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Correlations between the Laboratory Test Methods for Potential Alkali-Silica Reactivity of Aggregates

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Abstract

In the present study, the alkali-silica reactivity of forty aggregates from different sources in the United States has been investigated using ASTM C1260, ASTM C227 and ASTM C1293. Results indicate that ASTM C1260 can produce both false-positive and false-negative results on about 72% of the aggregates tested. On approximately 28% of the test results by C1260 agreed well with the results by C1293. Based on tests from a limited set of aggregates, it appears that ASTM C227 and ASTM C1293 are more consistent in their ability to indicate the potential for alkali-silica reactivity than either of these tests has with ASTM C1260. Findings from this work suggest for a given aggregate without field performance data, it is advisable to conduct ASTM C1260 and ASTM C1293 simultaneously together with petrographic examination (ASTM C295).

Keywords: aggregates, alkali-silica reactivity, laboratory test methods, correlations.

1 INTRODUCTION

There are many standard laboratory test methods used for identifying the potential alkali-silica reactivity of aggregates. Probably the three most commonly used ASTM test methods are ASTM C1260 [1], *Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*; ASTM C227 [2], *Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)*; and ASTM C1293 [3], *Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction*.

ASTM C1260 is a relatively severe test and generally is used as a screening technique, i.e. as an accelerated method for evaluating ASR susceptible aggregate. According to ASTM C33 [4], *Standard Specification for Concrete Aggregates*, there is good agreement in the published literature cited in the C1260 test method for expansion limits: (1) expansions of less than 0.10% at 14 days immersion in 1N NaOH solution (16 days after casting) are indicative of innocuous behaviour in most cases; (2) expansions of more than 0.20% at 14 days immersion in 1N NaOH solution (16 days after casting) are indicative of potentially deleterious expansion; and (3) expansions between 0.10 and 0.20% at 14 days immersion in 1N NaOH solution (16 days after casting) include both aggregates that are known to be innocuous and deleterious in field performance.

ASTM C227 is also a mortar bar test method and is generally used to evaluate the reactivity of cement and aggregate combinations. The equivalent alkali content (Na_2Oeq)[1] of the cement used for fabricating specimens should be at least 0.80%. Generally it is recognized that a cement-aggregate combination having an expansion greater than 0.05% at 3 months or 0.10% at 6 months is considered to be potentially deleterious, and a combination having an expansion greater than 0.05% at 3 months but below 0.10% at 6 months should

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[1] Equivalent alkali content is defined as $Na_2Oeq = Na_2O + 0.658\ K_2O$.

not be considered to be potentially reactive. However, the line of demarcation between innocuous and potentially deleterious combinations is not clearly defined [4].

ASTM C1293 can also be used as a test method to evaluate the reactivity of aggregates or as a test method to evaluate the combinations of aggregate with supplementary cementing materials (SCMs). In this test method, the alkali content of the cement is elevated to 1.25% Na_2Oeq. When evaluating aggregates independently, those with expansions greater than or equal to 0.04% at one year are considered potentially deleteriously reactive. This test method is (by many) considered to be the most reliable procedure among ASTM test methods for the evaluation of aggregates for alkali-silica reaction [4, 10]. A major drawback of this test method is its long test duration, which is 1-year for evaluating aggregate reactivity and 2 years for evaluating the efficacy of SCMs to mitigate deleterious expansion.

Due to the long test duration for ASTM C1293, tremendous efforts have been directed toward developing quick and reliable test methods to predict the potential alkali-silica reactivity of aggregates [5-7, 11]. The correlations between laboratory testing methods, especially ASTM C1260 and ASTM C1293 have been an interesting topic for both engineers and scientists [12-13]. It is well established that if an aggregate fails the accelerated mortar bar test (expansion > 0.10% at 14 days), its reactivity should be confirmed by testing using the concrete prism test. It is commonly assumed that aggregates that pass the accelerated mortar bar test will most likely pass the concrete prism test, and such aggregates could be accepted for use in concrete without the need for confirmatory testing using the concrete prism test. However, more and more it has been noticed that ASTM C1260 can provide a false interpretation on the reactivity of the aggregates [5-9]. Sometimes it may classify an innocuous aggregate as reactive, while in other cases, it may classify a reactive aggregate as innocuous (known as false negative, and false positive respectively), hence ASTM C33 states, "Results of this test method should not be used for rejection of aggregates unless it has been established using the sources of supplementary information cited in the test method that the detected expansion is actually due to alkali-silica reaction." In addition, there is an increasing trend for coarse aggregates that pass the accelerated mortar bar test and fail the concrete prism test [12]. Hence, it is necessary to conduct additional study to investigate the correlations between the two common laboratory test methods.

