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

COMPARISON OF RESULTS OF THE CHEMICAL METHOD AND MORTAR BAR EXPANSION TEST FOR DETERMINING AGGREGATE REACTIVITY

Kiyoshi KATAWAKI, Susumu MORIYA, Yasuhiko WAKISAKA
Public Works Research Institute, Ministry Of Construction
Asahi 1, Thukuba Science City 305 Japan
Osamu KATO
Research and Development Laboratory
The Cement Association of Japan
Teshima 4-17-33, Kita-ku Tokyo 114 Japan

ABSTRACT

An appropriate judgment chart was called for in the chemical method, because the reactivity of the aggregate was judged on the basis of the ASTM judgment chart.

The chemical method and the mortar bar test were conducted for 299 aggregate samples collected at quarries over the country. A comparison of results of these tests was made to review the judgment chart. As a result, it has been proved that the improved chemical test yields a precision high enough to judge the alkali-silica reactivity.

INTRODUCTION

Accurate and prompt judgment of the reactivity of the aggregate for concrete was required to prevent the alkali aggregate reaction by adopting safe aggregates for construction works. The authors intended to prepare promptly a standard testing method. Testing methods include chemical tests, mortar bar test, concrete bar tests, and others.

The authors focused on a chemical test, taking account of the rationality of its principle, its advanced analytical technique, and promptness of the test. ASTM C 289 (Chemical Test) is one of a well-known chemical test. This test was found to have several problems in its testing procedure and judgment method. The modification of the testing procedure has been already published in a different paper. This report presents improvement of the judgment method mainly by reviewing the judgment chart.

PURPOSE OF THIS STUDY

The chemical test (ASTM C 289) is a test to judge the presence or absence of the aggregate reactivity based on a reduction in alkali concentration (RC) and the amount of soluble silica(SC), when a finely crushed aggregate is subjected in a high temperature sodium hydroxide solution.

This method is advantageous in terms of a smaller volume of aggregate sample, a shorter required time (several days), and possible treatment of many samples. However, the ASTM judgment chart (ASTM C 289 Figure 2) has several problems; the applicability of the chart prepared in the U.S.A. to Japanese aggregates, the possibility of clearer and logical lineation for judgment(division) in the chart, and others.

In order to solve these problems, the chemical test and the mortar bar test were conducted for aggregates produced in Japan to prepare an experimental judgment chart by determining the relation between these tests.

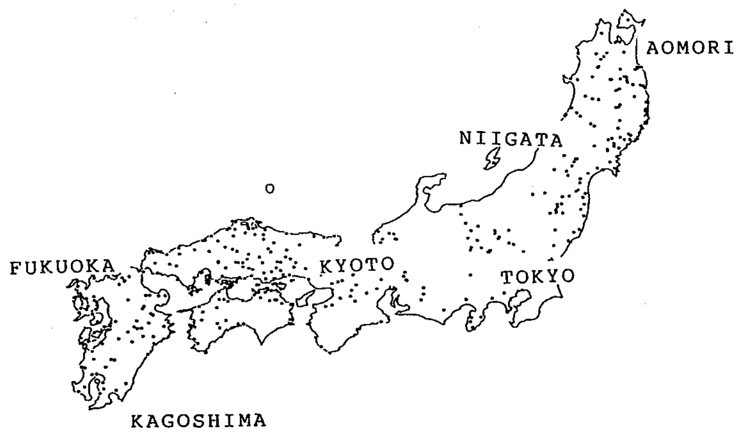

Figure 1 Collection of Aggregates Around Japan

COLLECTION OF AGGREGATES

Aggregates were obtained mainly at quarries under operation. In selecting these quarries, geology/rock bodies to which each quarry belong were chosen in reference to geological maps. The locations of the aggregate collection are indicated in Figure 1.

