Evaluation of Alkali Silica Reactivity (ASR) Mortar Bar Testing (ASTM C1260 and C1567) at 14 days and 28 days

PCA Durability Subcommittee

Alkali silica reaction (ASR) is a chemical reaction between certain reactive minerals in some aggregate and alkalies in the pore solution of concrete (Farny and Kerkhoff 2007). This reaction can result in expansion and cracking of the concrete leading to shortened service life. Guidance on preventing deleterious ASR is available from a number of sources (Thomas et al. 2008; ACI 2008; PCA 2007; and CSA 2004) and several mitigation strategies are often available.

To determine whether an aggregate is potentially reactive, ASTM C1260, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)* is often used as a screening test. A similar test, ASTM C1567, *Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method),* is used to evaluate the efficacy of mitigation using hydraulic cement and supplementary cementitious materials (SCM) combinations. In the ASTM C1260/C1567/accelerated mortar bar test (AMBT), aggregate with a specified gradation is used in making 25 mm × 25 mm × 285 mm (1 in. × 1 in. × 11.25 in.) mortar bars that are cured for 48 hours, and then stored in a 1M NaOH solution at 80°C (176°F).

In ASTM C1260 testing, bars that expand in this harsh environment by more than 0.20% after 14 days of soaking are considered to be made with aggregates that are potentially ASR-reactive. Bars that expand between 0.10% and 0.20% include aggregates that are known to be both innocuous and deleterious in field performance. In both of these cases, supplemental information should be developed. Such supplemental information might include petrographic analyses to confirm that the expansion is due to ASR, as well as a review of service history records (when available). However in the absence further information, the aggregate should conservatively be considered reactive and mitigative measures should be taken. Expansions of less than 0.10% at 14 days are generally indicative of innocuous aggregate, using ASTM C1260, or of effective mitigation using ASTM C1567. ASTM C1260 is a screening test and is known to provide both false positives (that is, classifying an aggregate as reactive when it is not) and false negatives (classifying reactive aggregates as innocuous).

Many consider ASTM C1293, *Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction* (also known as the concrete prism test or CPT), to be the best test method for evaluating deleterious ASR potential in terms of providing the strongest correlation to field performance. However, ASTM C1293 takes 1 year to perform when evaluating aggregate reactivity, or 2 years when evaluating the efficacy of SCMs to mitigate deleterious expansion. Therefore ASTM C1260/C1567/AMBT has a significant practical advantage in its speed. The relatively high correlation between AMBT and CPT is coincidental, as the different specimen sizes, materials, proportioning, curing and exposure conditions all lead to different mechanisms dominating the rate and extent of the ASR distress observed. Changing one of the parameters, like test duration, may easily reduce the correlation between them.

Both standard AMBT tests, ASTM C1260 and ASTM C1567, use a 14-day exposure in an aggressive solution/temperature regime. It has been suggested that in order to provide more conservative results, the AMBT tests should be evaluated at 28 days rather than 14 days (all other conditions of the test are kept the same). However, this is not good practice for two reasons:

- Correlation between the 28-day versions of the AMBT tests and CPT expansion is notably less than for the 14-day tests, and
- The 28-day version of the ASTM C1567 test provides estimates of SCM contents that are approximately 1.5 times higher than actually required for effective ASR mitigation.

Thus, not only is the 28-day AMBT over-conservative and more time consuming, it provides recommendations for potentially inefficient concrete mix designs, which may be

