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A STUDY ON THE SIMPLE RAPID TEST METHOD USED TO JUDGE THE ALKALI REACTIVITY OF AGGREGATE

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ABSTRACT

In Japan, the alkali reactivity of aggregate is normally judged based on either the chemical method of analysis or the mortar-bar method. Among these two methods, the former is a complicated one for concrete researchers, which the latter takes a long period of time for test results to be gained. In this study, accelerated tests with mortar specimens were conducted in order to gain results more easily than can be done with the chemical method and more rapidly than with the mortar-bar method.

In this experiment, the influences that various conditions had on the behavior of the mortar were investigated. The conditions examined included the influence of various kinds of aggregate, the alkali content of the cement, the pessimum of aggregate, the kind of added alkali, the term of the curing before the accelerated test, the temperature and term of the accelerated test, and the conditions under which the specimen was stored. The test results showed that, except for the alkali content of the cement, the temperature and term of the accelerated test, the conditions can be set in the same way as is done in the mortar-bar method. Moreover, it was found that these three conditions have good relation to one another.

In order to study the ranking of this simple rapid test method, about 70 samples of aggregate were tested under set conditions. Under these conditions, the temperature was placed at 100℃, the alkali content of the cement, 2.5%, and the term of the accelerated test, 10 hours. These conditions were selected due to the fact that they are one of the sets in which the expansion of mortar in the accelerated test will always be larger than that achieved through the mortar-bar method. This would apply for any aggregate. Thus, the aggregate that is judged to be reactive by the mortar-bar method will always be judged reactive by this test method. However, the reverse will not always be true. Moreover, the aggregate that is judged non-reactive by the chemical method will almost always be judged to be the same by this test method, and, in addition, the reverse will almost always be true. Accordingly, the ranking of this simple rapid test method has been regarded as the same one as that of the chemical method.

1. Introduction

The Ministry of Construction of Japan issued a circular notice on tentative technical guide-lines of counterplan on alkali aggregate reactions in 1986. Chemical method and mortar-bar method were proposed in this tentative guide-line. It takes a long term, about 6 months to have the test result with the mortar-bar method. Some accelerated test methods, including GBRC(General Building Research Corporation) method, have been investigated in order to shorten the term of testing hours in mortar-bar method.

In this paper the influence of various factors on expansion of mortar was mentioned and the ranking of the accelerated test was investigated.

2. Test Program

The outlines of test program is shown in Table 1. The purpose of series 1 is to investigate the influence of alkali content of cement, term of accelerated test and condition of storage of specimen on the expansion behaviour of mortar. In series 2, influence of kind of alkali which is added to adjust the alkali content of cement, temperature of accelerated test, curing term before the test and percentage of reactive aggregate in the whole aggregate were investigated.

In series 3 and 4, many kinds of aggregate, which contained both nonreactive and reactive aggregates, were tested in a fixed condition based on the test results obtained in series 1 and 2. At the same time, chemical test and mortar-bar test(tentative method of Ministry of Construction) were done.

Table 1 Factors and levels of experiment

Factors		Levels			
		Series 1	Series 2	Series 3	Series 4
kind of aggregate	reactive	8	5	1	47
	nonreactive	1	1	11	1
alkali content		1.5, 2.5, 3.5%	0.86~3.00%	2.5%	same as series 3
kind of added alkali		NaOH	NaOH, NaCl, NaOH+NaCl $NaNO_2$, Na_2SO_4, Na_2CO_3 KOH, KCl	NaOH	
temperature of test		100℃	60, 80, 100, 120℃	100℃	
term of precuring		1 day	1, 3, 7 day	1 day	
percentage of reactive aggregate		100%	0,20,40,60,80,100 %	100%	
term of test		2,4,6,8,10 hours	5,10,15,20,25 hours	5,10 hours	
condition of storage of specimen		・in saturated air ・sealed ・in water	in saturated air	in saturated air	
items of measurement		・observation of surface ・length ・weight ・ultrasonic pulse velocity ・dynamic elasticity	observation length weight	same as seriers 1	same as seriers 2

3. Method of Experiment

3.1 Materials used

(1) Aggregate

In series 1, 2 and 4 most of the used aggregate were judged reactive and in series 3 those were judged nonreactive by the chemical test. Most of them had been used in practical work but the damage of concrete with the aggregate has not been known precisely.