In the past few years, CTLGroup has had the opportunity to perform these test methods (ASTM C1260 and ASTM C1293 and/or ASTM C227) on the same aggregates. In the current paper, forty aggregates originating from different sources throughout the United States representing different rock types and different mineralogy are studied. From this systematic study, the correlations between the test results obtained from the different test methods will be analyzed and evaluated.

2 MATERIALS AND METHODS

2.1 Materials

Forty aggregates including both coarse and fine aggregates were collected from different sources within the United States. Six different portland cements with the alkali content ranging 0.18 – 0.61% Na_2Oeq were used in the ASTM C1260 testing. Seven higher alkali portland cements with the alkali content ranging from 0.90 – 1.00% Na_2Oeq were used in the ASTM C227 and ASTM C1293 testing. All thirteen portland cements meet the standard physical and chemical requirements of ASTM C150, *Standard Specification for Portland Cement*, for Type I portland cement. United States Pharmacopeia (UPS) grade NaOH pellets were used to boost the alkali content of the cement in the ASTM C1293 test. Six aggregates were tested in all three tests (ASTM C1260, ASTM C227, and ASTM C1293).

2.2 Experimental procedures

All testing procedures, including aggregate preparation, aggregate gradation, mix proportioning, mixing, test specimen preparation, curing and length readings were conducted in accordance with the relevant standard test methods specified in ASTM C1260, ASTM C227 and ASTM C1293. Testing of nine aggregates by ASTM C1260 was extended to 28 days immersion in 1N NaOH solution at 80ºC. Expansion of the forty aggregates by ASTM C1293 was monitored through one year. Among the forty aggregates, the expansions of six cement-aggregate combinations by ASTM C227 were monitored to one year as well.

3 RESULTS

Accelerated mortar bar test (ASTM C1260)

Figure 1a shows the average expansions vs. days immersed in 1N NaOH solution for thirty-one aggregates that were monitored to 14 days. Expansions of nine aggregates were monitored to 28 days; results are shown in Figure 1b. Among the forty aggregates studied, thirteen of them have average expansions at 14 days below 0.1%, five of them are between 0.10 to 0.20%, twenty-two of them have the expansion above 0.20% with an maximum expansion of 0.81% at 14 days.

For the nine aggregates with extension to 28 days, the expansions continued increasing until the end of testing period. There are two aggregates that had the expansion below 0.10% at 14 days immersion, but one aggregate exceeds this limit at 28 days, another one is close to the limit at 28 days (0.09%).

Mortar bar test (ASTM C227)

The alkali-silica reactivity of six aggregates and cement combinations was also tested in accordance with ASTM C227, and the expansions were monitored to one year. No aggregate/cement combination showed excessive expansion at 3 months (0.05%) and 6 months (0.10%), and the expansions at one year are still below the 3 months criterion. Results are shown in Table 1.

Concrete prism test (ASTM C1293)

Figure 2a shows the expansion results for thirty two aggregates that have the 1-year expansions below the 0.04% criterion. Due to the overlap of data, the graphs do not clearly identify each aggregate. Figure 2b shows the expansion results for the other eight aggregates that exceed the 1-year expansion limit. Among the eight aggregates, one exceeds the 1-year expansion limit at only 90 days; two exceed the 1-year expansion limit at 180 days; the other five exceed the 1-year expansion limit after 270 days.

4 DISCUSSION

ASTM C227 vs. ASTM C1260 and ASTM C1293

Only six aggregates were evaluated by all three test methods - ASTM C227, ASTM C1260 and ASTM C1293. Results are summarized in Table 2. All six aggregates exceed the 14-day criterion (0.10%) in ASTM C1260, but both ASTM C227 and ASTM C1293 test results indicated that these aggregates are innocuous and have low risks in field conditions. It appears that ASTM C1260 is over-conservative, while ASTM C227 and ASTM C1293 are more consistent in predicting the aggregate reactivity.

