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Reliability of new Australian test methods in predicting alkali silica reaction of field concrete

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HIGHLIGHTS

- New Australian Standard test methods to test alkali-silica reactivity of aggregates.
- AS1141.60.1 classified most 'reactive' aggregates consistent with field performance.
- AS1141.60.1 is a poorer screening test for non-reactive aggregates than ASTM C1260.
- Both concrete prism tests were found to be more reliable than AMBT.

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ABSTRACT

Two new Australian Standard methods to test alkali-silica reactivity (ASR) of aggregates – AS 1141.60.1 accelerated mortar bar test (AMBT) and AS 1141.60.2 concrete prism test (CPT) were published in September 2014. The methods adopted test procedures correspondingly from ASTM C1260 and ASTM C1293 with improved performance limits leading to a new class of slowly reactive aggregates. This paper examines the accuracy of these new testing methods in predicting the ASR of aggregates in field conditions based on international research data. AS 1141.60.1 was found to be a relatively good accelerated test which correctly classified 'slowly reactive' and 'reactive' aggregates consistent with field performance with few exceptions. It is however a poorer screening test for non-reactive aggregates than ASTM C1260. Both AS 1141.60.2 and ASTM C1293 concrete prism tests were found to be more reliable than AMBT as both correctly classified almost all 64 aggregates against known field performance.

1. Introduction

Test methods used to test the potential alkali-silica reactivity (ASR) of aggregate are an important part of a suite of tools used to prevent the deleterious reaction caused by the reaction between alkali from cement and reactive silica in aggregates. Australian standards also limit the maximum alkali content in cement and total alkali in concrete. The availability and popular use of supplementary cementitious material (SCM), and in particular fly ash, has successfully limited the scale of ASR problems in Australia. Research is continuing to determine the accuracy of test methods as well as to improve the interpretation of the more practical accelerated test methods.

2. Australian standard test methods

In 2014, Standards Australia CE-012 Aggregate and Rock for Engineering Purposes Committee has published two new standard test methods to test potential ASR:

AS 1141.60.1-2014 Potential alkali-silica reactivity – Accelerated mortar bar method (AMBT) [1] and AS 1141.60.2-2014 Potential alkali-silica reactivity – Concrete prism method (CPT) [2].

2.1. Accelerated mortar bar test (AMBT)

Accelerated mortar bar test (AMBT) is a rapid test method applied to determine the potential alkali-silica reactivity of aggregates by testing mortar specimens. Naturally occurring fine aggregates are tested in their natural form whereas coarse aggregates are crushed to specific grading. In general, the procedure of mortar bar testing involves casting mortar bars (normally in the size of 25 × 25 × 285 mm) and curing for 24 h in relative humidity of 95%. Afterwards, mortar samples are kept in potable water and

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heated to 80 °C before being transferred to storage in the 1 N NaOH solution at 80 °C for 24 h. After this time, the initial length of mortar bar is measured as the zero reading. Samples remain in 1 N NaOH until further measurements are undertaken at 10, 14, 21 or 28 days according to the different test methods.

During the development of the Standard AS 1141.60.1, three alternative AMBT testing procedures namely the fixed flow (Roads and Maritime Services RMS T363 [3] or VicRoads CR376.03 [4]), a fixed water-to-cement ratio (ASTM C1260 [5]) and a fixed free water-to-cement ratio (RILEM AAR-2 [6]) were considered. Free water-to-cement ratio is calculated from mix compositions with fine aggregate at surface saturated dry (SSD) condition. The committee agreed to adopt the fixed water-to-cement ratio method in ASTM C1260 due to three specific factors:

i. the more conservative and usually higher effective water-to-cement ratio mortar mix composition in ASTM C1260 compared to the fixed flow method [7,8],
ii. reduced variability due to the difficulty in determining the surface saturated dry condition (SSD) of crushed aggregates or flow measurement [9], and
iii. the possible benchmarking to international research data [10] and international proficiency program data [11].

In a recent study, Fournier et al. [11] investigated the proficiency of different AMBT test procedures, including the American ASTM, Canadian CSA and the European RILEM test methods. It should be noted that the ASTM and CSA test procedures are similar. As can be seen from Table 1, coefficients of variation of AMBT methods showed lower variation in the 14 days expansion for the ASTM + CSA methods compared to the RILEM test results; however, similar variations in the 28 days expansion were observed for all three test methods. By considering the 10 and 21 days limits for measuring the expansion of mortar samples in AS 1141.60.1, the outcomes of Fournier et al. investigation support the adoption of ASTM procedure from the test proficiency viewpoint.

