EFFECT OF PRE-CURING PERIOD ON ACCELERATED MORTAR BAR AND CONCRETE MICROBAR TESTS

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Abstract

Accelerated test methods such as accelerated mortar bar test and concrete microbar test involve a pre-curing period in water at 80°C for 24 hours. The zero length of the specimens is measured at the end of this period. The subsequent curing is in 1 N NaOH solution at 80°C and the expansions of the specimens are calculated by extracting the zero length reading from the length reading of the date in question. In this study, the specimens were cured for 4, 12, 16, 24 and 48 hours in 80°C water then in 1N NaOH solution at 80°C for the following test period, respectively. Expansion-time relationships were discussed. It was found that 4 hours pre-curing period seems to be sufficient to evaluate the reactivity of the aggregates. Strong relationship between AMBT and CMT test results indicates that CMT is a promising test method to evaluate the reactivity of coarse aggregates.

Keywords: alkali-silica reaction, accelerated mortar bar test, concrete microbar test, curing conditions

1 INTRODUCTION

In order to evaluate potential alkali reactivity of aggregates or the performance of aggregate-cementitious material combinations, several test methods are proposed, some of them are standardized in different countries. However, none of these test methods are accepted worldwide. Considering the choice of suitable test method for a particular purpose, objective of the test method is an important parameter. Some test methods evaluate the potential reactivity of the aggregate while others evaluate the performance of a cementitious material with reactive aggregate in alkaline environment.

Alkali aggregate reaction is a time dependent phenomenon, the expansions and deteriorations take place within months or years. Thus, the test methods in order to evaluate the reactivity of aggregates or aggregate-cementitious material combinations should be rapid and reliable. Rapid test methods are used to predict the reactivity through the length changes of mortar or concrete mixtures within a month or less. Increasing the alkali content, using highly reactive silica, or increasing the ambient temperature and/or pressure are among the methods for accelerating the reaction.

Accelerated mortar bar test (AMBT) method was developed by Oberholster and Davies [1] in 1986. The test involves the immersion of mortar bars in water at 80°C for 24 hours and in 1N NaOH solution at 80°C for the following 14 days to produce results within 16 days. AMBT is standardized by many standardizing agencies. Although the test is now widely used, it is generally considered highly severe as it identifies many aggregates as reactive despite good performance in the field and/or in concrete prism expansion tests. Consequently, the test should be used only to accept and not to reject the aggregate. Furthermore, if an aggregate fails the test, the concrete prism test should be used to confirm the results before the aggregate is either rejected [2, 3].

Recently, Grattan-Bellew et al. [4] proposed a universal accelerated test method, the concrete microbar test (CMT), by adopting the test method for alkali carbonate reactive rocks proposed by Xu et al. [5]. CMT is suitable for both alkali carbonate and alkali silica reactive rocks. Concrete microbars are prepared with aggregates between 4.75 mm and 12.5 mm, dry aggregate/cement ratio of 1 by weight and water/cement ratio of 0.33. Prismatic 40x40x160mm microbar specimens are cured in 80°C in 1N NaOH solution. The researchers studied the reactivity of carbonate reactive limestone, silica reactive limestone, greywacke and a non-reactive limestone and established a linear expansion-time relationship. One year concrete prism test (CPT) and 30-days CMT expansions were also

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compared. Siliceous limestone aggregates generated a different correlation line among the other aggregates. The proposed expansion limit at 30 days was 0.14% for siliceous limestone aggregates and 0.04% for other aggregates.

Both AMBT and CMT involve a pre-curing period in water at 80°C for 24 hours after which the zero-length of the specimens is recorded. The length measurement of subsequent readings is recorded for each period of measurement. The difference between the length at each period of measurement and zero-length is calculated and the expansion is computed by dividing this value to effective length of the specimen. Most of the specifications propose limits for the 14-day expansion of the specimens cast and cured in accordance with the AMBT method. Some researchers proposed limits for 30-day expansions for CMT specimens. 24 hours pre-curing period is advantageous in many ways; curing in hot water accelerates the strength gain, it is practical to take length readings everyday at the same time. However, it should be noted that curing in hot water might affect the chemical reactions in the cement paste from ASR point of view. It is also wondered whether the effect of the change in the pre-curing period is influenced by the type of the aggregate or not. This study investigates the effect of pre-curing period on ASR expansions measured by AMBT and CMT methods.

