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SOME FIELD STUDIES OF THE NEW INSITU METHOD FOR IDENTIFICATION OF ALKALI SILICA REACTION PRODUCTS

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1. INTRODUCTION

In two previous papers [1,2], the authors have described an insitu test for the identification of alkali silica reaction (ASR) products. The 'Cornell Gel Fluorescence test' is a staining technique for the identification of ASR products. The products of ASR were visualized as gelatinous silica with adsorbed sodium, potassium, and calcium ions. Based on a study of cation exchange properties of gelatinous silica, it was shown that a wide variety of cations can replace previously adsorbed Na^+, K^+, and Ca^{++} ions on silica gel. The uranyl ion (UO_2^{++}) was chosen for its characteristic fluorescence. Specimens were treated with uranyl acetate solution, and after proper conditioning observed under short wave ultraviolet light. The presence of gel was indicated by the characteristic greenish yellow fluorescence of the uranyl ion, selectively adsorbed to the gel surface.

The studies presented in the earlier papers were based on lab specimens using opal and chert as reactive aggregates. This paper presents the results of applications of the test to concrete specimens from field structures suspected of deterioration due to ASR. Samples sent to the authors from three field structures are analyzed. Petrographic thin section examination was performed in addition to the gel fluorescence test and the observations are detailed in the following sections.

2. GENERAL EXPERIMENTAL PROCEDURE

In general, freshly broken surfaces of the suspect specimens were washed with distilled water, sprayed with uranyl acetate solution, and allowed to stand for 5 minutes to allow adsorption of the uranyl ion on the ASR products. The specimens were then re-washed to remove non adsorbed uranyl acetate solution and observed under ultraviolet light in a darkened room. The presence of ASR products was indicated by the characteristic greenish yellow fluorescence of the uranyl ion.

Standard 2.5 cm x 2.5 cm petrographic thin sections were made from each of the four concrete specimens, and examined using transmitted light under both plane polarized (PP) and crossed nichols (XN) arrangements. The petrographic examination helped identify the reactive minerals, altered aggregates and the products of alkali aggregate reaction. A note about the photographs presented in this paper: The actual fluorescence of the uranyl ion is greenish yellow in color and can be easily distinguished in treated concrete specimens. Only black and white pictures are presented in this paper.

3. RESULTS

Concrete specimens from three structures were analyzed. The type of structure and geographical location of the structures in the U.S. are as follows:

- Concrete foundation piers of an electrical substation in Maryland
- Concrete floor slab of a subway station in Massachusetts
- Floor slab of a parking garage in Ohio

In the following paragraphs, the results of the gel fluorescence test, and petrographic examination of the specimens from each of the four structures are detailed. Brief summaries of the observed structural damage to the structures are also presented.

3.1 Structure 1: Foundation pier of electrical substation

The foundation piers of an electrical substation were found to be severely damaged in service. The top surface of the foundations showed lateral expansion and cracks almost 1.2 cm wide (Figure 1). The owner hired the services of an independent petrographer who concluded that the observed deterioration was due to alkali silica reaction [3]. The authors received two cores from cracked piers from the petrographer for analysis. The cores were 20-25 cm long and 5 cm in diameter. Both the cores had been saw cut longitudinally and were thus received as two half cylinders. The concrete was friable and the cores broke into pieces during transit.

The coarse aggregates in the concrete were composed of quartz, quartzite, and sandstones while the fine aggregate was made of quartz, quartzite, and chert. The sawn surface of the half cylinder, shown in Figure 2, exhibited distinguishable evidence of alkali silica reaction. The quartzite aggregates had distinct reaction rims and white products were found near the cherts in the fine fraction. The surface shown in Figure 2, after treatment with uranyl acetate is shown under ultraviolet light in Figure 3. The presence of ASR products around the coarse aggregate particles is clearly highlighted. A reacted chert particle 'C', not easily visible in Figure 2, is seen to fluoresce brightly.

3.2 Structure 2: Subway station floor slab

The floor slab of the subway station apparently showed signs of deterioration after about 15 years of service. The signs of deterioration included vertical movement of portions of the slab, spalling, and cracking of the top surface of the slab. The cause of the deterioration was determined to be alkali silica reaction and the authors received three cores from the slab for analysis. The cores varied in length from 20 to 28 cm and were 7.5 cm in diameter.

