8th ICAAR 1989 KYOTO 8th Internationl Conference on Alkali-Aggregate Reaction

STUDY ON THE RAPID ESTIMATION METHOD OF ALKALI AGGREGATE REACTION USING CONCRETE SPECIMENS

Tsutomu Kanazu*, Hiroshi Ohnuma*,
Takehiro Nakano* and Hiroaki Ishida*

*Materials Section, Earthquake Engineering
and Structure Department,
Abiko Research Laboratory,
Central Research Institute of Electric Power Industry,
1646 Abiko, Abiko-shi, Chiba 270-11, Japan

ABSTRACT

In order to rapidly identify the alkali reactivity of aggregates, various accelerated test methods, including the auto-clave(AC) curing method using mortar specimens as suggested by T. M. Shu et al. in 1983, have been investigated. It was also thought necessary to obtain more exact information including that about concrete specimens with coarse aggregates in order to judge the possibility of the alkali aggregate reaction (AAR) in concrete structures.

The experimental study was performed, in which the AC curing method was applied to concrete specimens, and the results were discussed.

1. INTRODUCTION

The certain method to prevent the alkali aggregate reaction (AAR) is to avoid the use of the reactive aggregates, but this is not a realistic method. Therefore, some methods to identify the reactivity of aggregates are specified in ASTM-for example the petrographic examination, the chemical examination and the mortar bar test. However, the first two methods cannot identify the real development of deterioration by the AAR and it takes at least six months to judge the reactivity by the latter method. Consequently there exists the need to investigate the rapid estimation methods. Some rapid estimation methods have already been suggested, that is, NaCl bath method (Danish method) [1], AC curing method by T. M. Shu et al. [2] and the methods by H. Tamura et al. and S. Nishibayashi et al.. [3] [4]

The study was performed to investigate the extension of the application of the AC curing method [5], in which concrete specimens close to the actual conditions of concrete structures were used, and the results were discussed.

2. MATERIALS AND TEST METHOD

2.1 Aggregates

Five kinds of aggregates were used, that is, chert, three kinds of andesite and sand-stone. The results of the reactivity of these aggregates, obtained by the other test method, were shown in Table 1. Only sand-stone was judged to be harmless while the other aggregates were harmful.

The particle size distributions of both fine and coarse aggregates were

Table 1 Results of the other test methods

Aggregate	Test Method						
	Petrographic Examination ASTM C 295		Chemical Examination ASTM C 289			AC method using mortar specimens	
				harmful			
	harmless	harmful	harmless	latent	manifest	harmless	harmful
Chert		○			○		○
Andesite(a)		○		○			○
Andesite(b)		○		○			○
Andesite(c)		○		○			○
Sand-stone	○		○			○	

Table 2(a) Particle size distribution of fine aggregate

Particle size (mm)	Percentage (%)
5.0 ～ 2.5	15
2.5 ～ 1.2	15
1.2 ～ 0.6	25
0.6 ～ 0.3	25
0.3 ～ 0.15	15
0.15 ～	5
Total	100
Finess Modulus	2.75

Table 2(b) Particle size distribution of coarse aggregate

Particle size (mm)	Percentage (%)
20 ～ 10	50
10 ～ 5	50
Total	100
Finess Modulus	6.5

shown in Table 2(a) and Table 2(b), respectively and came up to the standard range of those of the Japan Society of Civil Engineers (JSCE).

2.2 Cement

Ordinary portland cement was used and the alkali content of which was equivalent to 0.67 percent in R_2O. NaOH was added to control the alkali content in cement. Three levels of alkali content were adopted, that is, 0.67 percent, 1.10 percent and 1.50 percent.

2.3 Mix proportion

The mix proportion was selected as follows by the preliminary tests; the expansive strain of concrete specimen with the following mix proportion was confirmed to be the largest in the tests.

