Response of JCI to Alkali-Aggregate Reaction Problem— Guideline for Determining Potential Alkali Reactivity

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ABSTRACT

JCI established an AAR Committee in 1983 and started to carry out investigations and studies with three subcommittees. It is the aim of the AAR Comm. to establish a test method and to develop deterioration diagnosis and repair methods for structures based on the results of the investigations and studies of these subcommittees.

INTRODUCTION

The Japan Concrete Institute (JCI) established an Alkali-Aggregate Reaction Investigation and Study Committee (AAR Comm.) in 1983 and started to carry out investigations and studies with three subcommittees on literature search, deterioration mechanisms and reactivity determination testing methods. Of those, the Literature Search and Deterioration Mechanism Subcommittees completed their activities in 1985, while a subcommittee on structure diagnosis was newly inaugurated.

The Reactivity Determination Testing Subcommittee is carrying on various studies with the aim of establishing an alkali-aggregate reaction testing method unique to Japan. From among the methods being reviewed a modification of the chemical method, ASTM C 289 is being considered for evaluating the reactivity of Japanese aggregates. Drafts of a modified mortar bar method for determining the reactivity of aggregates have been prepared and are being circulated among various research institutions for study. Based on the results of comparative studies on several types of reactive aggregates, criteria for evaluating the mortar bar results have been proposed. Tests are also under way to develop a test using concrete samples. A draft of this test should be available in 1987.

The Structure Diagnosis Subcommittee has as its ultimate goal the establishment of a method of judging the soundness of a structure, in effect, a diagnostic method based on the results of detailed investigations carried out on several damaged concrete structures, and to propose optimum repair methods appropriate for the types of structures requiring repair.

It is the aim of the AAR Committee to present guidelines or principals for prevention of damage to concrete structures due to alkali-aggregate reaction based on the results of the investigations and studies of these subcommittees.

LITERATURE SEARCH SUBCOMMITTEE

The Literature Search Subcommittee investigated approximately 1,000 different items of literature from both Japan and abroad. After listing these papers according to chronological order of publication and by country, they were classified according to the thirteen categories below with individual items further divided into several sub-items (a total of 73 sub-items) for the convenience of those engaged in studies on AAR.

1) Type of reaction
2) Reaction mechanism
3) Test method
4) Laboratory experiment
5) Performances of structures in case studies
6) Cracks and pop-outs
7) Admixtures
8) Aggregate
9) Type of cement
10) Preventive measures
11) Remedial action
12) Reviews
13) Other articles

At present, there are more than 30 new papers reporting research results published every year in Japan by the academic societies concerned. These papers also are being added successively to the literature list and index, and are announced in the form of bulletins.

DETERIORATION MECHANISM SUBCOMMITTEE

The role of this subcommittee was to investigate the varieties of reactive aggregate currently causing deterioration in concrete structures in Japan, the regional distributions of these aggregates, and to obtain basic data for establishing a test method for judging reactive rock. These investigations and studies were carried out by the Structures Investigation Working Group and the Aggregate Working Group.

The principal results of the investigations are:

(1) Out of a total of 42 samples collected from concrete structures in which deterioration has been observed, 55% were judged to be due to AAR.

(2) Rock types with highest possibilities of causing AAR were andesites and siliceous rocks.

(3) Diagnosis of AAR based on the observation, of dark rings around aggregate particles and on cracking of aggregate

particles, by visual inspection coincided well with results obtained by microscopy. It is concluded that a combination of visual and microscopic observations provides a satisfactory method of diagnosing AAR in concrete structures.

This subcommittee completed its work in 1985; Subsequently investigations and surveys were transferred to the Structure Diagnosis Subcommittee were studies are being continued.

REACTIVITY DETERMINATION TESTING SUBCOMMITTEE

The aims of this subcommittee were the establishment of a test method for most effectively evaluating the reactive aggregate using ASTM and other test methods, of various countries, as references. Test methods which could be broadly divided into chemical methods, mortar expansion and concrete expansion testing methods were studied.

The results obtained with various test methods are described below:

1. CHEMICAL METHODS

Chemical methods were mainly evaluated at the laboratories of cement manufactures. As a result of common tests based on the ASTM method of eight reactive aggregates and two non-reactive aggregates, it was found that considerable scattering occurred between testing agencies. Thereupon, the testing method was re-examined and efforts were made to eliminate errors due to the testing procedure as far as was practicable. As a result, besides adding more detailed commentaries to the testing methods, in the tentative chemical method of Japan, it was decided that the accuracy of testing would be improved by changing the evaporate to dryness method to the dehydration method by use of perchloric acid for determination of the dissolved silica (Sc) for which errors had been comparatively large, and also by the combined use of the gravimetric method and the atomic absorption spectroscopy.

2. MORTAR-BAR METHODS

Examination of the Mortar-Bar Method was done by 17 research institutions, each institution carrying out tests of a number of items, with overlapping of items between institutions.