CHEMICAL TEST METHOD PROCEDURE

Aggregates are coarsely and finely crushed and their grain size is adjusted to 150-300um. A 25g of sample is placed in a stainless steel container, to which 25ml of 1n NaOH is added, and then kept in a pyrostat water tank at 80C for 24 hours. After the reaction has completed, the sample is cooled in cold water for 15 minutes, and then filtered with a buffer and titrated with 0.05N HCl to determine the reduction in alkali concentration, while the silica content is measured by atomic absorption, photometry and a gravimetric analysis to determine the amount of soluble silica.

MORTAR BAR TESTING PROCEDURE

Cement used was ordinary portland cement. Its alkali content is 0.31%. Ion exchanged water was used as water for mixing. The mixing ratio was water:cement:aggregate = 1:2:25, and 300g of water for mixing was used. The cement for mortar mixing was 600g, and the amount of aggregate was 1350g. The alkali content in mortar was raised to 1.2% by adding a sodium hydroxide solution to ordinary portland cement.

RESULTS OF THE CHEMICAL METHOD

Results of the chemical method are shown in Figure 2. This figure shows the soluble silica content(Sc)and the alkali concentration reduction(Rc).

One with the highest rate of alkali reactivity is chert, being approximately 90%. The next is andesite of approximately 50%, followed by volcanic rocks(basalt, basaltic andesite, dacite, thyolite) of 30-40%, and sandstone/shale/slate of 15-30%. In addition, some of tuff/dacitic pyroclastic/quartz, schist/slate /siliceous rocks/schalstein show the alkali reactivity, although a rather small number of samples.

