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CAN THE ACCELERATED PRISM TEST EVALUATE ALKALI-SILICA REACTIVITY?

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The purpose of this study was to evaluate the alkali-silica reactivity of twelve aggregates based on the ASR-induced expansions of ASTM C 1260 and modified ASTM C 1293. The mortar bars and concrete specimens were prepared and fully submerged in the 1.0N NaOH at the temperature of 80°C. The ASR-induced expansions of the test specimens were recorded at various immersion ages. The expansion limits of alkali-cured prisms were proposed at the test durations of 4 and 8 weeks. Finally, the trial aggregates were classified based on the aggregate mineralogy and the expansion limits of mortar bars at 14 and 28 days, and they were compared with the proposed expansion limit of concrete prisms at the ages of 4 and 8 weeks. It was acknowledged that the 4-week failure limit of concrete prisms under the 1.0N resulted in some innocuous aggregates to be rated as reactive. However, the ASR-classifications of the trial aggregates showed a perfect correlation based on the results obtained from the extended failure limits of mortar bars and concrete prisms, and those from the mineralogy of aggregates.

Keywords: Reaction, Modified ASTM C 1293, ASTM C 1260, Failure limits, Test durations, Aggregate mineralogy.

1 INTRODUCTION

Alkali-silica reaction (ASR) is a common cause of concrete cracking which can result in significant damages to concrete structures (Touma et al. 2001, Islam 2010, Islam 2014, Islam and Ghafoori 2014, Islam 2015). The deterioration caused by ASR is fairly slow, but progressive. Generally, cracking due to the ASR becomes visible when the concrete reaches at the age of 5 to 10 years. There are various standard methods to evaluate the alkali-silica reactivity of an aggregate. Due to the deficiencies of the prior screening ASR tests of ASTM C 227 and ASTM C 289, the use of ASTM C 1260 (Accelerated Mortar-Bar Test (AMBT)) and ASTM C 1293 (Concrete Prism Test (CPT) has become more popularity throughout the world (Golmakani 2013).

Compared to the AMBT, the CPT is more liable in assessing alkali-silica reactivity of an aggregate (Bérubé and Frenette 1994, Berra et al. 1998, Touma 2000, Folliard et al. 2004). Since the CPT requires a long time, at least one year, to decide the ASR reactivity of an aggregate, now-a-days the modifications of ASTM C 1293 have become more popular (Touma 2000). The modified ASTM C 1293 tests are being used whether they produced an identical result of ASTM C 1293 in a shorter span of time. Touma et al. (2000) slightly modified the procedure of ASTM C 1293 in changing the curing conditions and the duration of storage, and concluded that the concrete prism test was shown very much dependent on the curing environments and test duration.

Folliard et al. (2004) studied the use of two accelerated versions of ASTM C 1293, storing prism specimens above water at 60°C and 49°C, with the standard testing at 38°C to assess alkali-silica reactivity. The overall findings show that the typical long-term expansions measured at 60°C are significantly less than those measured at 49°C and 38°C. This reduction in expansion is shown to be mainly caused by increased specimen drying out of the prisms and increased alkali leaching at higher temperatures, as well as changes in pore solution composition.

Bérubé and Frenette (1994) conducted concrete prisms test of two highly alkali-silica reactive aggregates in NaOH solution at two distinct temperature of 80°C and 38°C. Results obtained from the study indicated that (i) prisms testing in 1.0N NaOH at 80°C shows the most rapid testing procedure due to the initial concrete alkali content, and is unreliable for determining the potential alkali-reactivity of aggregates; (ii) testing in 1.0N NaOH at 38°C appears the most promising procedure, compared with the concrete prism method C 1293 (CSA A23-2-14A, testing in air at ~100% RH) and the test duration could be reduced from 1 year to 6 months.

Past research studies were limited to the early age (4 weeks) expansion limit of the ASTM C 1293 for the 1.0N NaOH at the elevated temperature of 80°C. Therefore, it is in a great need to evaluate this modification of ASTM C 1290 by extending the test duration beyond 4 weeks. Additionally, no failure limits of alkali-cured prisms were proposed in the previous studies.