2 MATERIALS AND METHODS

2.1 Materials

Two types of aggregates are used in this study. S1 is a crushed clinopyroxene-olivine basalt aggregate [6] supplied from Aliağa, Aegean Region, Turkey. S2 is a siliceous river gravel and sand which is supplied from Altınoluk, Aegean Region, Turkey. Both of these aggregates are found to be suspicious to ASR by both AMBT and CMT methods [7]. Cement is CEM I 42.5 type in accordance with TS EN 197-1 [8]. Na_2O and K_2O content of the cement is provided by the producer as 0.36% and 1.11%, respectively.

2.2 Test methods and mix proportions

AMBT was applied in accordance with ASTM C1260 standard test method [9] except for the pre-curing period (24 hours in water at 80°C). The mortar mix was prepared by using fine aggregate (<No.4) graded in accordance with the standard. Aggregate/cement ratio of the mix was 2.25 and water/cement ratio was 0.47 by weight. Three samples were cast from each mixture and were cured in 1N NaOH solution after the pre-curing period. The expansions of the specimens were calculated by extracting the zero length reading (the reading taken right after pre-curing) from the length reading at the date in question.

In addition, the alkali-reactivity of the rock was assessed by CMT [4]. Concrete microbars were prepared with aggregates between 4.75 mm and 12.5 mm, dry aggregate/cement ratio of 1.0 by weight and W/C ratio of 0.33. The gradation of the aggregate was chosen as 40% 4.75-9.5 mm and 60% 9.5-12.5 mm. Prismatic 40×40×160 mm microbar specimens were cured in 80°C water (pre-curing) and in 80°C 1 N NaOH solution for the following test period. The expansions of CMT mixtures were calculated by the same method as AMBT.

The pre-curing period was adjusted to 4, 12, 16, 24 (control) and 48 hours for both of the test methods. A set of specimens was soaked in 1N NaOH solution right after demolding and zero length of these specimens were taken 24 hours after the soaking in solution. The test mixtures and their designations are given in Table 1.

3 RESULTS

The expansion-time diagram of S1 aggregate containing mixtures which were cured at different pre-curing periods were plotted in Figure 1. 14-day expansion values of all mixtures are similar to each other except for S1/16 mixture. The distance between the expansion curve of S1/16 mixture and others decreases at later ages. S1/NaOH mixture exhibits a faster expansion than other mixtures at early ages, the expansions decline below the expansions of other mixtures by passing test period.

The expansion versus test period graph of S2 specimens cast in accordance with AMBT method and cured for different pre-curing periods is shown in Figure 2. The expansion curves are similar to each other except for the S2/NaOH mixture. The expansion of S2/NaOH mixture is significantly lower than that of other mixtures.

The expansion-time graph of the CMT specimens containing S1 and S2 are given in Figure 3 and 4, respectively. The specimens were cast in accordance with CMT method and cured at different pre-curing periods. Since at the beginning of the test period (x=0), no expansion is observed (y=0), the regression lines start from x, y = 0. In both of these Figures, the samples cured directly in NaOH expand significantly more than other samples.

Table 2 shows the 14-day expansion values of AMBT samples, the equation of regression line, regression coefficient of CMT samples and 30-day expansion of CMT samples calculated by regression equation. A linear correlation between 14-day expansions of AMBT mixtures and 30-day expansions of CMT samples having different pre-curing periods was also observed (Figure 5). Note that the 30-day expansion values plotted in this figure are calculated from the regression equation. The expansion values of the samples soaked directly in NaOH solution are not considered in this data group. Soaking directly in NaOH solution and taking the zero length 24 hours after soaking in solution resulted in different behaviors for two aggregates having different reactivity.

4 DISCUSSION

Considering the expansion-time relationship of S1 specimens having different pre-curing periods (Figure 1), S1/NaOH mixture exhibits a rapid expansion at early ages which may be due to the boasting of alkalis to the empty pores of the mortar. This is compensated at later ages possibly due to the fact that highly reactive S1 aggregate reacted very fast and these expansions continued after the first 24 hours period (note that the expansions were recorded right after 24 hours NaOH curing). The resultant ASR gel filled the pores of the mortar resulting in reduction in permeability, therefore, leading to decreased expansions at later ages. Considering S2 bearing mixtures, soaking directly in NaOH solution and taking the zero length after 24 hours (S2/NaOH mixture) results in lower expansion than other S2 bearing mixtures (Figure 2). It is important to note that reactivity of S2 aggregate is lower than that of S1 aggregate. It seems that the amount of ASR products formed after reaction of S2 aggregate is lower than that formed after reaction of S1 aggregate. Thus, some of the S2 bearing ASR products fill the pores at first 24 hours (not recorded as expansion) and the remainder cause a slight increase in the volume of the mortar. Thus, soaking directly in NaOH solution seems to be improper for evaluating the reactivity of the aggregates.