(2) Cement

Ordinary portland cement was used. Alkali content of cement is 0.8% in series 1, 0.49% in series 2 and 4 and 0.48% in series 3.

(3) Mixing water and Added alkali

Distilled water was used. To adjust the alkali content of cement NaOH was added to it. Six kinds of alkali other than NaOH were used in series 2 as shown in Table 1.

3.2 Mix proportion of mortar

The mix proportion of mortar is as follows :

Water : cement : aggregate = 250ml : 500g : 1125g

The quantities of each material are 5/6 of those which are prescribed in tentative method of Ministry of Construction (Mortar-bar test).

3.3 Dimension of specimen

The dimension of specimen is 4x4x16cm. In each side of the specimen a stainless steel tip is buried. The effective gauge length is 13.2cm in series 1 and 3, and 14cm in series 2 and 4.

3.4 Accelerated test of apparatus

The capacity of an autoclave test apparatus which is used in this investigation is as follows :

The range of temperature : 100 to 130°C

The humidity : 100% only

In series 2 a container which can be shut tight was used in the test in which the temperature of accelerated test was below 100°C. The container which contained water in the bottom was set in an temperature controlled apparatus.

3.5 Test procedure

After mortar was placed in the mold, the mortar specimen was cured in the mold so as not to become dried and the next day the mold was removed. After removal, weight, length, dynamic elasticity and ultrasonic pulse velocity were measured and after prescribed curing the accelerated test was started. The term of accelerated test per cycle was 2 hours in series 1, and 5 hours in series 2, 3 and 4. After being cooled to 20°C in the moisturized atmosphere at 20°C the same measurement as mentioned above was repeated.

3.6 Method of measurement

The length between the tips on both sides of specimen was measured with a comparator equipped with a dial gauge, of which the minimum scale is 0.001mm. The dynamic elasticity was determined by measuring the primary responce frequency in bending vibration, and to determined the ultrasonic pulse velocity the transit time of ultrasonic pulse in the longitudinal direction of specimen was measured.

4. Test result

4.1 The influence of alkali content of cement on expansion

In the case that alkali content is 1.5% the mortars with reactive aggregate showed expansion very little, but in the case of 2.5% they showed considerable expansion and in the case of 3.5% the expansion increased more.

4.2 The influence of the condition of storage of specimen on expansion

The expansion of mortar which is sealed is lower than that in saturated air, and that in water is higher than that in saturated air. But the difference is about 10% in each case.

4.3 The influence of the kind of added alkali on the expansion behaviour

The expansion behaviour showed a very different tendency depending on the kind of added alkali as shown in Fig. 1. The expansion of mortar with NaCl, $NaNO_2$ and KCl was very small. The mortar with NaOH showed the largest expansion in 5 hours of accelerated test, and the mortar with Na_2SO_4 showed nearly equal the expansion to that with NaOH in 10 hours.

4.4 The influence of the temperature of accelerated test on expansion

Within the range from 60°C to 120°C the mortar with NaOH showed linear increase of expansion with the increase of temperature as shown in Fig. 2. However, the mortar with NaCl showed little expansion at any temperature.

4.5 The influence of the curing term before the accelerated test on expansion

The mortar with NaOH showed nearly the same expansion not depending on the curing term before accelerated test less than 100°C as shown in Fig. 3. In the case of 120°C, the expansion of mortar for 7 days of curing term became larger than that at 1 day.

4.6 The influence of the percentage of reactive aggregate on expansion

In the case of 2.5% of alkali content the mortar with any reactive aggregate showed the largest expansion at 100% of reactive aggregate as shown in Fig. 4. The reason why pessimum effect was not recognized is thought to mainly depend on the large quantity of alkali content.