2 RESEARCH SIGNIFICANCE

Past studies were on evaluating the reactivity of aggregates were mostly restricted to the standard failure limit of mortar bars at 14 days. The expansion limits of the alkali-cured prisms were proposed at the test durations of 4 and 8 weeks. This study focuses the relationships of ASR classifications of the investigated aggregates based on the results obtained from mineralogy of aggregate, the expansions of mortar bars at 14, and 28 days, and those of alkali-cured concrete prisms at the ages of 4 and 8 weeks.

3 PREVIOUS EXPERIMENTAL STUDIES

The database used in this study was compiled from two existing experimental studies conducted by Touma (2000) and Islam (2010). The raw materials utilized in this study consisted of twelve aggregate groups (six from Touma (2000) and the remaining six from Islam (2010). The identification and rock type of the investigated aggregate groups were shown in Table 1. The susceptibility of the aggregates to alkali-silica reaction were then determined by their rock type according to the geological nomenclature, as described in the studies conducted by Islam (2010), Ghafoori and Islam (2010), Ghafoori and Islam 2013, Islam and Ghafoori (2013a,b) and Islam and Akhtar (2013), and the results are presented in Table 1. The compositions of Portland cement used in the studies are shown in Table 2. The expansion reading of mortar bar was taken until the test duration had reached at 28 days for the ASTM C 1260 and 8 weeks for the modified ASTM C 1293.

Table 1. Identification, rock type and ASR potential of investigated aggregate groups

Previous Studies	Aggregate Id	Rock Type	Potential ASR Reactivity
	A1-WY	Rhyolite	0.050 (I)
	B4-VA	Quartz	0.502 (R)
	D2-IL	Dolomite	Innocuous
	E2-IA	Shale	0.599 (R)
	E6-IN	Natural siliceous	0.109 (I)
Touma (2000)	E8-NM	Rhyolite, andesite	Reactive
	SN-A	Dolomite	Innocuous
	SN-C	Dolomite-Limestone	Reactive
	SN-E	Dolomite	Innocuous
	SN-G	Andesite	Reactive
	NN-B	Andesite	Reactive
Islam (2010)	NN-C	Basaltic-andesite	Reactive

Table 2. Composition of Portland cement used in the study

Studies	SiO_2	Al_2O_3	Fe2O3	CaO	MgO	Na_2O^*	SO3	LOI
Touma (2000)	20.90	4.43	3.01	62.65	2.97	1.14	3.06	1.68
Islam (2010)	21.00	3.60	3.40	63.10	4.70	0.84	2.60	1.30

$^*Na_2O_{eq} = Na_2O + 0.658 \times K_2O$

4 RESULTS AND DISCUSSIONS

4.1 Progression in mortar and prism expansions

The development of expansion of alkali-cured mortar and prism is shown in Figure 1. As can be shown, the expansions of both specimens prepared with each aggregate group varied widely depending on aggregate's geology. Some aggregates expanded more at early age and continued at higher values with the immersion age. For some aggregate groups, the expansions were very slow through the test duration.

4.2 Relationships between mortar expansions and concrete prism expansions

Fig. 2 shows the correlations of ASR-induced expansions of mortar bars and concrete prisms. The linear relationships between the 14-day mortar expansions and 4-week prism expansions, and those of 28-day mortar expansions and 8-week prism expansions are presented by Eq. (1) and Eq. (2), respectively. A very good correlation was existed between the dependent and independent variables. The failure criteria of the alkali-cured prisms at the test durations of 4 and 8 weeks were determined by using the Eqs. (1) and (2) and the expansion limits of the mortar bars at the test durations of 14 and 28 days, respectively.

$$PE_{4w} = 0.2912 * ME_{14d} \quad (1)$$

$$PE_{8w} = 0.2855 * ME_{28d} \quad (2)$$

Where: PE_{4w} and PE_{8w} are the concrete prism expansions at the test durations of 4 and 8 weeks, respectively; ME14d and ME28d are the mortar expansions at the test durations of 14 and 28 days, respectively

