CONTROL OF AAR BY CATALYZED ALKALI DISCHARGE

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ABSTRACT

This paper presents the results of the study about catalyzed alkali discharge of concrete as a measure to check AAR of structures in service Reaction of a particular type waterproofing agent with mortor test pieces which were artificially effected with AAR was examined. Results of the analyses showed that this agent noticeably reduces sodium concentration of the AAR gel in the mortor test pieces.

1. CONVENTIONAL COUNTERMEASURES AGAINST ALKALI-AGGREGATE REACTIONS (AAR)

The AAR countermeasures for concrete structures in service where alkali-aggregate reactions (AAR) have already occurred are required to suppress AAR without destroying the structures. Ordinary methods conventionally used so far are mainly designed to prevent water infiltration from the concrete surface through the application of coating materials on the structures. This process is commonly referred to as passive protecting methods.

However, these kinds of passive methods are not adequate for preventing water infiltration from the portions of foundations which directly contact with the ground water. In addition, there are some possibilities that the passive methods accelerate AAR on contrary to the desired outcomes because of their shielding and insulating effects inside the concrete body. This implies the necessity of development of the AAR countermeasures that chemically inactivate the concrete mass from AAR.

Mixing concrete with pozzolan type materials such as slag powder is a well-known method for suppressing AAR. This method is, however, cannot be applied to structures in service.

There are several experimental reports[1),2),3)] that argue the effects of mixing lime to concrete as a suppressing measure of AAR. As can be imagined from is the observations in many cases of efflorescence, where alkali metal sulfates constitute the main component of efflorescence, it may be expected that the alkali metal as the main cause of AAR will be combined with SO_4^{--} of lime according to reaction (1) as shown below and its natural by-product, efflorescence will be discharged outside of the concrete body.

$$Na_2O \cdot nSiO_2 + CaSO_4 \longrightarrow CaO \cdot nSiO_2 + Na_2SO_4 \quad \cdots\cdots (1)$$

However, according to the reports [1),2),3)], it has not been found that the expected effects are materialized.

2. EXPERIMENTS ON CATALYZED ALKALI DISCHARGE AND ITS VERIFICATIONS

However, reaction (1) is extremely close to reaction (2) shown which is catalyzed by the particular waterproof agent when it produces crystals within the concrete body.

$$Na_2O \cdot nSiO_2 + Ca^{++} \longrightarrow CaO \cdot nSiO_2 + 2Na^{+} \quad \cdots\cdots (2)$$

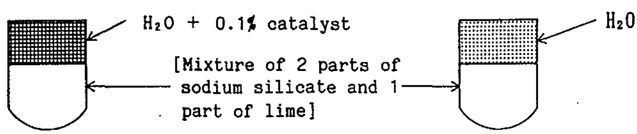
Our hypotheses are that this crystal breeding type waterproof agent can catalyze the reaction (1) as well, and it is also effective to check AAR in existing structures. The following tests were conducted, to verify them. In these tests, we employed a similar catalyst to that used by XYPEX as a hypothetical catalyst.

Test 1 (Verification of the acceleration of crystal breeding reaction bycarrier functions of catalyst)

[Method] In order to verify whether reaction (1) actually progresses as expected and also whether the catalyst used for breeding crystal type waterproof agents of reaction (2) affects reaction (1), a test was conducted using the following procedure.

First, sodium silicate and lime were mixed together at a weight ratio of 2:1; the mixture was placed at the bottom of two test tubes and the results of the reactions were compacted. One of the test tubes was filled with water over the mixture, while the other test tube was filled with water dissolved with 0.1% of the catalyst. Changes in water layers were observed.

[Results] Each solution gradually became opaqued white with the passage of time, and the formation of precipitates was observed. The opaquing white was extremely significant in the solution of the test tube to which the catalyst was added compared to other test tube.



The precipitate was filtered and dried, and was subjected to material identification by X-ray power diffraction identification methods and determined to be Na_2SO_4.

This suggests that the sodium silicate reacts with lime and produces calcium silicate and sodium silicate. It is indicated as well that the catalyst does accelerate the reaction.

Test 2 (Verification of suppression effect by changes in Na concentration in AAR portions)

[Method] Mortor specimens artificially born alkali-aggregate reactions were prepared. Lime and catalyst were added to these specimens, and changes in sodium concentration in AAR effected areas measured.

A) Preparation of specimens

Mortor specimens 4 × 4 × 16cm in size shown in (Table 1) with composition for artificial AAR were prepared and cured for 8 weeks under ambient conditions of 40 ℃ and R.H. 100% after air drying for one day. AAR was induced for a glass aggregate.