CMT method was used to evaluate the effect of pre-curing period on coarse aggregate-bearing samples. Figure 3 and Figure 4 show that soaking directly in NaOH solution considerably increased the expansions during the test period. This may be due to boasting of NaOH into empty pores of highly porous CMT mixtures. Slope of the expansion lines of samples cured at different pre-curing periods are more or less similar to each other denoting the neutral effect of different pre-curing periods.

It can be concluded that a pre-curing period of 4 hours is sufficient to evaluate the reactivity of the aggregates. Pre-curing period is necessary not only for equalizing the recording temperature of length measurements, but also for strength gain and ASR point of view. The authors of this study carry out an ongoing research on the effect of different pre-curing periods on the strength of mortar.

The linear correlation between ABMT and CMT methods reveal that, CMT is a promising rapid test method although the particle size of the aggregates used and the mix proportions of these two methods are quite different. However, it is important to note that the reactivity of the coarse and fine particles of the aggregate to be tested should be similar. In this study, fine aggregates are the crushed pieces from the coarser ones.

5 CONCLUSIONS

Following conclusions were drawn from this experimental study:

- The change in pre-curing period applied in this study does not seem to considerably affect the ASR expansions. A pre-curing period of 4 hours seems to be sufficient in order to evaluate the reactivity of the aggregates.
- Soaking directly in NaOH solution is an improper method for evaluating the reactivity of aggregates. Aggregates having different reactivity levels express different reactivity trends when the expansions were measured 24 hours after curing in NaOH solution.
- There is a strong linear relationship between AMBT and CMT test results, indicating that CMT is a promising rapid test for testing the reactivity of coarse aggregates.

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TABLE 1: Test mixtures and their designations.

Aggregate Type	Pre-curing period					
	4 hours	12 hours	16 hours	24 hours	48 hours	Directly in NaOH
S1	S1/4	S1/12	S1/16	S1/24	S1/48	S1/NaOH
S2	S2/4	S2/12	S2/16	S2/24	S2/48	S2/NaOH

TABLE 2: AMBT and CMT expansions.

Type of the mixture	AMBT Method	CMT Method		
	14-day expansion	Regression equation	Regression coefficient	30-day expansion
S1/4	0.734	y = 0.0113x	0.9807	0.339
S1/12	0.725	y = 0.0113x	0.9311	0.339
S1/16	0.927	y = 0.0113x	0.9902	0.339
S1/24	0.693	y = 0.0119x	0.9356	0.357
S1/48	0.804	y = 0.0114x	0.9814	0.342
S1/NaOH	0.790	y = 0.0218x	0.9633	0.654
S2/4	0.234	y = 0.0018x	0.9321	0.054
S2/12	0.257	y = 0.0019x	0.9421	0.057
S2/16	0.306	y = 0.0027x	0.9487	0.081
S2/24	0.246	y = 0.0023x	0.9712	0.069
S2/48	0.324	y = 0.0028x	0.9950	0.084
S2/NaOH	0.109	y = 0.0120x	0.9614	0.360