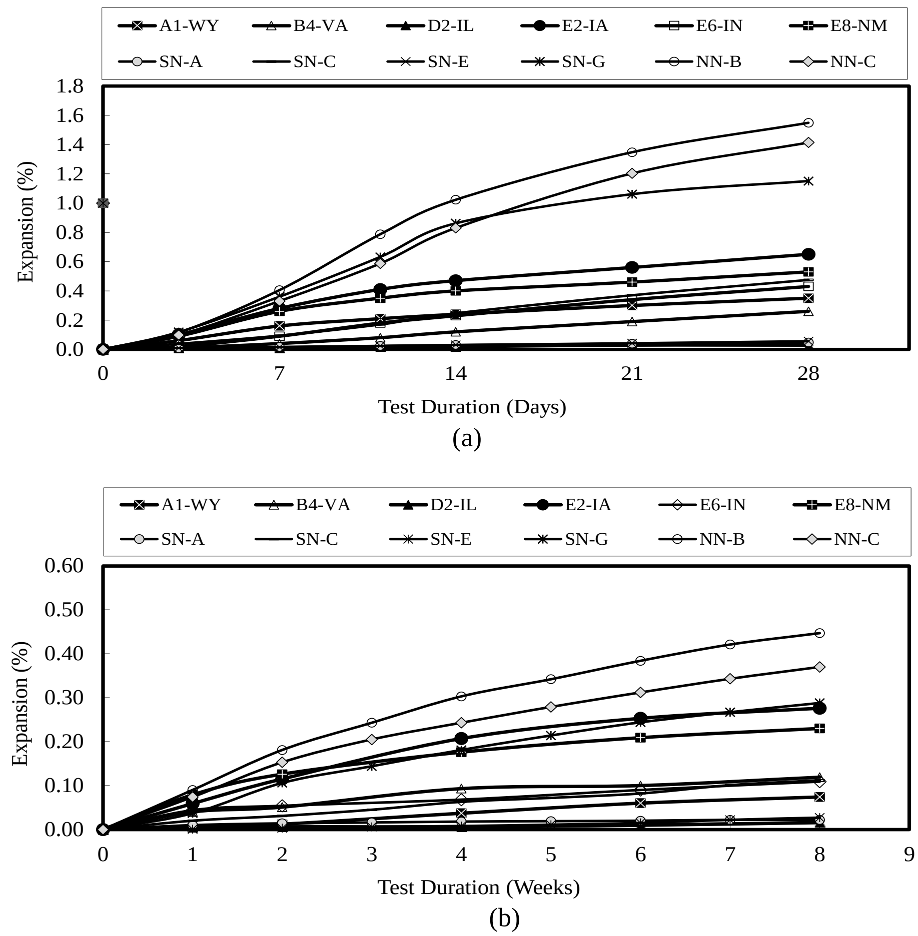
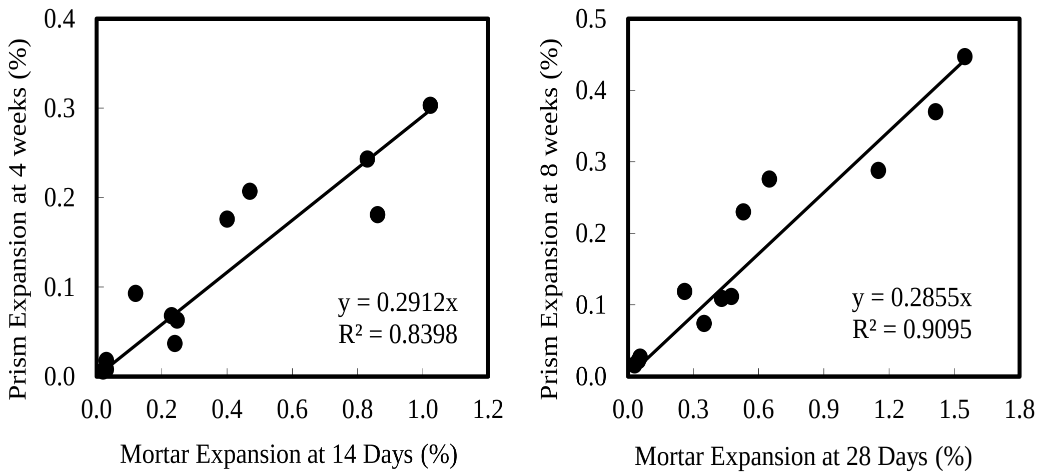


