COMPARISON BETWEEN TWO ACCELERATED METHODS FOR DETERMINING ALKALI REACTIVITY POTENTIAL OF AGGREGATES

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The standard methods of testing for the expansivity of combinations of cement and aggregate, such as the mortar bar test (ASTM C227 or Australian Standard AS 1141–38), are known to be slow and not always reliable. In the past few years, different accelerated methods have been introduced in several countries, each with some degree of success.

Two rapid test procedures, viz. that used at the CSIRO, Australia, which takes about 4 weeks to complete, and the Japanese GBRC method which requires only a few days, have been used to assess the susceptibility of 25 different aggregates to AAR. Both methods predicted the reactivity of the more reactive aggregates, but expansion of mortar bars containing the slowly reactive aggregates was smaller in the Japanese method. Changing the mix proportions in the mortar bars increased the expansion for some aggregates, but had no significant effect on others.

It is concluded that both methods are suitable for detecting moderately to highly reactive aggregates. The existing procedure at CSIRO is satisfactory for the slowly reactive aggregates. However, the Japanese method would probably need modifications to mix proportions and curing regime, and this could easily be done using a versatile testing machine manufactured by Marui Company, Japan.

INTRODUCTION

It is well recognised now that the conventional standard test methods for determining the alkali reactivity of combinations of cement and aggregate, such as the widely used mortar bar test ASTM C227 (or Australian Standard AS 1141–38), are very slow and often unreliable. Testing concrete prisms has improved the reliability, but this still suffers from being slow and requiring large storage spaces. In the past few years, several accelerated methods have been introduced in a number of countries, each with some degree of success with local materials.

Among the new methods, storage of mortar bars in 1M NaOH solution at 80°C has shown promise in identifying alkali reactivity of a variety of aggregates. Oberholster and Davies (1) found that mortar bar expansions greater than 0.11% after 12 days of storage identified reactive aggregates. Shayan *et al.* (2) developed different procedures, but still using 1M NaOH at 80°C, and found that for Australian aggregates of moderate reactivity, mortar bar expansions were greater than 0.1% at 10 days, but that for slowly reactive aggregates the expansions were 0.1% or greater at 21 days. These slowly reactive aggregates could not have been identified had the limit set for the South African aggregates (1) been applied.

In Japan, an accelerated method, known as the GBRC method (Tamura (3)), has been used with some success in identifying the Japanese reactive aggregates. In China, an autoclave method using very small specimens was developed by Tang *et al.* (4) for Chinese aggregates. This has recently been extended by the French workers Criaud and Deffosse (5) to include three different aggregate-to-cement ratios for each material and is claimed to be successful in identifying reactive aggregates.

This paper compares the results of testing a large number of aggregates using the procedure used at the CSIRO, Australia (Shayan *et al.* (2)), and the Japanese GBRC method (Tamura (3)), and comments on their applicability to various aggregates.

EXPERIMENTAL

Materials

Twenty-five aggregates of different origins, some from overseas, were used in this work. Some of these aggregates have reacted in concrete structures and some others have been shown to be reactive in laboratory testing. Table 1 contains a list of the aggregates, their locality and reactivity status.

A type A Portland cement was used throughout the experiments.

Procedure

The procedures for preparation and treatment of the specimens used at CSIRO have been described earlier by Shayan *et al.* (2). The grading of the aggregate in mortar bars for this test is the same as that in the ASTM C227 test method. The aggregate-to-cement ratio is 2.25. No alkali is added to the mortar mix before casting.