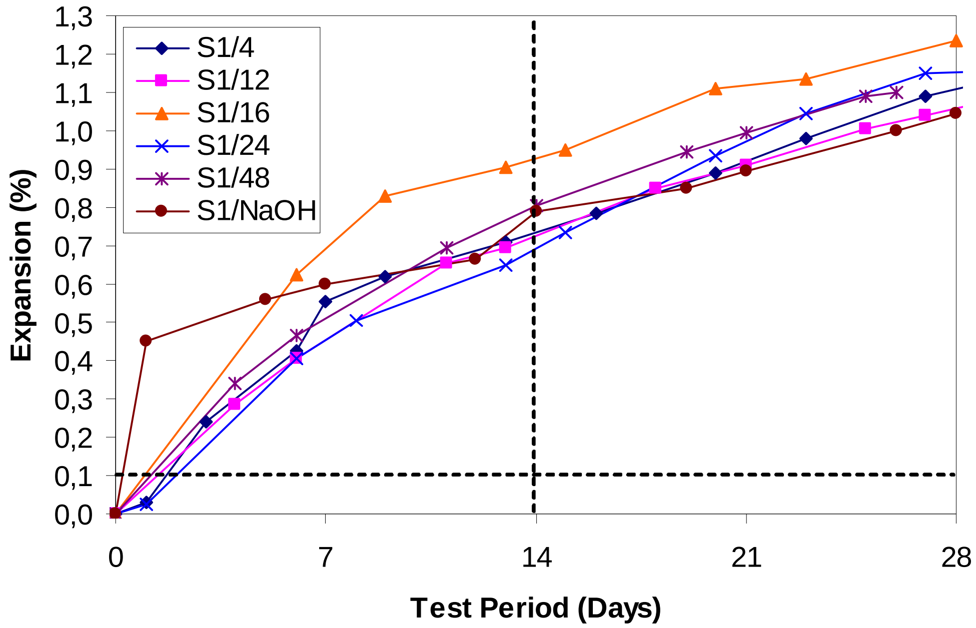

Figure 1: Expansion-time graph of S1 specimens having different pre-curing periods (AMBT method).

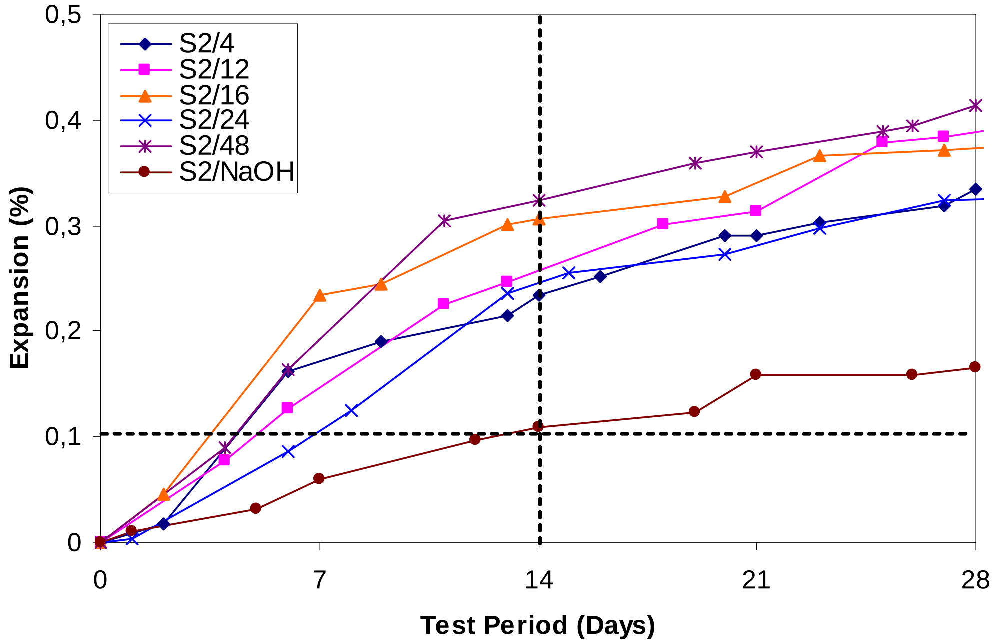

Figure 2: Expansion-time graph of S2 specimens having different pre-curing periods (AMBT method).