Figure 1: Progression of ASR-induced expansion of a) mortar bars and b) concrete prisms

The proposed expansion limits of concrete prisms for the 1.0N NaOH were revealed to be 0.030% at 4 weeks and 0.080% at 8 weeks. This demonstrated that the aggregates having the alkali-cured prism expansions of more than 0.030% at 4 weeks and 0.080% at 8 weeks were treated as reactive, and those having the expansions of less than the above-mentioned suggested criteria were declared as innocuous.

4.3 ASR Classifications of the Aggregates

The aggregates were classified into reactive and innocuous based on the expansion limits of mortar bars at 14 and 28 days, and those of alkali-cured prisms at the ages of 4 and 8 weeks. The susceptibility of the selected aggregates to the alkali-silica reaction were also evaluated. The results are shown in Table 3. As can be shown, of the twelve aggregates, ASR classifications of the ten aggregates perfectly matched based on the aggregate mineralogy, and expansion limits of mortar bars at 14 and 28 days and those of alkali-cured prisms at the ages of 4 and 8 weeks. The 4-week failure limit of alkali-cured prism overestimated the reactivity of A1-WY and E6-IN aggregate groups. The severity of the modified ASTM C 1293 tests can be partially eliminated by utilizing the proposed failure limit of 0.080% at 8 weeks.



(a) Touma (2000)

(b) Islam (2010)

Figure 2. Time required to reach percent of ultimate mortar expansion

Table 3. ASR classifications based on the expansion limits of mortar bars

Agg. ID	Aggregate Mineralogy	ASTM C 1260		Modified ASTM C 1293	
		14 days (0.10%)[a]	28 Days 0.28%[b]	4 Weeks 0.030%[c]	8 weeks 0.080%[c]
A1-WY	I	I	R	0.037 (R)	0.074 (I)
B4-VA	R	R	R	0.093 (R)	0.119 (R)
D2-IL	I	I	I	0.006 (I)	0.016 (I)
E2-IA	R	R	R	0.207 (R)	0.276 (R)
E6-IN	I	I	R	0.068 (R)	0.109 (R)
E8-NM	R	R	R	0.176 (R)	0.230 (R)
SN-A	I	I	I	0.018 (I)	0.022 (I)
SN-C	R	R	R	0.063 (R)	0.112 (R)
SN-E	I	I	I	0.008 (I)	0.027 (I)
SN-G	R	R	R	0.181 (R)	0.288 (R)
NN-B	R	R	R	0.303 (R)	0.447 (R)
NN-C	R	R	R	0.243 (R)	0.370 (R)

[a]Failure limit recommended by ASTM C 1260 (2007); [b]Failure criteria suggested by Islam (2010)

[c]Failure limit suggested in this study

5 CONCLUSIONS

The findings of this research study can be summarized below:

(1) The 4-week expansion limit of modified ASTM C 1293 overestimated the level of some aggregate groups. The conflicting results can be eliminated by extending the test duration of modified ASTM C 1293 from 4 weeks to 8 weeks, and utilizing the extended expansion limit of concrete prism of 0.080% at 8 weeks.

(2) Of the twelve aggregates investigated, the alkali-silica reactivity of ten aggregates showed a perfect correlation based on the aggregate mineralogy and the extended failure criteria of ASTM C 1260 at 14 and 28 days, and those of modified ASTM C 1293 at the test durations of 8 and 13 weeks.

(3) Since the ASR of an aggregate depended on many factors, it can be stated that, the aggregate mineralogy coupled with the results obtained from the expansion limits of ASTM C 1260 at 14 and 28 days and those of modified ASTM C 1293 at 4 and 8 weeks would be a reliable indicator to evaluate the actual reactivity of an aggregate.

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