4.7 Other indices of deterioration except expansion

We had thought that dynamic elasticity and ultrasonic pulse velocity of mortar could be used as the index of deterioration of mortar. But we could not determine the primary resonance frequency precisely. And the ultrasonic pulse velocity did not decrease after 2 hours of accelerated curing term even in the case that high reactive aggregate was used. This phenomenon may be explained based on the increase of mortar strength by the accelerated curing.

5. Determination of test condition

Being based on the test results mentioned above it was found that it was not necessary to change the test conditions except for alkali content of cement, temperature and term of accelerated test. The condition determined tentatively are shown in Table 2 compared with that of the mortar-bar test. The conditions were set up so that the expansion by the accelerated test might exceed that by the mortar-bar test.

6. Ranking of accelerated test

The first time the research on the accelerated test was started it had been thought that the test was ranked between the chemical test and the mortar-bar test as shown in Fig. 5. Fig. 6 shows the relation of these three tests. Any aggregate that was judged deleterious by the mortar-bar test was judged deleterious by the accelerated test without exception. However, most of the aggregate that were judged potentially deleterious or deleterious by the chemical test were judged deleterious by the accelerated test. Therefore, the accelerated test can be ranked as the same as the chemical test.

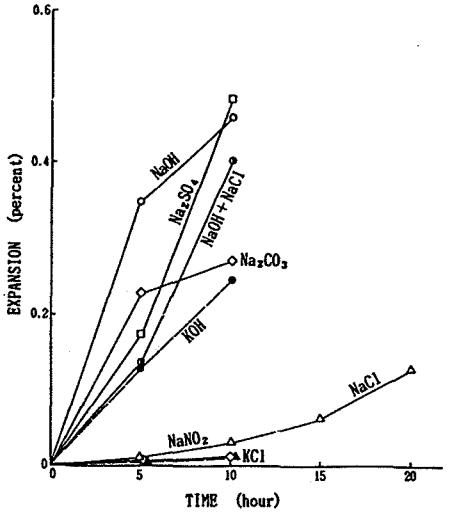

Fig. 1 The influence of Kind of Added Alkali on Expansion