The materials used in common by these research institutions were an ordinary portland cement of Na_2O equivalent of 0.53%, three reactive aggregates and one non-reactive aggregate. Additional alkali was added as NaOH or NaCl. The mix design for mortar for the common tests was cement : aggregate = 1 : 2.25, total alkali content as Na_2O equivalent 1.5%, and W/C = 0.45 and 0.50, while the storage conditions were 18 to 22°C at the time of casting and measuring of expansion, and 38 to 40°C during storage, both at relative humidities of 95% or higher.

The items of test and the results obtained for them were as follows:

(1) Test in common according to the above mentioned conditions (All institutions)

(2) Aggregate grading, particle size and pessimum proportion

Regarding the influence of aggregate gradation on expansion, the standard gradations stipulated in ASTM, JASS and JSCE were examined. Changes to grading, particle size or pessimum proportions had little effect on the observed expansions.

The maximum expansion occurred with aggregate sizes of 0.3 to 0.6 mm.

Examinations were made combining proportions of reactive aggregates (0 to 100% at 20% intervals) and total alkali content (0.5 to 2.5% in terms of Na_2O equivalent, at 0.5% intervals). The results were that pessima differed according to variety of aggregate used. It occurred at between 40 and 60% at Na_2O eq.= 1.5%. A trend was seen for the pessimum to shift to a larger percentages with increase in alkali content.

(3) Influence of specimen dimensions

As a result of comparing amounts of expansion with specimens made according to ASTM and JIS specifications, the JIS specimen (4 X 4 X 16 cm) showed slightly higher values.

(4) Influence of alkali content

Expansion increased slightly as alkali content was increased to a maximum of 2.5%.

(5) Influence of water/cement ratio

Although differing slightly depending on variety of aggregate the maximum expansion was obtained with water/cement ratio of 0.50.

(6) Storage conditions

There was no significant difference between the expansion under forced fogging conditions at 40°C and due to ordinary storage conditions (40°C, 95% R.H. or higher).

With the above results as references, and broadly following ASTM specifications, the following guidelines were established for the mortar bar testing method: Specimen size 4 X 4 X 16 cm, total alkali content 1.2% and water/cement ratio 0.50. The ASTM expansion limits were adopted, but because some aggregates showed large expansions after longer periods of time, it was recommended that the minimum period of measurement should be one year.

3. CONCRETE-BAR METHOD

Tests using concrete bars had the objective of evaluating the reactivity of aggregates under conditions of actual use. Since there had been few cases of experiments on concrete in the past, this subcommittee organized a Concrete Method Working Group. Ten research institutions participated to carry out common tests to resolve problematic points. At present, studies are being mainly made of the five test items below:

(1) Influence of shape and dimensions of test specimens

Studies are being made on the influences of specimens of shape and dimensions 10 X 10 X 40 cm, 7.5 X 7.5 X 40 cm and 15 X 15 X 15 cm on expansion and crack occurrence.

(2) Influence of storage conditions

Studies are being made of the six storage conditions: 40°C, 95% R.H. or higher; 20°C, 95% R.H. or higher; 20°C in water; 20°C in sea water; 20°C one-half immersed in water; and outdoor exposure.

(3) Influence of unit cement content

Studies are being made of the influences in case of varying unit cement content for 350, 450, 550 kg/m^3 under the storage condition of 40°C, 95% R.H. or higher.

(4) Influence of variety of alkali (NaOH, NaCl) added.

(5) Comparisons of test results obtained with concrete and mortar specimens

The materials used were 8 varieties of reactive aggregates and 2 varieties of non-reactive aggregates, and ordinary portland cement with an alkali content of 0.8%. In addition the alkali content of the cement was increased to 1.5% by the addition of NaCl and NaOH to the mixing water, as part of test (4) above. The ratio of reactive to non-reactive aggregates was either 1 : 1 or 100% reactive aggregate. Expect for test (1) above the specimen size was 10 X 10 X 40 cm. The unit cement content was 450 kg/m^3 except for series (3). Except for series (2) the storage conditions were: 1) 20°C and 95% R.H., 2) 40°C and 95% R.H..

The items measured were length change, variations in dynamic modulus of elasticity and ultrasonic pulse velocity and crack growth patterns.

STRUCTURE DIAGNOSIS SUBCOMMITTEE

This subcommittee presently has the objectives following.

(1) Diagnosis and investigations of actual structures

Appearance surveys, expansion tests using cores and aggregate tests are being carried out on actual structures in four districts.

(2) Laboratory tests concerning effects of repairs

Laboratory tests with the principal objectives of recovery of load-bearing strength and improvement of deformation characteristics of low-reinforcement-ratio concrete members are being performed.

Besides carrying out the above on a continual basis, the correlations of (1) and (2) are being studied with the ultimate objective of

(3) Preparation of guidelines of structure diagnosis and repair methods.