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

STUDY ON NEW RAPID TEST METHOD FOR EVALUATING AGGREGATE REACTIVITY

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1. Introduction

In selecting aggregate that can be recognised as safe, the "Provisional Specifications of the Ministry of Construction for Tests on Alkali-Silica Reaction of Aggregate (Chemical Method and Mortar Bar Method)" is used at present in Japan for methods of testing the aggregate.

The chemical method conforms to ASTM C 289 and the mortar bar method to ASTM C 227, with some improvements in the procedures of the test based on the results of experimental investigation. Other methods for testing the alkali-aggregate reaction have also been known such as the mineral test method (ASTM C 295), the infrared absorption spectrum method, the method using reduction of weight by soaking in sodium hydroxide (the German Method) and various methods using mortar bars and concrete bars.

These methods including the chemical method and the mortar bar method are methods of test carried out in laboratories and require at least two to three days and, in the case of the mortar bar method, as long as three to six months before the results can be obtained after sampling. In all these methods, there are various obstacles such as that expensive laboratories and equipment are needed in carrying out the experiments and that experienced specialists are needed in the handling of the tests.

As a recent tendency, test methods that are so compact in scale that they can be performed in open air and in short periods of time are in demand. The authors of this article wish to report the possibility that has been discovered through experimental study of turning two methods into simplified test methods on alkali-silica reaction of aggregate.

2. Test Methods

2.1 Method using Electric Conductivity

Approximately 180 samples of aggregate collected in Japan whose data and types had been ascertained by the chemical method were used and their conductivity was measured using the following procedure.

Adjustment of Pulverised Particle Size of Aggregate	Representative aggregate is pulverised in mortars and particle groups of 150 μm to 300 μm are obtained.
Washing	Pulverised samples are washed in running water in small quantities. Samples rid of minute particles by washing is then rinsed in distilled water. The rinsed samples are dried for 20 ± 4 hours in drying bowls adjusted at 105 ± 5 °C. After cooling, the minute particles are removed and the remnant is used as the samples for the test.

Collection of Sample

20 g of the sample is placed in a 500 mℓ polyethylene container and 200 mℓ of 0.01 N hydrochloric acid is added.

Shaking

The sample is shaken in a shaker for 15 minutes and then left standing for 24 hours.

Measurement of Conductivity

Approximately 50 mℓ of the supernatant liquid created by shaking is separated and its conductivity is measured using a conductometer.

2.2 Method using Pigmentation

Approximately 50 samples of aggregate whose data and types had been ascertained by the chemical method were used and the adsorption of pigments was measured according to the following procedure.

The procedures for adjusting the particle sizes of the aggregate and washing the sample are the same as in the method using electric conductivity.

Handling of Reaction between Acid and Sample

1 N hydrochloric acid is added to the sample which is then shaken and made to react for 30 minutes at room temperature. The supernatant is removed and the remnant is washed in distilled water.

Reaction of Sample with Alkali

4 N potassium hydroxide solution is added to the sample which is then shaken and made to react for 30 minutes at room temperature. The supernatant is removed and the remnant is washed in distilled water.

Colouring with Methylene Blue

5 mℓ of 0.005% methylene blue solution is added to the prepared aggregate particles which is shaken up and down every ten minutes and absorbancy of light with wavelengths of 650 nm is measured after 30 minutes. The degree of colour is also confirmed at the same time using standard chromaticity.

3. Results of Experiments

3.1 Method using Electric Conductivity

The conductivity of the shaken liquid ranges between 1000 and 3000 μs/cm as compared with the conductivity of the 0.01 N hydrochloric acid solution at 4600 μs/cm. Shown in the table below are the ranges of electric conductivity of the aggregates of various rock types.

Table-1 Occurrence according to Ranges of Conductivity

Electric Conductivity (μs/cm) / Rock Type	below 1000	1000 to 1500	1500 to 2000	2000 to 2500	2500 to 3000	3000 or above	Total
Hard Sandstone	0	17	0	2	0	0	19
Slate	0	8	1	0	1	0	10
Limestone	0	4	0	0	0	0	4
Rhyolite	0	4	0	6	0	0	10
Andesite	0	27	14	10	8	1	60
Basalt	0	10	2	0	0	0	12
Tuff	0	10	0	2	0	0	12
Chert	0	2	0	1	1	3	7
Shale	0	8	1	3	0	0	12
Granite	0	1	0	1	1	1	4
Crystalline Schist	0	6	0	1	0	0	7
River Gravel and Sand	0	5	0	1	1	0	7
Diabase	0	1	1	0	0	0	2
Others	0	7	5	5	2	2	21

Occurrence of the ranges of electric conductivity of aggregates arranged according to findings on alkali-silica reaction of the aggregate using the chemical method are shown in Table-2.