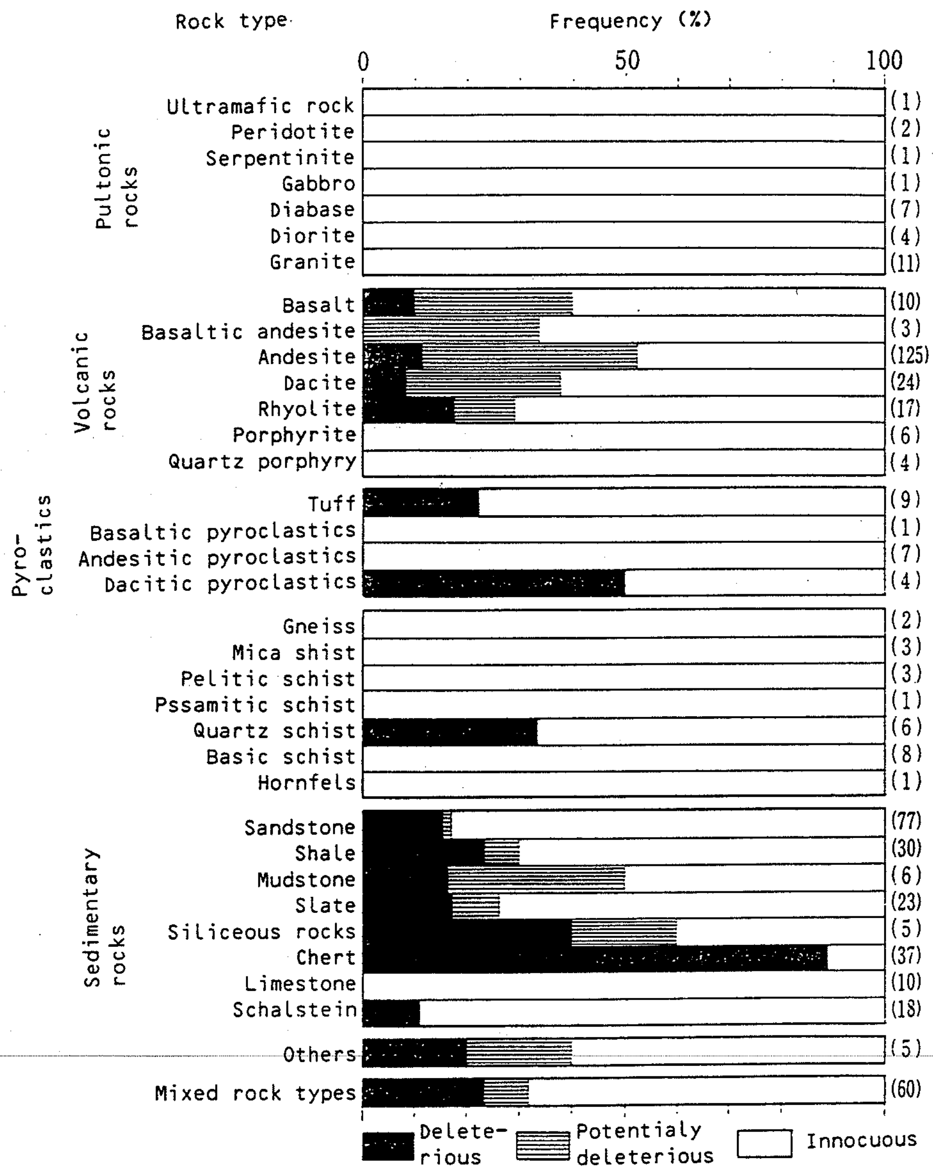

Figure 2 Results of the Chemical method

Thus, characteristics of the reactivity for each rock type are relativity similar, and this seems to be because the alkali reactivity of rock depend mainly on a combination of minerals.

RESULTS OF THE MORTAR BAR TEST

Results of the mortar bar test for 300 samples are summarized in Figure 3. One with the highest rate of the reactivity is chart, being approximately 40%, followed by volcanic rocks of approximately 20%, shale/slate of 20-30%, and sandstone of about 6%. In addition, some of psamitic schist show the alkali reactivity, although a small number of sample. Thus, the alkali reactivity by the rock type corresponds with that by the chemical test.