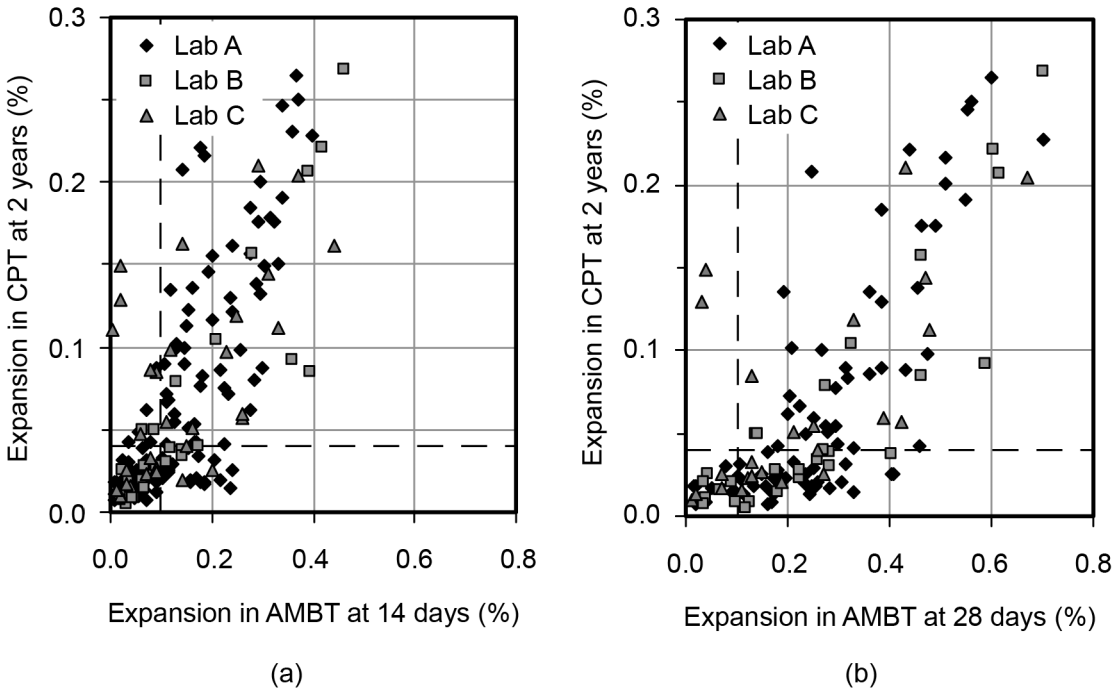

Figure 1. Comparison of 2-year expansion in ASTM C1293 concrete prism test (CPT) with expansion of the same SCM-aggregate combinations in the (a) standard ASTM C1260/C1567/AMBT tests at 14 days and (b) non-standard 28-day test (Thomas et al. 2007).

unacceptable from an engineering perspective. Thomas et al. (2007) provide a detailed review of this issue and provide strong support for the standard 14-day version of the test. Their data is summarized here.

The correlation between standard AMBT data and CPT data is fairly strong, as shown in Fig. 1a and Table 1, which compares results from 3 laboratories that tested 39 aggregates in 182 material combinations. The outcome from the two tests (i.e. both tests pass or both fail) are in agreement about 77% of the time. Only about 7% of the time did the results of the AMBT test pass aggregates that failed subsequent CPT testing. In about 16% of the cases the AMBT failed aggregate that passed subsequent CPT testing—cases in which the AMBT is over-conservative.

In contrast, Table 2 and Fig. 1b provide data for 3 labs using 39 aggregates in 142 materials combinations for

Table 1. Summary of ASTM C1293 and Standard ASTM C1260/C1567 Results (Thomas et al. 2007)

ASTM C1293 Concrete Prism Test	Standard (14-day) ASTM C1260/C1567 Accelerated Mortar Bar Test	
	Passed (≤ 0.10%)	Failed (> 0.10%)
Passed (≤ 0.04%)	62	29
Failed (> 0.04%)	13	78

Table 2. Summary of C1293 and Non-Standard (28-d) Accelerated Mortar Bar Test Results (Thomas et al. 2007)

ASTM C1293 Concrete Prism Test	Non-Standard (28-day), Accelerated Mortar Bar Test	
	Passed (≤ 0.10%)	Failed (> 0.10%)
Passed (≤ 0.04%)	23	57
Failed (> 0.04%)	2	60

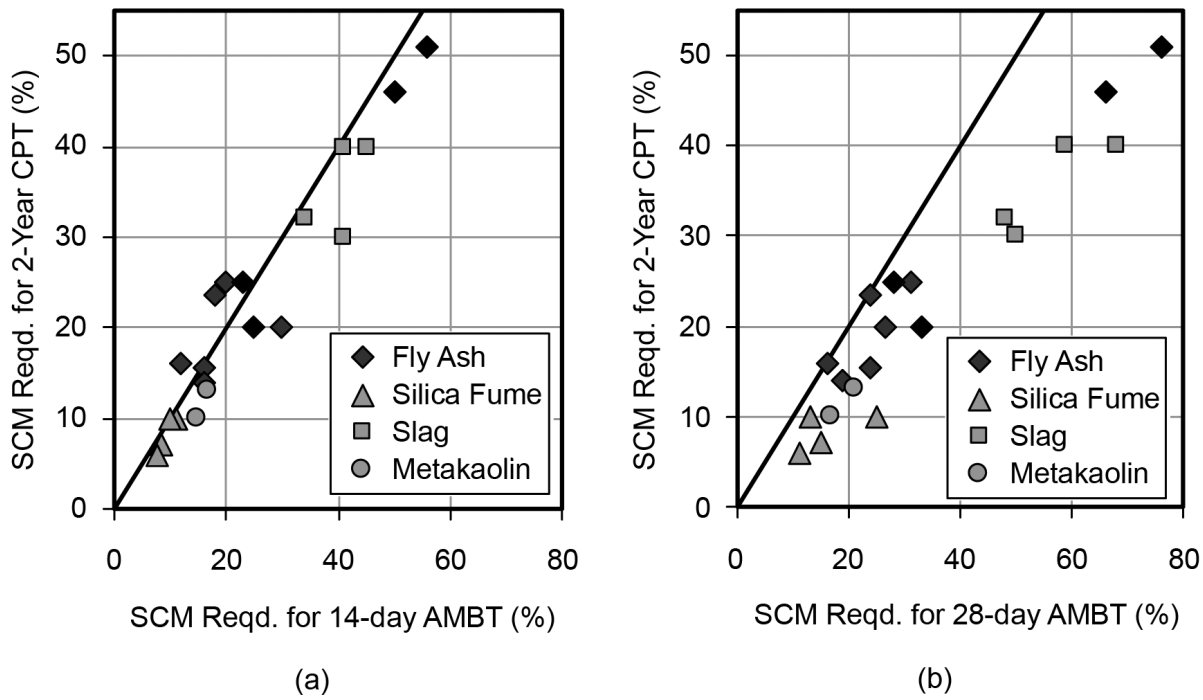

Figure 2. Estimated minimum level of SCM required to suppress 2-year expansion in ASTM C1293 concrete prism test (CPT) compared with level required to suppress expansion in a) standard ASTM C1260/C1567/AMBT tests at 14 days and b) non-standard 28-day testing (Thomas et al. 2007).