ASTM C1260 vs. ASTM C1293

Figure 3 shows the correlation of 1-year expansion with C1293 and 14-day expansion with C1260 for forty aggregates. No clear trend can be established between these two results. Figure 4 shows the correlation of 1-year expansion in C1293 and 28-day expansion in C1260 for nine aggregates. It seems the correlation of

1-year C1293 and 28-day C1260 is good except for two samples, but no definitive conclusions can be drawn based on the small number of aggregates tested.

Table 3 gives another interpretation of the observations. Approximately 28% of the test results are consistent with the two test methods, i.e. both tests pass or both fail. About 60% of the test results failed in ASTM C1260 but passed in ASTM C1293; again indicating that ASTM C1260 is over conservative. Hence, some researchers have recommended lower limits and a limit of 0.08% at 14-day immersion has been adopted by ACI 211.1 and many states' related projects [14-16].

It is generally believed that a few percent of aggregates will pass ASTM C1260 test but fail ASTM C1293, as evidenced in Folliard, et al.'s work [12], and other researchers' observations [6-7, 9], but it is contrary to the general interpretation of the results from these two procedures. In normal cases, if the 14-day expansion by C1260 is below 0.10%, the aggregate will be considered as non-deleterious, therefore, less attention is paid to the group of aggregates that pass the C1260 but fail the C1293.

It has been reported that ASTM C1260 may produce a false-negative result with aggregates suspected of containing deleterious strained quartz and some granitic gneisses and metabasalts [5, 7]. It may also produce a false positive result with a number of marginally reactive aggregates [6], therefore, ASTM C1260 may not be able to accurately evaluate some aggregates containing varieties of quartz. Unfortunately, the rock type and mineralogy of the forty aggregates are not available for further investigation.

5 CONCLUSIONS

Based on the work conducted in this study, the following conclusions can be drawn:

- ASTM C1260 can produce both false-positive and false-negative results on predicting the potential alkali-silica reactivity of aggregates when compared with ASTM C1293. Caution should be exercised when interpreting the test results.
- It appears that ASTM C227 and ASTM C1293 are more consistent with each other than either of them are correlated with ASTM C1260.
- The correlation between 1-year expansion by C1293 and 14-day expansion by C1260 indicated that ASTM C1260 either over or under-evaluate the reactivity of about 72% of the aggregates tested, while a good agreement was achieved with approximatelty 28% of the aggregates.
- Without history of field performance, it is advisable to conduct the C1260 and C1293 simultaneously together with a petrographic examination to confidently identify possible ASR potential.

6 REFERENCES

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Table 1: Expansion results obtained from ASTM C227

	Average length expansion, %		
	3-month	6-month	12-month
Aggregate 1	0.00	0.01	0.01
Aggregate 2	0.00	0.01	0.01
Aggregate 3	0.00	0.01	0.01
Aggregate 4	0.00	0.00	0.00
Aggregate 5	0.00	0.00	0.01
Aggregate 6	0.01	0.01	0.01

Table 2: Summary of ASTM C227, ASTM C1260 and ASTM C1293 results (average length expansion, %)

	C1260 at 14-day	C227 at 6-month	C1293 at 1-year
Range of expansion, %	0.16-0.41	0.00-0.01	0.01-0.03

Table 3: Summary of C1293 and C1260 results		
1-year C1293	14-day C1260	
	Passed (≤ 0.10%)	Failed (> 0.10%)
Passed (≤ 0.04%)	8	24
Failed (> 0.04%)	5	3