- Cement : Fine aggregate : Coarse aggregate = 10 : 1 : 6
- Water : Cement = 1 : 0.35

2.4 Test Procedure

The method used was the same one as suggested by T. M. Shu et al. except that 10cm × 10cm × 36cm concrete prism specimens were used. Test procedures were shown in Fig. 1 and described as follows.

(1) Moist curing for one day at constant temperature and humidity after the placing of concrete.
(2) Measurement of the original length immediately after the removal of forms.
(3) Steam curing for about 19 hours, in which a temperature cycle up to 90°C was given and the maximum temperature was kept for 10 hours.
(4) First measurement of the expansive strain after the steam curing.
(5) AC curing for about 48 hours, in which a temperature cycle up to 150°C was given and the maximum temperature was kept for 6 hours and specimens were allowed to cool down naturally. During the AC curing concrete specimens were soaked in 10 percent KOH solution.
(6) Final measurement of the expansive strain after the AC curing.

It took about four days to complete the test.

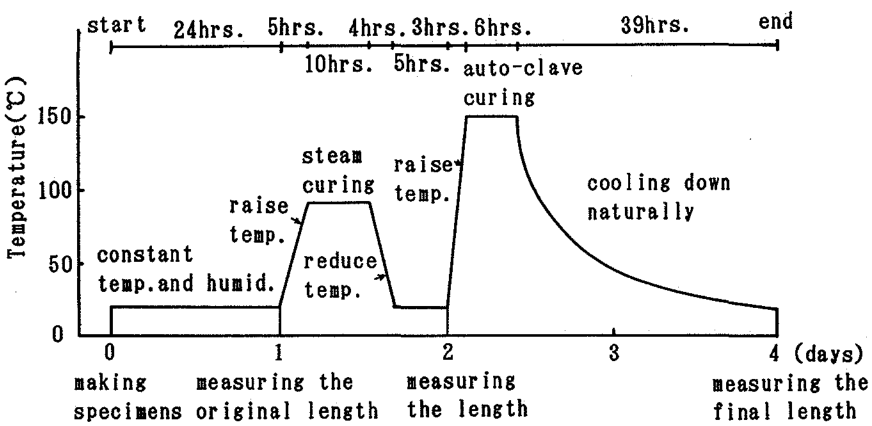

Fig. 1 Test procedures of the rapid estimation method

2.5 Measurement of expansive strain

The sizes and configurations of concrete specimens were shown in Fig. 2. The plugs for measuring the change of the length of specimens were installed at both ends of the specimens(see Fig. 2). The length change was measured by using the instrument, which was developed for measuring the expansive strain of concrete mixed with the expansive admixture and both the instrument and the method were specified in the standard of the expansive concrete of the JSCE.

2.6 Other observations

Other observations included direct observations with the naked eye and those with the microscope, the SEM and the X-ray diffraction.

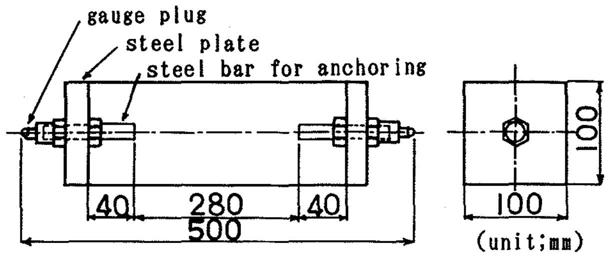

Fig. 2 Size and configuration of concrete specimen

3. RESULTS AND DISCUSSIONS

3.1 Rapid estimation method

The measured results of each specimen after the completion of the whole process were shown in Table 3 and Fig. 3. The left half and the right half parts of Table 3 indicated the results measured after the steam curing and the AC curing, respectively. It was confirmed that the large difference of expansive strains between the specimens with the same alkali content was not observed after the steam curing and also not observed even after the AC curing in the cases with the alkali content of 0.67 percent. However, when the alkali content was increased to over 1.10 percent, the difference became sufficient to judge the reactivity of aggregates. Particularly, every specimen including andesites and chert expanded extremely larger than the one with sand-stone in the cases with the alkali content of 1.50 percent. This showed that the AAR was accelerated during the AC curing and that the expansive strain progressed considerably.