The Japanese procedure consists of making 40 x 40 x 160 mm mortar bars with a mix of 600 g cement, 600 g fine aggregate, 600 g sand and 300 g of an NaOH solution with an appropriate concentration to make the alkali content of the cement 2.5%. After demoulding, the mortar bars are cured in water for 24 hours, then placed in an autoclave and subjected to a heat regime consisting of 50 minutes of temperature rise from room condition to 127°C, 4 hours of heating at 127°C, and 50 minutes of cooling from 127°C to room temperature (20°C). Marui Company, Japan, has manufactured a programmable autoclave which can perform this and many other functions. The expansion of the mortar bars is then measured and their cracking noted. Expansions greater than 0.1% indicate alkali reactivity of the aggregate. Measurement of the modulus of elasticity is also used to indicate reactivity, but it is considered that expansion is a more direct measure of reactivity. If the Japanese method was found to apply to Australian aggregates, then it would have the advantage of being a much more rapid test than the accelerated test currently being used.

RESULTS AND DISCUSSION

Table 1 also shows the expansion results obtained for each aggregate by the two accelerated methods.

TABLE 1 – Expansion results (%) for the various aggregates

Aggregate	Locality	Reactivity*	Aust. Procedure		Japanese Procedure (4 hours)†		
			10 days	22 days	Standard mix 1:1:1:0.5	1:0:1:0.5	2:0:1:0.5
PM (quartzite)	Aust.	Y	0.279	0.383	0.136	0.163	0.266
NRG (greywacke)	Aust.	Y/L	0.238	0.416	0.100	0.056	0.061
TWD (basalt)	Aust.	Y/L	0.355	0.491	0.063	0.059	0.051
BR (gravel)	Aust.	Y/L	0.090	0.138	0.076	0.116	–
RN (ignimbrite)	Aust.	Y	0.184	0.374	0.137	0.239	0.159
JA1 (andesite)	Japan	Y	0.415	0.923	0.883	–	–
JA2 (andesite)	Japan	Y	0.246	0.380	0.118	0.145	–
JAB (bronzite)	Japan	Y	0.291	0.767	0.594	–	–
JNC (chert)	Japan	Y	0.192	0.328	0.117	0.080	–
NZ (andesite)	New Zealand	Y	0.687	1.014	0.416	–	–
WRL (granite)	Aust.	Y/L	0.040	0.106	0.031	–	–
SUD (gravel)	Canada	Y	0.175	0.311	0.057	0.057	–
UY (phyllite)	Aust.	Y	0.040	0.100	0.014	0.014	–
NBB (sandstone)	Aust.	Y pessimum	0.010	0.027	0.080	–	1:2:3:1.5 0.208
GSN (metadolerite)	Aust.	Y	0.097	0.207	0.040	0.034	–
TLK (gravel)	Aust.	Y/L	0.163	0.270	0.048	0.066	–
HC (gravel)	Aust.	Y/L	0.144	0.243	0.049	0.067	0.043
SAF (greywacke)	South Africa	Y	0.294	0.426	0.199	0.173	–
MDH (dacite)	Aust.	Y	0.259	0.373	0.080	0.100	–
GSG (granite)	Aust.	Y	0.046	0.163	0.039	0.031	–
JDM (metadolerite)	Aust.	N/L	0.017	0.040	0.040	–	–
SPK (gravel)	Aust.	Y/L	0.030	0.226	0.036	–	–
TRN (metadolerite)	Aust.	N/L	0.008	0.039	0.025	–	–
HME (quartzite)	Aust.	Y/L	0.169	0.378	0.082	0.097	–
GRD (basalt)	Aust.	N	0.014	0.016	0.022	0.015	–

* Y/L = yes, in laboratory testing, N/L = no, in laboratory testing.
† Mix proportions refer to aggregate:sand:cement:water ratios.

According to the criteria for the Australian procedure, all aggregates except NBB standstone, JDM metadolerite, TRN metadolerite and GRD basalt are classed as reactive. However, the sandstone has been shown to be reactive and to cause significant mortar bar expansion when used in proportions <30% (Shayan *et al.* (2)). The reason for the low observed expansion is that this aggregate has a pessimum proportion below 30%, whereas it was used as 100% of the total aggregate in the mortar bars. Mortar bar expansions of 0.108 and 0.170% are obtained when NBB aggregate makes up 34 and 15% of the total aggregate. In the Japanese procedure also, it results in 0.08% expansion when used as 50% of the aggregate (50% is sand), but causes 0.208% expansion when it forms 30% of the aggregate. However, this high expansion is also partly due to the higher cement and alkali contents in the mix (1:2:3:1.5).