Table-2 Occurrence according to Ranges of Conductivity

Electric Conductivity (μs/cm) / Findings of Chemical Test	below 1000	1000 to 1500	1500 to 2000	2000 to 2500	2500 to 3000	3000 or above	Total
Non-Reactive	0	93	13	9	1	0	116
Potentially Reactive	0	0	16	4	3	1	24
Reactive	0	7	3	10	5	6	31

3.2 Method using Pigmentation

Shown in Table-3 are the standard chromaticity numbers, colour tones, classification of alkali-silica reaction of aggregate and representative colour tones and rock types tested.

Table-3 Results of Test by Methylene Blue Adsorption

No.	Colour Tone	Classification of Alkali-Silica Reaction of Aggregate	Representative Rock Type Tested
I	Dark Blue	Applies to both non-reactive and reactive aggregate Samples classified as reactive except for special rock types	Chert, limestone, rhyolite etc.
II	Blue	Distributed in all classes of non-reactive, potentially reactive and reactive.	Represented by hard sandstone, also rhyolite etc.
III	Light Blue	Corresponds to non-reactive, large amount of weathered rocks	Coarse basalt, andesite etc.
IV	Slightly Blue	Distributed in all classes of non-reactive, potentially	Coarse basalt, pyroxene andesite etc.
VI	Almost No Colour	Belongs to potentially reactive class and includes large amount aggregate for which damages were	Reactive pyroxene andesite etc.

In Figure-1, the areas of each standard chromaticity numbers are shaded in on a chart showing the reactivity of aggregate judged according to the chemical method. It can be observed that certain areas on the charts correspond to the chromaticity numbers of the methylene blue adsorption. The aggregates for which chromaticity numbers of IV and U were obtained are likely to be reactive while with aggregates which showed chromaticity numbers of I, II and III reactivity decreases in that order. The test using methylene blue adsorption, however, cannot be used to separate these from non-reactive aggregate.

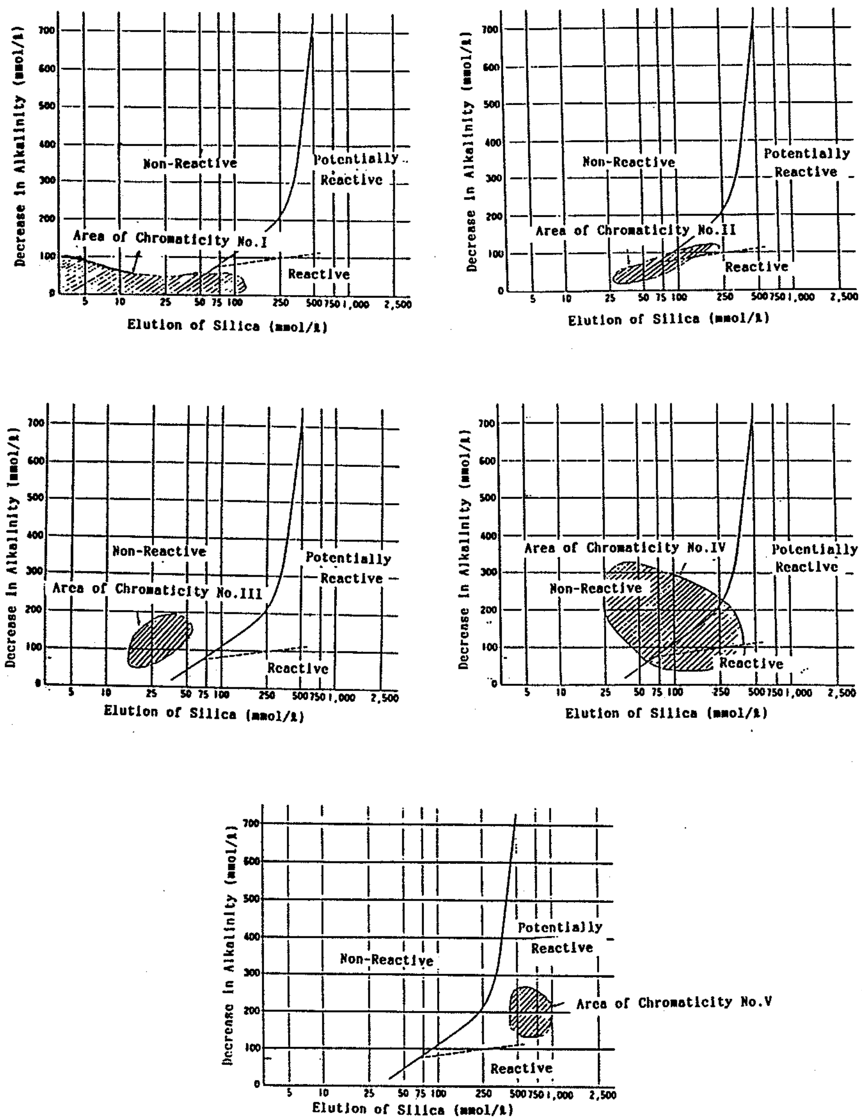

Figure-1 Occurrence of Chromaticity Groupings in Test Using Pigmentation Method

4. Observations on Results of Experiments
4.1 Method using Electric Conductivity
4.1.1 Inference on Mechanisms of Reaction