comparison of the non-standard 28-day AMBT with CPT results (the AMBT was not extended to 28 days for all of the cases discussed above). In this case, there is agreement between the two tests (both pass or both fail) only about 58% of the time. Furthermore, in about 40% of cases the non-standard 28-day test predicted failure of an SCM-aggregate combination that performed satisfactorily in the concrete prism test.

Figure 2 compares the amount of SCM required to control expansion in the CPT test with portland cement-SCM-aggregate combinations, with the amount required for the same materials tested in both a) the standard AMBT (14 days) and b) the non-standard (28-day) test. There is generally good agreement between concrete and mortar tests when a 14-day test is used. However, using a 28-day result yields significantly higher amounts of SCM being required to mitigate ASR: On average the level of SCM required using 28-day results is 150% higher than that required in CPT testing, which is a significant disparity between results. This is inefficient from an engineering perspective as high amounts of SCMs can change the performance of concrete.

After evaluating these and other data (including field performance), Thomas et al. (2007) drew the following conclusions:

1. The data indicate that reactive aggregate-SCM combinations that pass the 14-day expansion limit [in the AMBT] of 0.10% are unlikely to produce damaging expansion in the field;
2. Using the more stringent 28-day limit of 0.10% fails many reactive aggregate-SCM combinations that perform well in concrete (in field and laboratory exposure);
3. Using the 14-day limit of 0.10% to determine the minimum level of SCM required to control ASR expansion in mortar bars produced with a specific reactive aggregate produces data that are generally consistent with the minimum level required to control expansion in concrete. Using the 28-day limit results in much higher levels of SCM being required (by 1.5 times on average) in mortar bars than are actually required in concrete.

These conclusions are consistent with FHWA recommendations (Thomas et al. 2008). The 14-day version of the ASTM C1260/C1567/AMBT is preferred and the use of the non-standard 28-day modification of the test should be discouraged.

References:

ACI Committee 221 (ACI), *State-of-the-Art Report on Alkali-Aggregate Reactivity*, ACI221.1R-98, American Concrete Institute, Farmington Hills, Michigan, 1998, reapproved 2008.

ASTM C1260-07, *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*, *2009 ASTM Annual Book of Standards*, Volume 04.02, *Concrete and Aggregates*, ASTM International, West Conshohocken, Pennsylvania, 2009.

ASTM C1293-08b, "Standard Test Method for Determination of Length Change of Concrete Due to Alkali- Silica Reaction," *2009 ASTM Annual Book of Standards*, Volume 04.02, *Concrete and Aggregates*, ASTM International, West Conshohocken, Pennsylvania, 2009.

ASTM C1567-08, "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)," *2009 ASTM Annual Book of Standards*, Volume 04.02, *Concrete and Aggregates*, ASTM International, West Conshohocken, Pennsylvania, 2009.

Canadian Standards Association (CSA), *Standard Practice to Identify Degree of Alkali-Aggregate Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete*, CSA A23.2-27A, Canadian Standards Association, Toronto, Ontario, 2004.

Farny, J. and Kerkhoff, B., *Diagnosis and Control of Alkali-Aggregate Reactions in Concrete*, IS413, Portland Cement Association, Skokie, Illinois, USA, 2007, 26 pages.

Portland Cement Association (PCA) Durability Subcommittee, *Guide Specification for Concrete Subject to Alkali-Silica Reactions*, IS415, Portland Cement Association, Skokie, Illinois, USA, 2007, 8 pages.

Thomas, M.D.A.; Fournier, B.; Folliard, K. J.; Shehata, M. H.; Ideker, J. H.; and Rogers, C., "Performance Limits for Evaluating Supplementary Cementing Materials Using Accelerated Mortar Bar Test," *ACI Materials Journal,* Vol. 104, No. 2, March-April 2007, pages 115 to 122.

Thomas, M.D.A.; Fournier, B.; and Folliard, K. J., *Report on Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction*, FHWA-HIF-09-001, Federal Highway Administration, Washington, D.C., April 2008, 28 pages.

Portland Cement Association
5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9781

500 New Jersey Avenue NW, 7th Floor
Washington, DC 20001-2066
202.408.9494 Fax 202.408.0877
www.cement.org

An organization of cement companies to improve and extend the uses of portland cement and concrete through market development, engineering, research, education, and public affairs work.