These specimens were divided into 2 groups as shown in Fig .1, and a bore holes were driven in each specimen.

As shown in Fig. 2, each hole in the central portions was filled up with the catalyst for one group and with ordinary mortar for the other, while other peripheral holes were filled with the 0.5g of lime.

Table-1 Mix proportions in mortar

	Artificial AAR mortar (Ratio to cement by weight)
Portland cement	1
Pyrex glass	2.25
Water	0.45
Na_2O equivalent	0.02

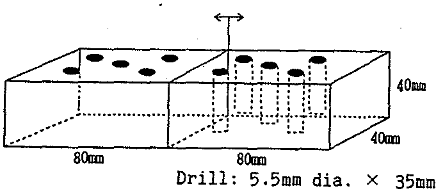


Fig. 1 Specimens

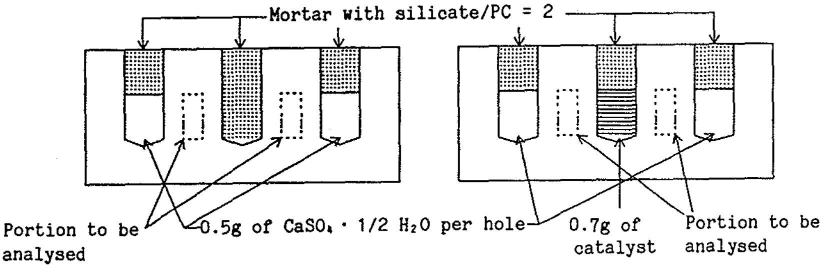


Fig. 2 Sampling location of specimens for analysis

The lower ends of these two specimens were immersed in distilled water and stored for 15 weeks at the room temperature.

B) Collection of analytic specimens

Two specimens stored for 16 weeks were ruptured and the broken pieces were sampled (Fig. 2).

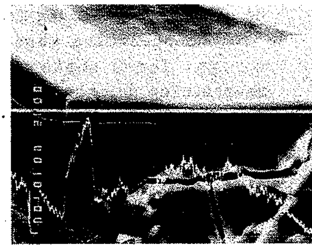
C) Method of analysis

Carbon deposition tests were conducted on the broken sample pieces and sodium concentration in the AAR portion was measured with an EPMA (Electron Probe Micro Analyzer) and compared each other.

[Results] Results of line analysis of sodium concentration in AAR portions are shown in Fig. 3. As can be seen in the figure, the concentration of sodium in AAR portions from the specimens filled with catalyst is extremely low compared to that of the specimens which were not treated with the catalyst.

[Review] Five broken pieces for testing were sampled from each specimen and sodium content was measured by line analysis. Significant differences in sodium concentration were noted among four specimens, and it was recognized that this catalysis indicates a greatly accelerating effect on the reaction between lime and sodium silicate.

Specimen filled with catalyst



Specimen filled with ordinary mortar

Fig. 3

Review 3 (Macroscopic verification experiments of AAR suppression effect)

[Purpose] General Pyrex glass particles are used as reactive aggregates in experiments of alkali-aggregate reactions.

In the present experiment, the specimens shown below were used and experimented under ambient atmospheric conditions where AAR was artificially developed by using Pyrex glass particles as an aggregate (mean particle size of 0.65mm), and the effect of this added catalyst on AAR suppression was observed.

[Method]

A) Preparation of specimens

The specimens shown in Fig. 4 were prepared using high alkali standard sand mortar having the mixture composition shown in Table 2.

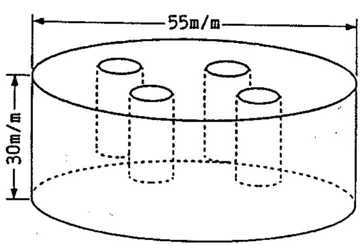


Fig. 4 Specimens

Table 2 Mixture composition of high alkali mortar

	High alkali mortal (Ratio to cement by weight)
Portland cement	1
Standard sand	2
Water	0.63
Na_2O equivalent	0.02

Four holes in each specimen were filled up with Pyrex glass particles, lime and catalyst respectively as shown in Fig. 5.