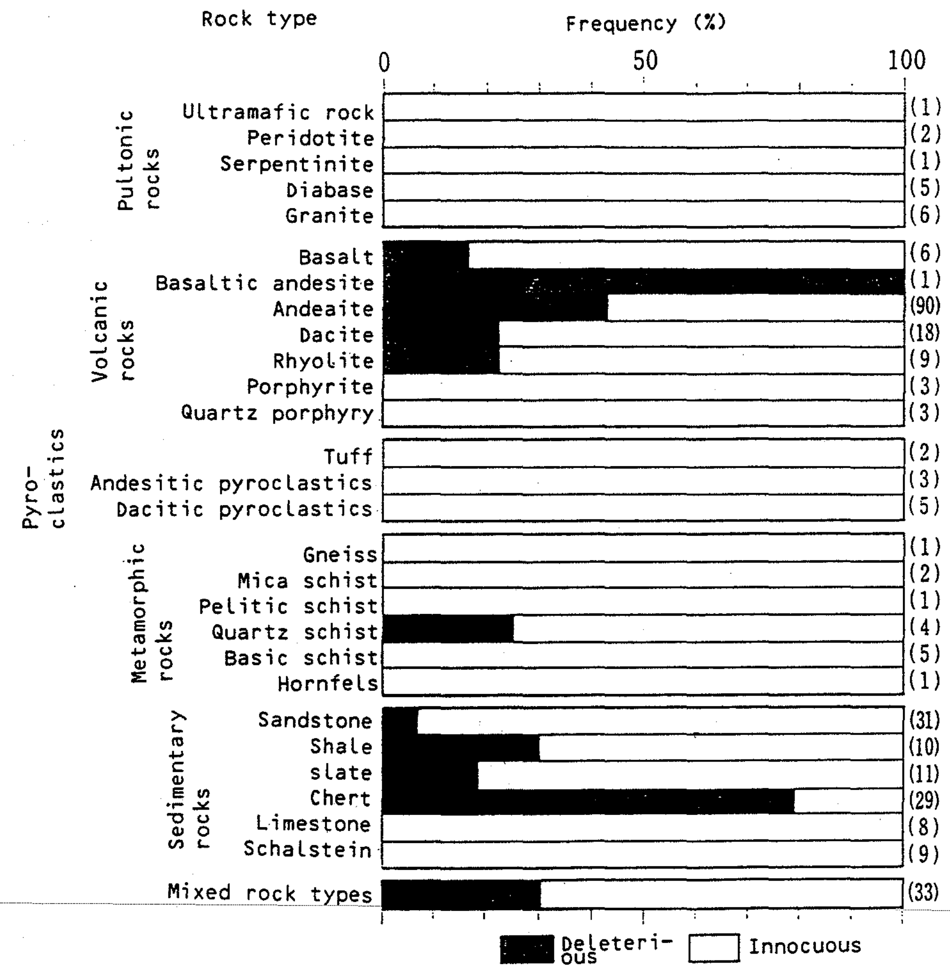

Figure 3 Results of Mortar Bar Test

RELATION BETWEEN THE RESULTS OF THE CHEMICAL METHOD
AND THE RESULTS OF THE MORTAR BAR TEST

Review of the chemical test and the mortar bar test for the aggregates collected at quarries over the country(299 aggregates) were used to review the judgment chart.

Results of the chemical test and the mortar bar test for 267 single rock type aggregates were plotted in the judgment chart of the chemical test. This is shown in Figure 4 (Results for 130 andesite aggregates and 98 sedimentary rock aggregates).

When the expansion at 6 months in the mortar bar test is divided into a group with more than 0.1%(judged to be deleterious and a group with less than 0.1%(judged to be innocuous, an appropriate line to judge deleterious/innocuous in the chemical test seems to be the solid line drawn in the figure (Rc-Sc), which is not so different from the ASTM judgment line, talking account of the practice of traditional judgment based on the ASTM line.

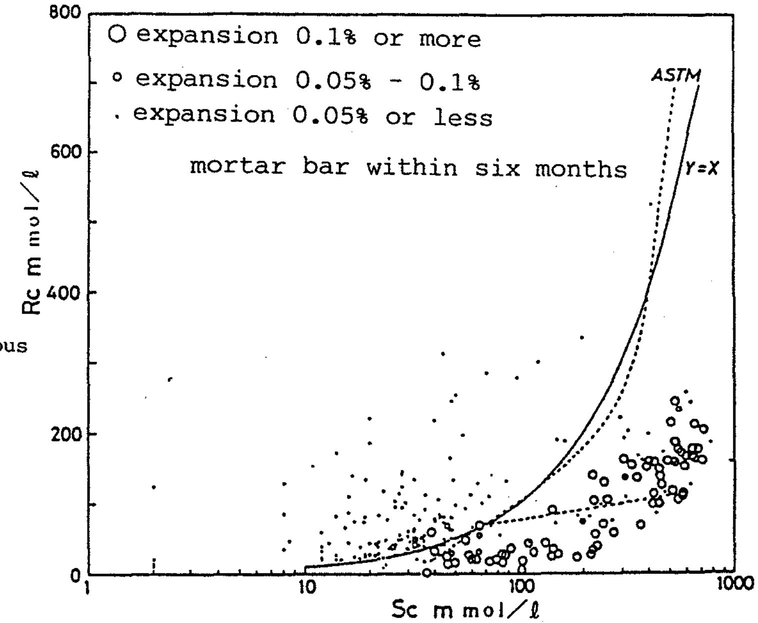

Figure 5 The Relation Between The Chemical Method and The Mortar Bar Test

However, the Rc-Sc border line between 25 and 50 of Sc has one sample (sandstone of sedimentary rocks) with the expansion of more than 0.1% (deleterious in the mortar bar test) which is above the border line (innocuous in the chemical method). In addition, there are 4 samples with the expansion of 0.05%-0.1%(2 samples of slate of sedimentary rocks, one sample of chert, and one sample of pelitic schist of metamorphic rocks. That is, of the 299 single rock type aggregates, at least one deviates from this border line, but with only 5 samples at maximum. Therefore, shifting the traditional border line dividing deleterious and innocuous to the new one does not lead to a serious error. Furthermore, as 4 samples have the expansion of 0.05-0.1% at 6 months, the expansion of these mortar bar samples at one year was measured. The result was the same with that at 6 months.