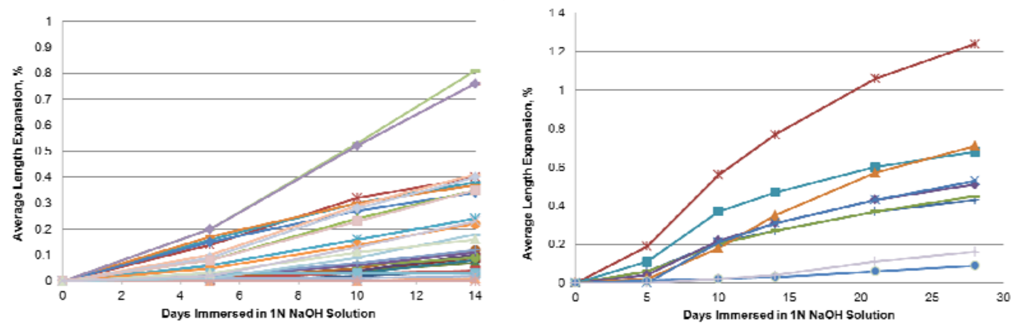

Figure 1a Figure 1b

Figure 1: Expansion results obtained from ASTM C1260

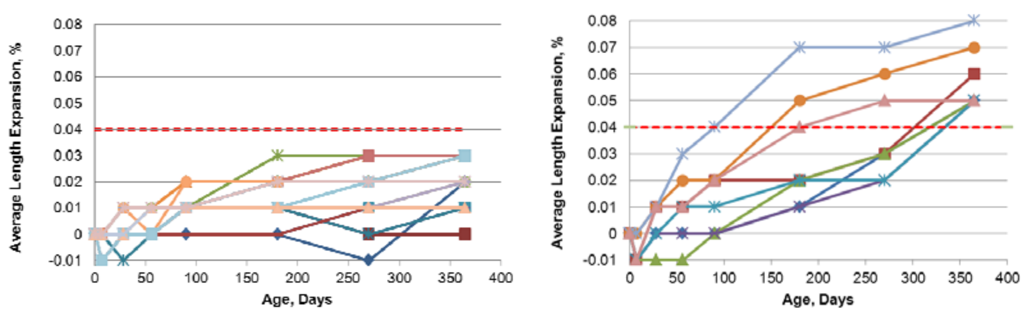

Figure 2a Figure 2b

Figure 2: Expansion results obtained from ASTM C 1293

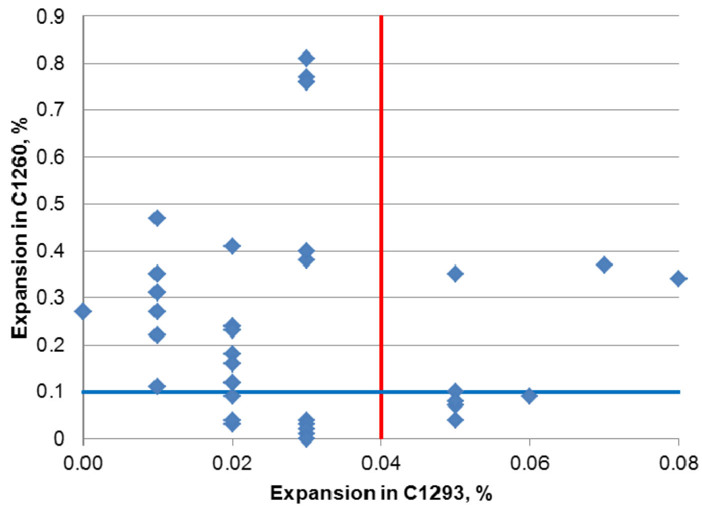

Figure 3: Correlation between the expansions of 1-year C1290 and 14-day C1260 for 40 aggregates.

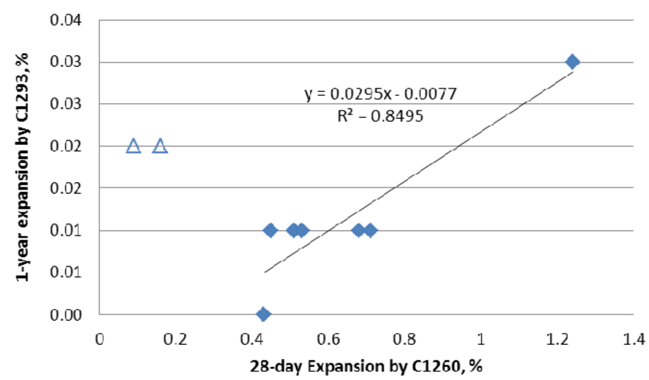

Figure 4: Correlation between the expansions of 1-year C1293 and 28-day C1260 for nine aggregates.