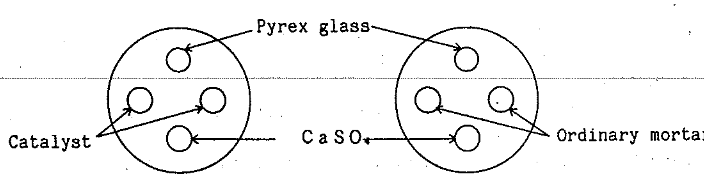


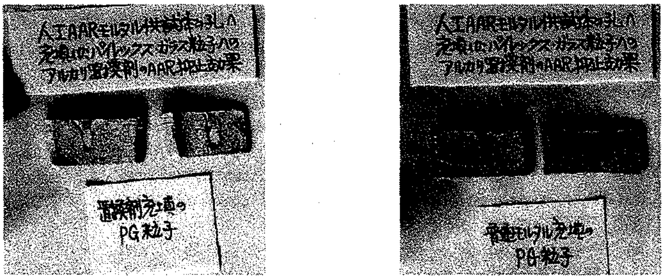
Fig. 5

B) Accelerated curing for AAR

The specimens were placed in a sealed container and kept upright for 9 weeks in an ambient atmosphere of 40℃ While maintaining moisture.

C) After the curing period, the portion filled with Pyrex glass particles in the specimen was cut off with a diamond cutter and any changes were observed.

[Results] The results are shown in Fig. 6. As can be seen in Fig. 6, the Pyrex glass particles embedded in the specimen filled with the catalyst hardly indicated any change; however, those in the specimen not treated with any catalyst were liquefied by AAR thereby demonstrating that none of the particles retained their original shape.



Pyrex glass particles with catalyst fill

Pyrex glass particles with ordinary mortar fill

Fig. 6

3. EXAMPLES OF AAR COUNTERMEASURES

Examples of the AAR countermeasures taken using the said catalyst will be explained below.

(1) Piers of the Susobana River Bridge between Nagano and Amori on the Shinetsu Railway Line

The Susobana Bridge was constructed in 1971. The first anomaly (Hair cracks) in part of the bridge was found during an inspection conducted in 1982 but was not severe. However, during the inspection performed in 1987, the occurrence of many net-shaped cracks and hair cracks in the piers and abutments was found. To counter to such failure, several waterproofing agents and an AAR material (product of Japan XYPEX) were used. Thereafter, the suppression effect was inspected and the AAR material (product of Japan XYPEX) containing this catalyst was found to be very effective. At present, a follow-up survey is being conducted, and the portion repaired by the said catalyst has indicated no further anomalies.

According to the outline the application used method, a portion of the defective concrete was chipped off, fresh concrete surface exposed and bore holes made, and a chemical agent containing the said catalyst was applied, poured, and covered with mortar.

(2) The Ryusaku Elevated Bridge between Niigata and Tsubame-sanjo on the Joetsu Shinkansen Railway Line

This elevated bridge was constructed in 1978 to 1979. This is a girder type elevated bridge with a total length of about 800m and consists of 19 prestressed concrete box girders connected together. On the upper face of the box girders, there are slab tracks (2 lines), a cable duct and noise-shielding walls in addition to a return water channel for circulated water for melting snow in winter by spraying water.

About 5 years after construction, the girder was found to be warped upward. In 1989, defective concrete was removed from the return water channel on the upper slab face; a chemical agent containing the AAR material (product of Japan XYPEX) containing this catalyst was applied and then covered with special mortar. Then the inner portion of the box girder was coated with the chemical agent in 1990.

Test piece cores were taken and a detailed inspection using an electron microscope performed. It was confirmed that there was almost no growth of needle-like crystals of alkali component thereby confirming the AAR suppression effect. This bridge is still inspected regularly to determine the occurrence of any other anomalies.

4. CONCLUSION

As the result of a series of tests conducted so far, the suppression effect of the catalyst argued here on AAR has been verified. In the future, it is hoped that further testing and quantitative analysis of reactions with emphasis on the detailed process of AAR suppression of the catalyst.

The authors are going to conduct further experimental studies on both test pieces and on the *in situ* concrete in order to determine more detailed mechanism of the reaction and the optional atmosphere for the reaction to develop as well as to abtain long term information about the effects of the countermeasure by the catalyst.

Literature

1) Shigetoshi Kobayashi, Hirotaka Kono, Shinichi Numata, Takao Chikada: "Study on Mechanism of ASR Suppression Effect of Blast Furnace Slag Powder", Annual Report of Cement Technology, No. 40, 1986

2) Minoru Makita, Shigetoshi Kobayashi, Yoshu Moriyama, Hideaki Hoshi: "Research on Mechanism of ASR Suppression Effect of Blast Furnace Slag Powder by Actual State Study in Japan", Annual Report of Cement Technology, No. 40, 1986

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