In addition, Thomas and Innis [12] stressed that the usefulness of various tests may be judged on the basis of the ease of testing, the repeatability or precision of the outcomes, the time taken to complete the test and ultimately, the ability of the test to predict behaviour in the field. The test procedures adopted in AS 1141.60.1 satisfied the first three requirements. The performance limits will be tested in this paper to ascertain if they can better predict field behaviour.

2.2. Concrete prism test (CPT)

Concrete prism test (CPT) is medium-term 52-week test. A fine or coarse aggregate is tested for it potential reactivity in a concrete mix prepared with a known non-reactive coarse or fine aggregate respectively. The potential reaction is accelerated by artificially elevated alkali content and high curing temperature. The Australian Standard AS 1141.60.2 test method adopts procedures similar to ASTM C1293 [13] in measuring the expansion of $75 \times 75 \times 285$ mm concrete prisms made with a cement content of 420 ± 10 kg/m^3 and a dry mass of coarse aggregate per unit volume of concrete equal to 0.70 ± 0.02 of its dry-rodded bulk density at a water-to-cementitious material ratio (w/cm) of 0.42–0.45 by mass. The cement has a total alkali content of 1.25% of Na_2O equivalent (Na_2O_e) by mass of cement. Specimens are placed in a container stored in a 38.0 ± 2 °C. Expansion measurements are performed up to 52 weeks.

2.3. Field testing (Outdoor exposure)

Field testing (Outdoor exposure) provides the most realistic conditions for ASR testing of concrete with sample dimensions closer to the scale of real structures. Concrete may be cast with normal or slightly elevated alkali content before exposure and monitoring of expansion and other visible deterioration for longer periods of time (5–20 years).

It is implied by the literature [14] that the best method to determine whether an aggregate is potentially reactive or innocuous is to study the history of the aggregate in field conditions. An aggregate can be used in concrete provided that satisfactory field performance was achieved and the cement content (the total alkali content of the cement) should be the same or higher in the field concrete than that proposed in the new structure. The outdoor field exposed concrete should be at least 10 years old. In addition, the exposure conditions of the field concrete should be at least as severe as those in the proposed structure [14].

3. Performance limits in Australian test methods

In both the AMBT and CPT methods, expansion limits after a particular period are used to indicate/classify the potential reactivity of aggregates tested. These expansion performance limits were derived from research and field experiences with the use of a wide range of aggregates.

3.1. Accelerated mortar bar test (AMBT)

Shayan and Morris [7] compared the accelerated mortar bar expansion of 18 aggregates of known service record, based on procedures in the RMS T363 [7] and ASTM C1260 [5], and found lower expansion in the RMS mortars than the corresponding ASTM mortars for reactive aggregates. The lower expansion of the RMS mortars were thought to be due to the lower water/cement ratio in the range of 0.40–0.42 in RMS T363 compared to 0.47 used in the ASTM method. The mortar bar expansions were similar for the less reactive aggregates possibly because they consumed less alkali and were not affected by the differences in supply of alkali in the two methods. They found both test methods and their corresponding expansion limits to be capable of assessing the alkali reactivity of non-reactive or very reactive aggregates. However for slowly reactive aggregates, both methods can be used provided that the RMS

Table 1
Statistical analysis of different accelerated mortar bar test [11].

Test age	Method of testing	Number ofresults	Mean [%]	Standard deviation	Coefficient of variation [%]	Min [%]	Max [%]
14 days	CSA	26	0.375	0.043	11.6	0.307	0.486
	ASTM	24	0.374	0.055	14.8	0.206	0.451
	ASTM + CSA	50	0.375	0.049	13.1	0.206	0.486
	RILEM	3	0.291	0.071	24.5	0.230	0.369
28 days	CSA	26	0.591	0.067	11.3	0.450	0.725
	ASTM	24	0.571	0.064	11.2	0.470	0.700
	ASTM + CSA	50	0.582	0.066	11.3	0.450	0.725
	RILEM	3	0.547	0.065	11.9	0.500	0.621