Consequently, the alkali reactivity of aggregates could be judged by using the expansive strain of 0.10 percent as a critical value. All aggregates except for sand-stone were judged to be harmful in conformity

Table 3 Measured expansive strain and judged results

Aggregate	After steam curing			After autoclave curing			Judgement
	Alkali content (%)			Alkali content (%)			
	0.67	1.10	1.50	0.67	1.10	1.50	
Chert	0.031	0.037	0.050	0.013	0.053	0.110	harmful
Andesite(a)	0.028	0.032	0.041	0.023	0.072	0.195	harmful
Andesite(b)	0.009	0.018	0.028	0.024	0.070	0.180	harmful
Andesite(c)	-----	0.011	0.044	0.014	0.130	0.270	harmful
Sand-stone	0.021	0.017	0.028	0.009	0.030	0.060	harmless

* The reactivity of aggregates was judged to be harmful if the expansive strain after the AC curing was over 0.1 percent-which was the critical value suggested here.

to this rule. The results coincided with those obtained by the other tests, that is, ASTM C295 and ASTM C289. Therefore, it was considered that the expansive strain of 0.10 percent could be a provisional criterion in the rapid estimation method using the AC curing.

3.2 Observation of the reaction rim and the results of XRD

The cut sections of the specimens were observed with the naked eye, the microscope and the SEM in order to confirm the reaction rim, which was the symptom of the alkali aggregate reaction. Three examples of the observed results were shown in Photo. 1, Photo. 2 and Photo 3.

In the cases of andesites and chert with 1.50 percent alkali content, the reaction rim manifested was the gelatious matter, which was clearly visible with the naked eye. However, this was not the case when sand-stone was used. In the cases of andesite(b) and chert, the small protuberances, which have been confirmed to be usually observed in the

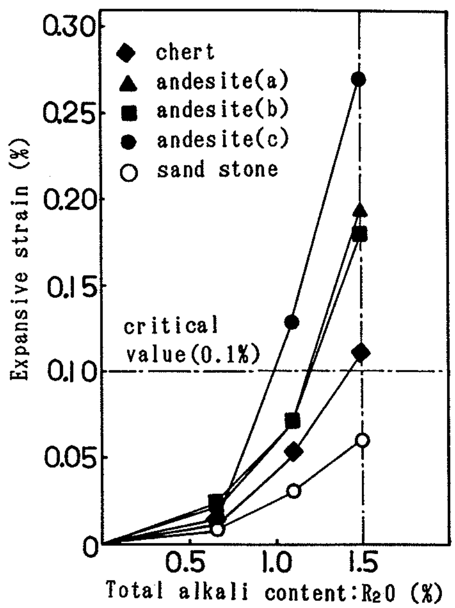

Fig. 3 Relationship between total alkali content and expansive strain of test specimens

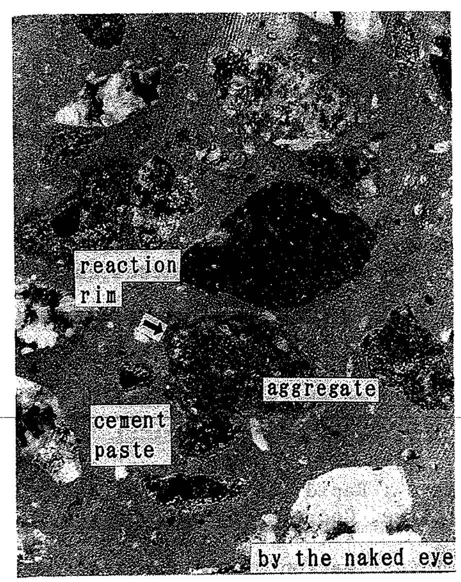

Photo. 1 Andesite(b)

