PRESENCE OF ALKALI-SILICA REACTIVE AGGREGATES IN KOREA

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ABSTRACT

Forty different aggregates commonly used in ready-mixed concrete plants in Korea were tested for their alkali-silica reactivity by petrographic examination, chemical method and mortar bar method, respectively. Test results indicate that several aggregates be alkali-silica reactive. And alkali-silica reaction(ASR) products are also confirmed to be present in the cement composites of these aggregates by scanning electron microscope (SEM) and electron dispersive spectroscope(EDS).

It is found from this investigation conducted in the area, where the seemingly reactive aggregates had been used in producing ready-mixed concrete that several structures seem to have been deteriorated by ASR, indicating the presence of alkali-silica reactive aggregates in Korea.

Keywords: alkali-silica reaction, alkali-aggregate reaction, field investigation

INTRODUCTION

In Korea, mass construction started in the late 1960's with the rapid economic development. Numerous concrete structures have been constructed during the past thirty years. The annual cement consumption in the 1990's exceeded 1,000kg per person. Nevertheless, the deterioration of concrete structures caused by alkali-aggregate reaction(AAR) has not been reported in Korea, because alkali content of cement is not high enough and crushed aggregates had not been used until 10 years ago.

The natural river aggregate was exhausted in the latter of the 1980's in Korea. And 200 million tons of aggregates had been consumed due to the rushed construction demand for housings and infra-structures, use of crushed aggregates was legally permitted. Therefore, the risk of AAR has been increasing in Korea due to the rapid increase in crushed aggregates consumption. Figure 1 shows a pattern of several aggregates consumption to be expected in Korea until 1998.

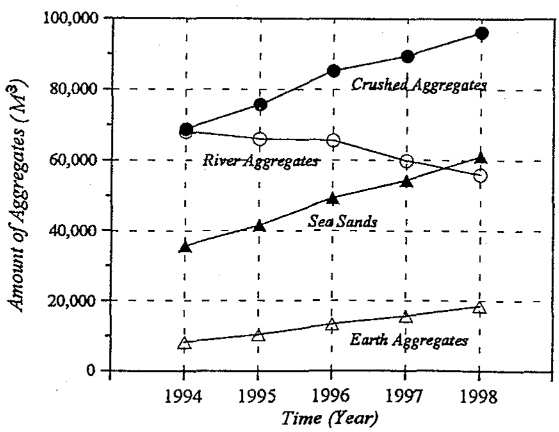

Fig. 1 Aggregates consumption in Korea

Forty samples of crushed stone being used at the ready-mixed concrete plants in Korea(*see Fig.* 2) were tested by petrological method using X-ray diffractometer (XRD), SEM and polarized light microscope, chemical method and mortar bar method to identify whether they are alkali-silica reactive or not.

From these results, several aggregates are found to be alkali-silica reactive. Cracks of concrete structures were discovered from investigation in the area where deleterious crushed stones were used as ready-mixed concrete aggregates.

Fig. 2 Location of sampling aggregates in Korea

EXPERIMENTS FOR ALKALI-SILICA REACTIVE AGGREGATES

Forty crushed aggregates in this study were used in the ready-mixed concrete plants in Korea. The location of sampling aggregates are shown in *Fig.* 2.

The petrological properties of aggregates were investigated by chemical analysis, x-ray diffractometer(XRD), and polarized light microscope. Then, alkali-silica reactivity of aggregates was tested by chemical method(ASTM C 289).

Mortar bar method(ASTM C 227) was performed with the aggregates identified as deleterious in chemical method.

SEM and EDS were used to observe the microstructure of expanded mortar bars.

Mortar bar tests were then performed with various types of alkalies, contents and alkali-silica reactive aggregates. Cement was replaced with pozzolanic materials to test the effects to reduce the mortar bar expansion.

Petrographic examination

From the results of chemical and XRD analyses(*see Fig.* 3a), the major ingredients are found to be quartz and feldspar, and the minor ones are muscovite, olivin, and etc. for the most part of aggregates.

However, several volcanic aggregates have alkali-silica reactive, high temperature phased cristobalite (*see Fig.* 3b). They may have some amorphous glass because of the low peak intensity of these aggregates.

Fineiy grained silica crystallines were observed by the polarized light microscope analysis in these volcanic aggregates (*see Photo* 1) that are identified as alkali- silica reactive aggregates in the future results of chemical method and mortar method.