In this test, the alkali-silica reaction of the aggregate is judged from the lowering of the electric conductivity of the diluted hydrochloric acid as a result of the hydrogen ions in the hydrochloric acid being adsorbed onto the surface of the aggregate particles when the acid is shaken with the adjusted aggregate particles. As the rate of exchange of positive ions differs according to rock types of the aggregate, the conductivity obtained in the test appears as distinct values for each type of aggregate. If the alkali-silica reaction of the aggregate is related to the surface conditions of the aggregate, the alkali-silica reaction of the aggregate can be estimated to an extent by the indirect measurement of the electric conductivity of the diluted hydrochloric acid dissolved in the shaken liquid.

4.1.2 Accuracy of Test

The comparison between the data on the alkali-silica reaction of aggregate that had previously been obtained in the chemical test and the results obtained in the conductivity test is shown in Figure-2.

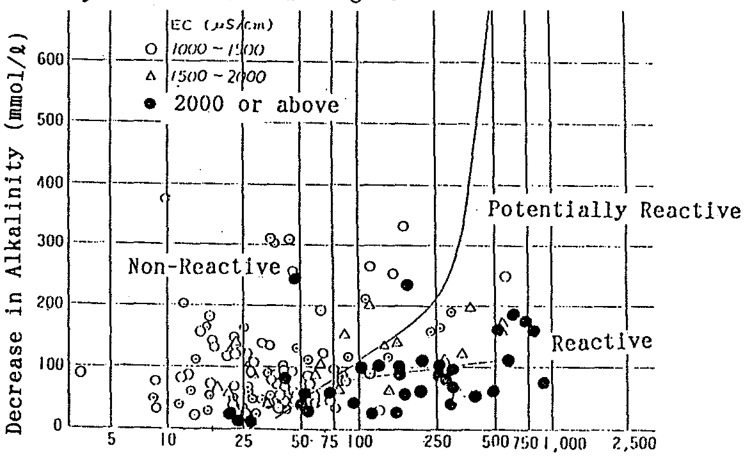

Figure-2 Comparison between Results of Chemical Test and Results of Electric Conductivity Test

It can be observed from the results of the experiments that a high proportion of aggregate that had been classified as reactive and potentially reactive is to be found among the aggregate showing conductivity of 2000 μs/cm or above and a correlation is found between the results of the chemical test and the results of the summary test using electric conductivity.

Taking the value for the borderline in the results of the conductivity test at 1500 μs/cm, the correlation between the occurrence of aggregate above and below the borderline and the results of the chemical test is as shown below.

Electrical Conductivity (μs/cm) Classification by Chemical Method	below 1500	1500 or above	Total
Non-Reactive	93 (80%)	23 (20%)	116
Potentially Reactive and Reactive	7 (13%)	48 (87%)	55

Approximately 80% of aggregate that registered as non-reactive in the chemical test showed values below 1500 μs/cm in the conductivity test and it is estimated that approximately 87% of aggregate that registered as potentially reactive or reactive in the chemical test will show values of 1500 μs/cm or above in the conductivity test.

4-2 Method using Pigmentation

4.2.1 Inference on Mechanisms of Reaction

If decomposition due strong alkali is observed on the surface of the aggregate, it is possible that water glass is formed, after strong alkali is made to act on the aggregate particles. This process itself is much the same as in the preparation for the alkali elution test in the chemical method and it is possible that the water glass forms through reaction or the alkali with the silica in the aggregate, as the amount of potassium itself in the potassium hydroxide decreases. As a result when water glass forms, methylene blue and glass are adsorbed and as the density of the methylene blue in the solution is reduced, the colour becomes lighter. The level of decolorisation is thought to be proportional to the reaction of the alkali with the aggregate.

4.2.2 Accuracy of the Test

As there are ambiguities in the borderlines between the non-reactive, reactive and potentially reactive particles, the results are rather rough compared with the chemical method. It is to be used only as means of summary estimation of the tendency and the outline of the alkali-silica reaction of the aggregate.

5. Conclusion

The accuracy of two summary test methods was investigated through experiments. Both methods have their advantages and disadvantages but it was found to be possible to make a speedy and rough appraisal of the alkali-silica reaction in aggregates, allowing for some exceptions. These methods could be used as methods of carrying out summary tests on site and will enable measurements to be performed by testers without special expertise at the sites of placement of ready mixed concrete or at the quarries with simple instruments and by aggregate numbers. Of the two methods, the electric conductivity method has the advantage from the point of view of accuracy and procedure and its future development can be expected.

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