In the Japanese method, aggregates of moderate to high reactivity, such as aggregates RN, JA1, JAB, NZ and SAF, produce mortar bar expansions of 0.1% or greater, when the prescribed mix proportions are used. However, slowly reactive aggregates, such as aggregates SUD, UY, GSN and GSG, produce mortar bar expansions below 0.1% and are therefore classed incorrectly as non-reactive. Eliminating the sand from the mix design caused additional mortar bar expansions for some aggregates (e.g. aggregates BR, MDH and HME), such that they approached or exceeded the 0.1% limit, but this did not happen for some other aggregates. Increasing the aggregate-to-cement ratio from 1:1 to 2:1 did not have a consistent effect, although this was attempted on only six aggregates. It is planned to extend this work and also to check the effects of varying the ratio to 1:2 for the slowly reactive aggregate. For optimum expansion to be achieved, it may be necessary to prolong the heating period and/or vary the temperature, in addition to alterations of the mix proportion. The programmable autoclave made by Marui Company, Japan, is a very convenient and versatile instrument for imposing the required temperature regime on the specimens, and could be used for optimising the Japanese method for the slowly reactive aggregates.

An overall comparison of the two methods is made in Figure 1, where the mortar bar expansions obtained by these methods are plotted against each other. Figure 1 shows that the methods agree on classifying 4 aggregates as non-reactive (one as showing the pessimum effect) and 12 as reactive. However, there is disagreement for nine slowly reactive aggregates. Further work is required to sort out this difference.

CONCLUSIONS

The two methods compared here agree on the classification of non-reactive and moderately to highly reactive aggregates, but there is disagreement for some of the slowly reactive agregates. The Japanese method is faster and produces results in a few days for aggregates of moderate to high reactivity. However, for the slowly reactive aggregates the mix proportion of the test mortar bars and the curing regime needs to be optimised to produce mortar bar expansions comparable to those obtained by the current procedure used at the CSIRO. The latter is slower than the Japanese method and takes about four weeks to complete.

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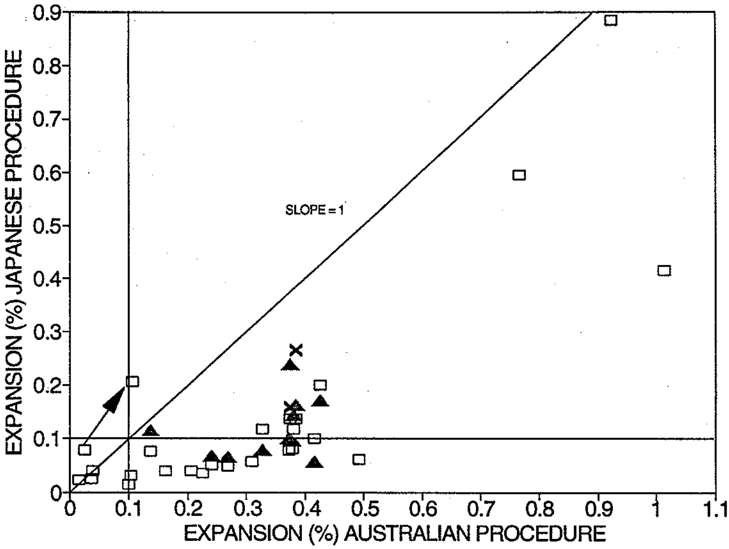

Figure 1 Comparison of mortar bar expansion in the two accelerated methods. Squares, triangles and crosses are for mixes in Table 1 from left to right, respectively. An increase in the expansion of mortar bars containing 30% NBB compared to 100% NBB sandstone is shown by the arrow.