All the three cores showed extensive cracking along horizontal 'bedding' planes (Figure 4). The cracks were filled with a white substance. On application of minimal hand pressure, two of the cores split along the horizontal crack planes, exposing the interior surface of the cores. The reactive aggregates had distinct reaction rims 'A' and were surrounded by white deposits 'B' (Figure 5). The top half of the core shown in Figure 4, after treatment with uranyl acetate is shown in Figure 6. Under ultraviolet light, it is seen that the horizontal cracks are filled with alkali silica reaction products. The gel fluorescence test was conducted on the interior surface of the core, shown in Figure 5, and the observed fluorescence is shown in Figure 7. It is seen that the white deposits are all fluorescent and thus are the products of the reaction between aggregates and alkalis. Note that the aggregates do not fluoresce.

Petrographic examination of thin sections made from the cores established that the aggregates were made of quartzite, quartz, chert and some twinned feldspar. Only the quartzites and chert seemed to have reacted while pure quartz particles showed only minimal damage.

3.3 Structure 3: Parking garage floor slab

The parking garage structure under discussion had numerous serviceability problems. Extensive spalling and cracking of the floor slabs was observed due to a combination of deicer scaling, freeze thaw deterioration, and reinforcing steel corrosion. After a number of remedial measures proved ineffective, the parking garage was finally demolished and rebuilt. One of the consultants involved in the project suspected alkali silica reaction in addition to the other problems and the authors were sent pieces of the demolished structure for investigation.

The underside of a 1.2 cm thick concrete piece, from the top surface of one of the floor slabs is shown in Figure 8. Visual examination shows little evidence of alkali silica reaction . The same surface, after treatment with uranyl acetate, observed under ultraviolet light is shown in Figure 9. Fluorescent gel products are observed extensively on the surface. Closer observation of Figure 9 in conjunction with Figure 8 shows that fluorescent products in Figure 9 are associated with white specks 'D' in Figure 8. The reactive particles thus seem to be present only in the fine aggregate fraction.

Petrographic examination revealed that the coarse aggregates were composed of fine sandstones, siltstones, limestones, quartz, and small amounts of volcanic fragments. The fine aggregate on the other hand, was mainly composed of carbonates and cryptocrystalline chert. The results of the gel fluorescence test when considered with the results of petrographic examination, thus shows that the chert particles are the reactive components of the concrete.

4. DISCUSSION AND CONCLUSIONS

The three structures discussed in this paper all had alkali silica reaction as the common feature. The specimens from the electrical substation foundation and subway station, Structure 1 and Structure 2, however, had already been diagnosed by others as suffering from alkali silica reaction damage. The gel fluorescence test in these two cases, therefore, was used to check for the amount and location of ASR products. In both cases, the test identified the presence of ASR products and provided additional information on the location of the products. The use of the test confirmed the suspicion that the cracks in the subway station slab, structure 2, were filled with reaction products (Figure 6).

In the case of specimens from the parking garage, structure 3, the gel fluorescence test proved to be a useful forensic tool. In this case, obvious signs of alkali silica reaction were not easily observable. The fluorescence test clearly showed the presence of alkali reaction products and thus confirmed the existence of ASR.

A word of caution. The reaction between alkalis and aggregates and the formation of reaction products is only one of the requirements for deterioration due to ASR. The environmental conditions to which the concrete is exposed, especially the ambient humidity and temperature, determine to a large extent whether the structure will crack and deteriorate due to ASR. The gel fluorescence test, however, can be successfully used to determine whether the products of alkali silica reaction are present in a structure suspected of undergoing ASR.

The following specific conclusions can be made from the results presented in this paper.

- The gel fluorescence test was successfully applied to identify the products of the reaction between alkalis and quartzite aggregates.
- The gel fluorescence test can be used as a forensic tool to determine the progress of ASR in a concrete specimen, even when other symptoms of ASR are absent.

5. REFERENCES

[1] Natesaiyer, K.C., and Hover, K.C., Insitu identification of ASR products in concrete, Cement & Concrete Research, 18, 3, 455, 1988.

[2] Natesaiyer, K.C., and Hover, K.C., Further study of an insitu identification method for alkali silica reaction products in concrete, to be published in Cement & Concrete Research, 1989.

[3] Ozol, M.A., Alkali silica reaction of concrete in electrical substation piers accelerated by electric currents, Symposium on Petrography Applied to Concrete and Concrete Aggregates, ASTM STP-1061, Bernard Erlin and David Stark, editors, ASTM, Philadelphia, 1990, to be published.