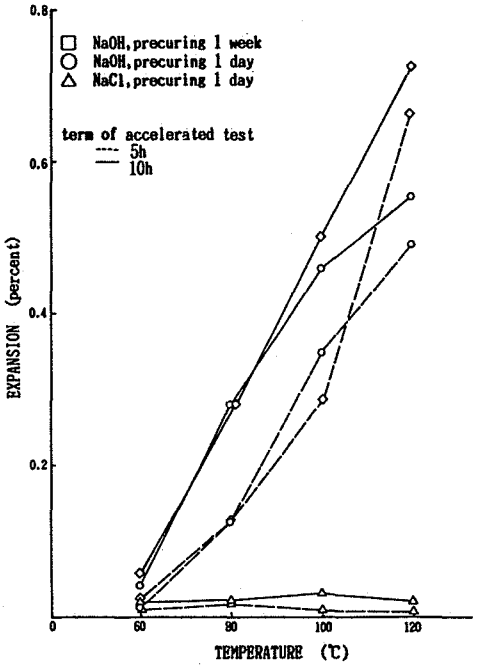

Fig. 2 The influence of Temperature of Accelerated Test on Expansion

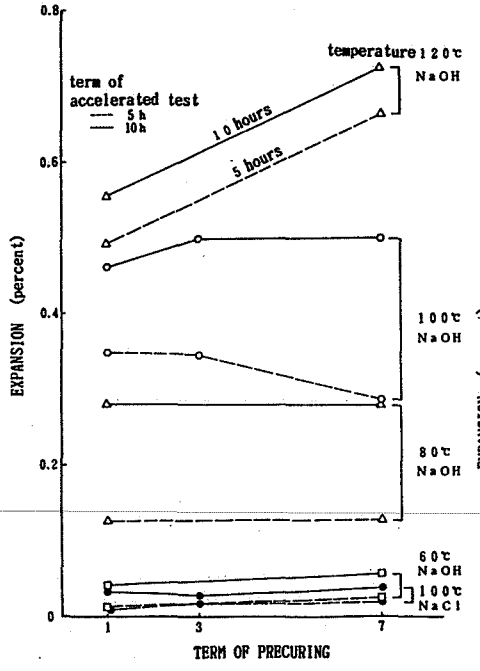

Fig. 3 The influence of Term of Precuring on Expansion

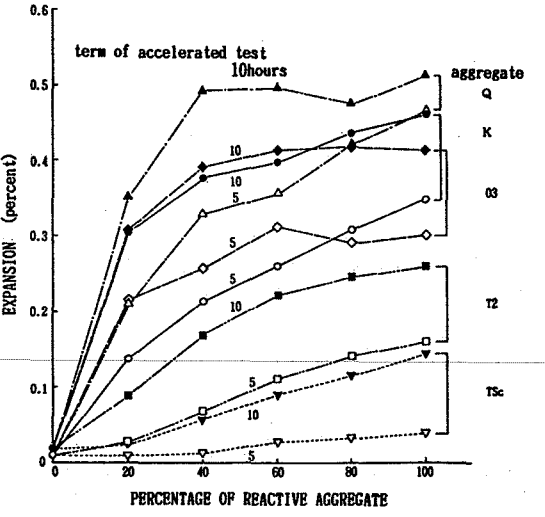

Fig. 4 The influence of Percentage of Reactive Aggregate on Expansion

Table 2 Comparison of test condition of mortar-bar test and accelerated test

Factor	mortar-bar test	accelerated test
alkali concent of cement	1.2 %	2.5 %
temperature of test	40℃	100 ℃
term of test	3 months, 6 months	5hours, 10 hours

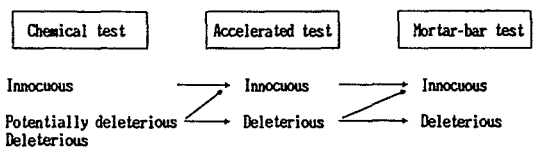

Fig. 5 Ranking of accelerated test

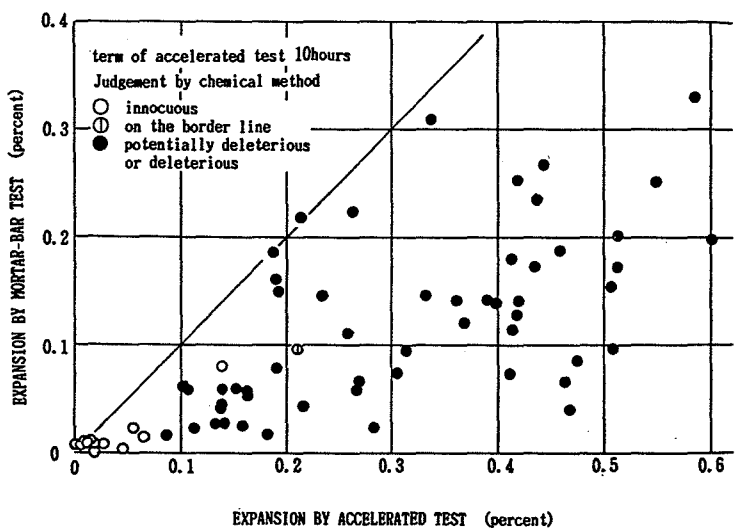

Fig. 6 Relationship between the Expansion by Mortar-bar test and that by Accelerated Test

7. Conclusion

In this experiment the influence of various factors on expansion of mortar and the ranking of this accelerated test were investigated. The results of investigations are summarized as follows.

(1) expansion is thought to be the best index of deterioration due to the fact that little individual difference and little influence of strength increases were observed.
(2) It is only necessary for the accelerated test to change three test conditions among those of the mortar-bar test, that is ; alkali content, temperature and term of test. It is not necessary to change the other conditions ; condition of storage of specimen, kind of added alkali, term of curing before test and the percentage of reactive aggregate.
(3) Under the test conditions of 2.5% of alkali content of cement, 100°C of temperature and 10 hours of term of the accelerated test, the ranking of the accelerated test became much the same as the chemical test.