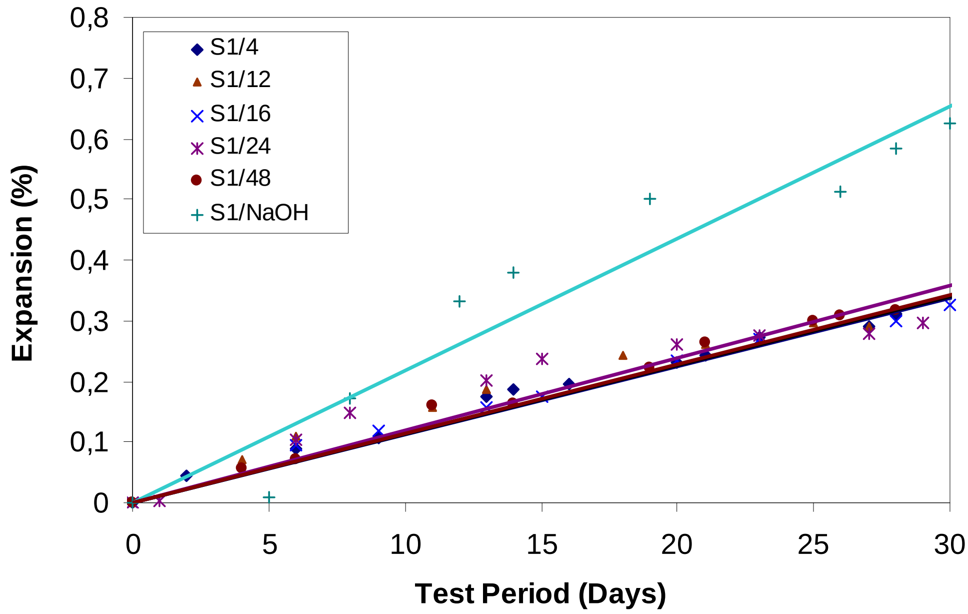

Figure 3: Expansion-time graph of S1 specimens having different pre-curing periods (CMT method).

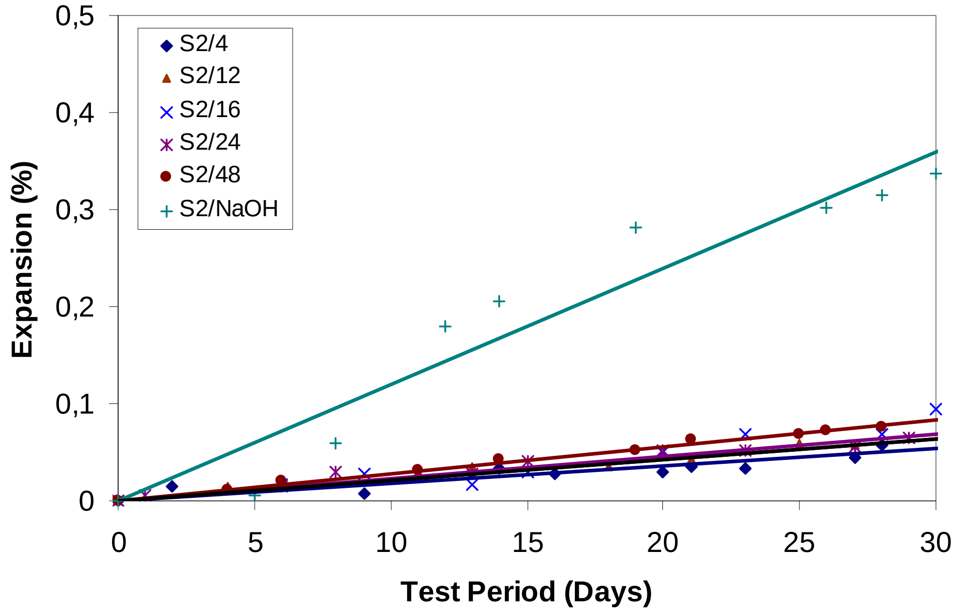

Figure 4: Expansion-time graph of S2 specimens having different pre-curing periods (CMT method).

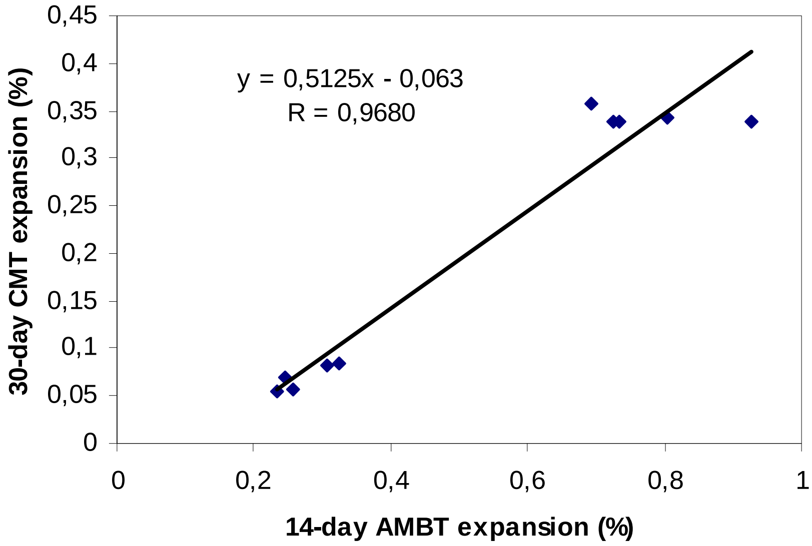

Figure 5: CMT (30-day) vs. AMBT (14-day) expansions relationship.