Figure 1. View of cracked foundation pier of electrical substation

Figure 2. Interior saw cut surface of core from cracked foundation; Electrical substation

Figure 3. Fluorescence of surface shown in Figure 2; UV light

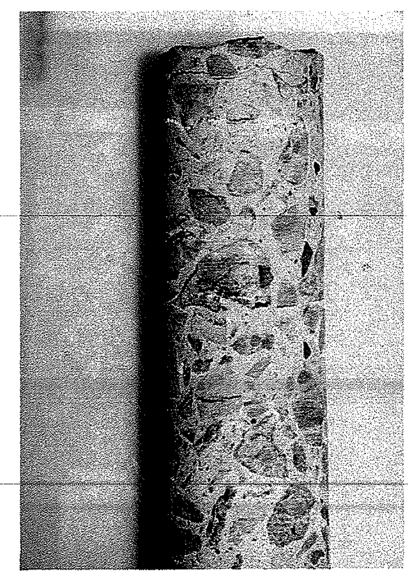

Figure 4. Core from subway station slab showing horizontal cracking

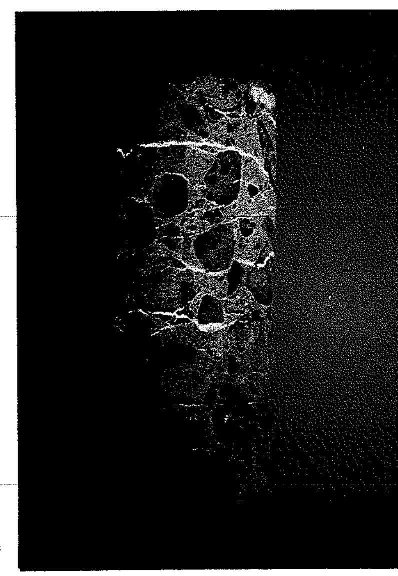

Figure 5. Interior surface of core from subway station slab.

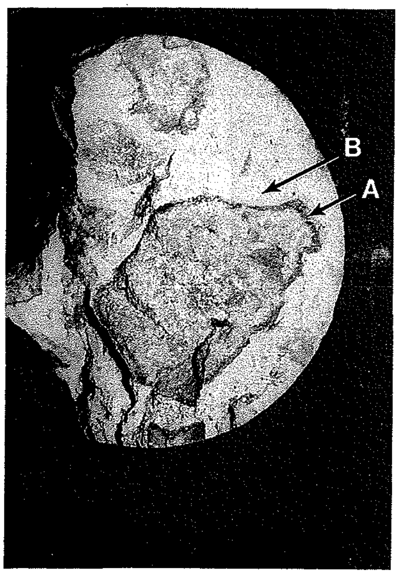

Figure 6. Fluorescence of top half of core shown in Figure 4; UV light

Figure 7. Fluorescence of specimen shown in Figure 5; UV light

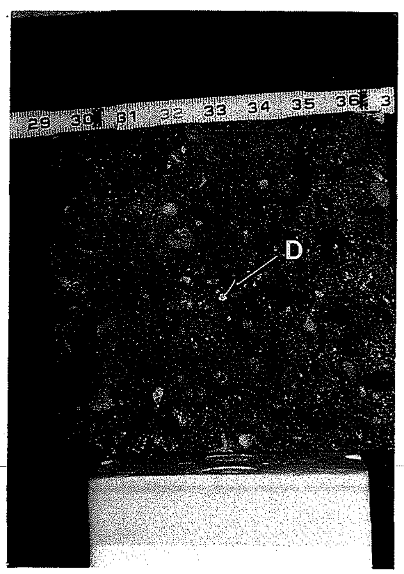

Figure 8. View of underside of concrete piece from top surface of parking garage floor slab

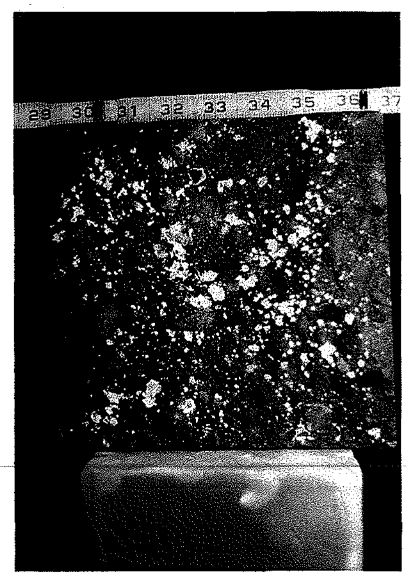

Figure 9. Fluorescence of concrete specimen shown in Figure 8; UV light