitigation measures that could result in other challenges such as prolonged setting time in cold weather or a slower rate of strength gain. This puts undue restrictions on the concrete producer – for example he may not be able to use high-lime fly ash available locally or a low alkali cement that might provide adequate mitigation for the aggregate in question; or he may have to obtain an alternative ingredient material from great distances and arrange for use with separate silos to supply certain projects. **It is clearly true that undue restriction resulting from very conservative concrete specifications increases the cost of concrete construction and renders it less competitive as a construction material.** This should be a cause of concern for every one involved. It is an even bigger concern if aggregates are classified as reactive purely based on the C 1260 mortar bar test that has shown to cause a high percentage of "failing" results for aggregates that have a long satisfactory service record.

The ASTM technical subcommittee C 09.26 on chemical reactions is in the process of developing standards that will classify the aggregates based on the expansions measured by ASTM C 1293. See chart on page 45.

Once the subcommittee achieves consensus on this classification, they will propose appropriate methods of mitigation based on the level of aggregate reactivity. The recently approved Canadian Standards Association CSA A23.1 and A23.2 have established measures of prevention for ASR in field concrete based on the degree of reactivity of the aggregate and the level of risk and intended service life of the concrete element. The options are rather extensive to discuss in this article but they include limiting the alkali content in concrete, using prescribed levels of supplementary cementitious materials or qualifying acceptable combinations of materials by performance tests like the mortar bar test and the concrete prism test taken out to two years. This is most likely the model that will be followed by ASTM.

ASTM has standardized a modification of the mortar bar test for evaluating the effectiveness of cementitious material combinations with specific aggregates. ASTM C 1567, *Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method),* provides a means to obtain a quick answer regarding the prevention level of fly ash or slag to be used with specific aggregates. It has been adopted by some specifying agencies such as the Texas DOT and other owners of commercial structures.

It is this author's opinion that if the potential for deleterious expansion in field concrete is tied to the alkali level in the concrete, then there should be a means of classifying the reactivity of an aggregate by modifying the concrete prism test to different levels of alkali content, sufficiently high enough to accelerate reactions and simulate the anticipated alkali levels in field concrete. This would be a more science-based approach with the disadvantage of requiring more long-term testing but it may be well worth the effort if it ensures that the specifications are not so conservative as to impact the competitiveness of concrete as a construction material. n

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