It is considered rational to classify into 3 groups; aggregates located on the right side of Rc-Sc-80 are deleterious those on the left side of Rc-Sc-20 are innocuous, and those in the section painted out are deleterious for sedimentary rocks, innocuous for volcanic rocks, or potentially deleterious for those of which rock type is not identified. However, because measures against the alkali-aggregate reaction have been taken depending on whether an aggregate is innocuous or deleterious it is rational to adopt Rc-Sc as the border line of deleterious-innocuous in the judgment chart in the chemical test. The final judgment chart is shown in Figure 6. Results of the exposure test of concrete specimens indicate that only a part of them showed a change in their appearance. These test results back up the confirmation of the chemical method.

CONCLUSION

(1) Approximately 532 aggregate samples collected at quarries over the country were subjected to the chemical test, after their mineral composition and rock types were judged. Of them, 299 samples were subjected to the mortar bar test.

(2) Since determination of a judgment chart which is applicable to Japanese aggregates and proper formulation was required, the judgment chart was re-examined based on results of the chemical test and the mortar bar test for the aggregates collected over the country.

(3) In order to elucidate the relation between concrete deterioration and the results of the chemical test, concrete specimens with a fixed alkali content were made from 100 aggregates, and the exposure test was conducted.

(4) The new judgment chart is planned to be adopted in new tentative measures against alkali aggregate reaction.

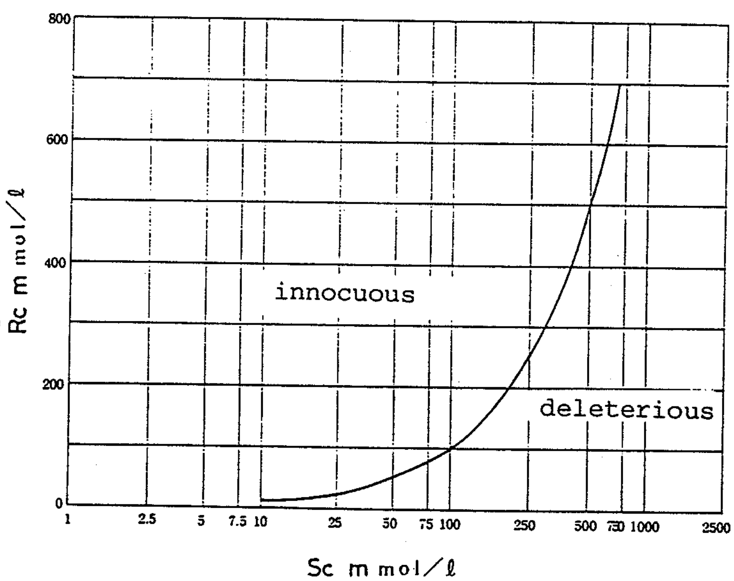

Figure 6 Revised Judgement Chart with The Chemical Method

ACKNOWLEDGMENT

This study was conducted as a part of the General Research Project for Improving Durability of Concrete. The authors appreciate the good advise from members of the research committee for The Concrete Durability and PWRI experts of concrete professionals. The Authors also appreciate the technical committee of The Cement Association for the helping cooperation from experts of chemical analysis and analyzing. The technical committee members of The Cement Association composes of Dr. T.UNO, Mr.K.KISHITA, Mr.S.SATO, Mr.S.TAKAHASHI, Mr.K.TAKEI, and Dr.M.FUNATO.