alkali content ; 1.50 percent

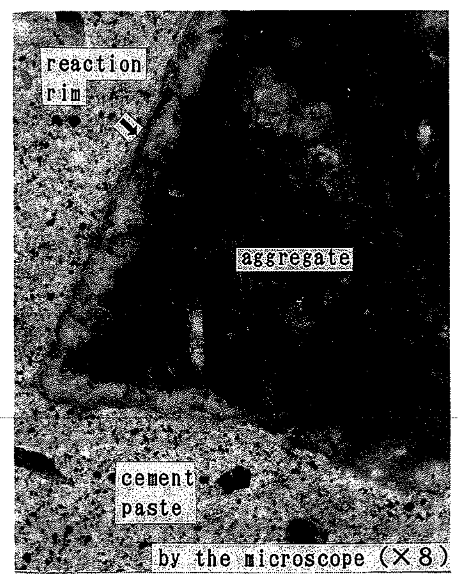

Photo.2 Andesite(a)

alkali content ; 1.50 percent

alkali aggregate reaction, were also observed with the SEM.

It was confirmed by the results of the XRD that cristobalite was observed in the cases of andesite and this was well known to be a cause of the alkali aggregate reaction.

The observed results showed that the alkali aggregate reaction certainly occurred in concrete specimens during the AC curing.

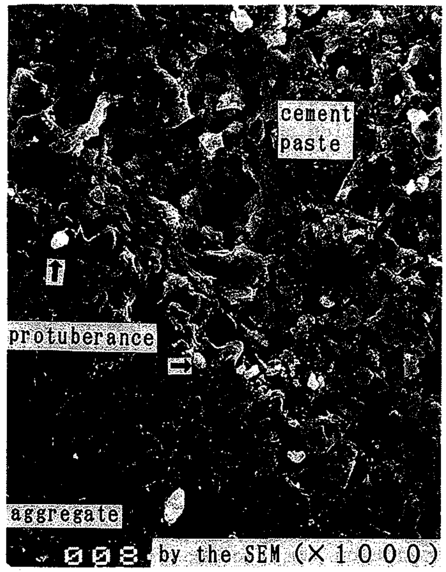

Photo. 3 Chert

alkali content ; 1.50 percent

4. CONCLUSIONS

The rapid estimation method by using the AC curing, in which concrete specimens were used, was investigated. Conclusions derived from the extent of the study were as follows.

1) A provisional criterion of the expansive strain to judge the alkali reactivity of aggregates was obtained in the suggested rapid estimation method.
2) The reaction rim surrounding coarse aggregate could be observed clearly even with the naked eye and the small protuberances, which were usually observed in the alkali aggregate reaction, were also observed with the SEM. It was judged from these results that the alkali aggregate reaction certainly occurred in concrete specimens during the AC curing.
3) In order to clarify the significance of the suggested method, more investigations to give the exact information cocerning the alkali reactivity on the actual conditions should be necessary; more experiments using various aggregates should be performed.

REFERENCES

(1) S. Chatteriji ; An accelerated method for the detection of alkali aggregate reactivities of aggregates, Cement and Concrete Research, Vol.8, 1978.

(2) T. M. Shu, H. S. Fen and Z. S. Hua ; A rapid method for identification of alkali reactivity of aggregate, Cement and Concrete Research, Vol.13, 1983.

(3) H. Tamura, K. Yamura and H. Saito ; Study on the rapid estimation method of the alkali aggregate reaction, Cement Gijyutu Nenpo, Vol.38, 1984, in Japanese.

(4) S. Nishibayashi, K. Yamura and K. Nakano ; Rapid test method of determining the alkali aggregate reaction by autoclave, Cocrete Journal, Vol.26, No.5, May 1988, in Japanese.

(5) T. Nakano, H. Ohnuma and T. Kanazu ; Investigation of the rapid estimation method of the alkali aggregate reaction of concrete by the autoclave curing, Report of Central Research Institute of Electric Power Industry, No.U87064, May 1988.