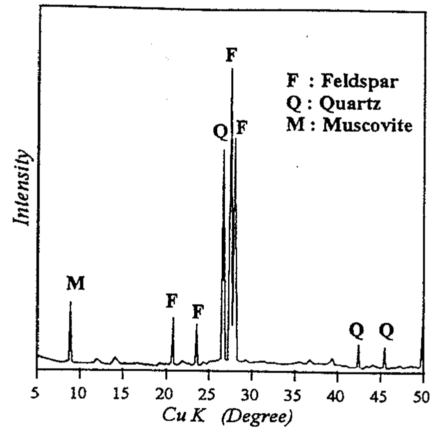

Fig. 3a XRD pattern of granite aggregate

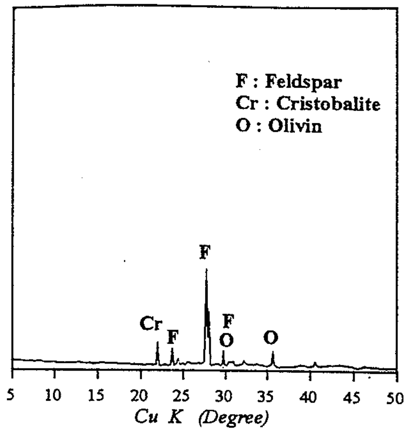

Fig. 3b XRD pattern of volcanic aggregate

Photo 1a Microscopic image at open nicol in thin slide of volcanic aggregate

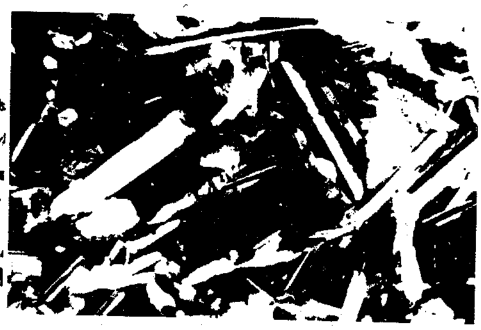

Photo 1b Microscopic image at crossed nicol in thin slide of volcanic aggregate

Chemical method

Crushed, washed and dried to 0.15~0.30mm aggregate particles were reacted with 1N NaOH solution at 80°C for 24hours to get the reduction in alkalinity and dissolved silica content as in ASTM C 289.

As shown in the *Fig.* 4, most part of aggregates is innocuous, however, several aggregates of Cheju island are deleterious, or potentially deleterious to be alkali-silica reactive.

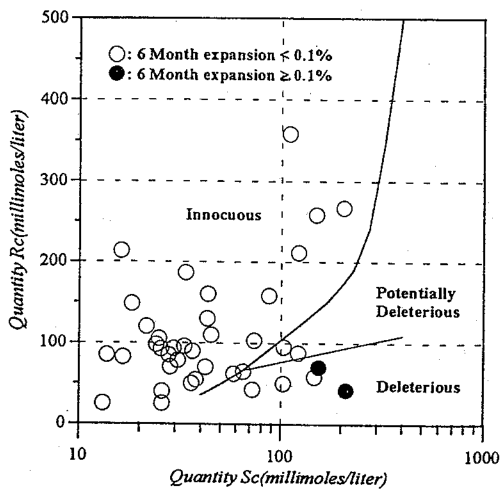

Fig. 4 Chemical method result

Mortar bar method

Mortar bar was molded at W/C 50%, and stored at 40°C, RH 95% according to ASTM C 227. Total alkali content of cement used in mortar bar method was controlled to 0.8%, 1.2%, 1.6%, 2.0% by adding NaOH, KOH, NaCl into cement with 0.72% alkali.

The result of mortar bar test was compared with chemical test in *Fig.* 5. Innocuous aggregates in mortar bar method were innocuous in chemical method. In some cases, deleterious in chemical method but innocuous in mortar bar method. The expansion of mortar bars with deleterious aggregates is over 0.1% in 6 months at 0.8% total alkali in cement. The more alkali content, the more expansion of mortar bar.

Fig. 6 shows the expansion of mortar bars adding NaOH, KOH and NaCl into cement. With equal alkali content, the mortar bar with NaCl added cement has large expansion than the mortar bar with NaOH or KOH added cement [1, 2].

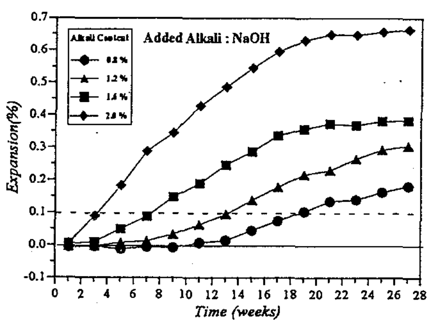

Fig. 5 Mortar bar expansions at various alkali content with a Cheju aggregate

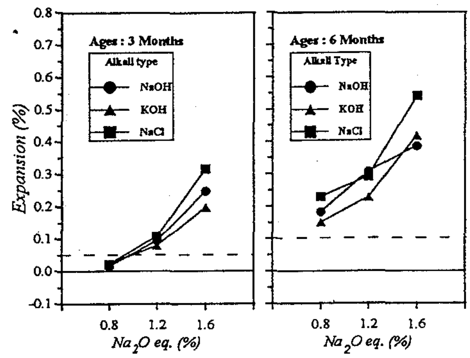

Fig. 6 Mortar bar expansions at various alkalies with a Cheju aggregate

Scanning Electron Microscopy

SEM and EDS were used to observe the microstructure of reaction products of a mortar bar expanded over 0.1% in 6 months. Photo 2a shows massive gel of primary reaction product and photo 2b shows spongy gel of secondary reaction product which is natrium and potassium rich silicates material in the dried mortar bar with alkali-silica reactive aggregate [3,4].

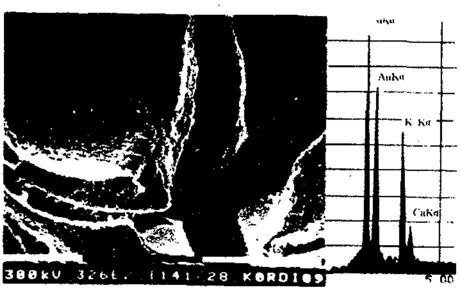

Photo 2a SEM and EDS of massive gel

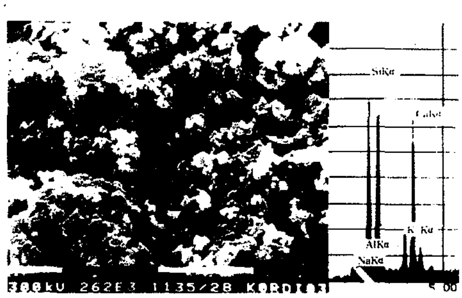

Photo 2b SEM and EDS of spongy gel

EFFECTS OF POZZOLANAS ON ASR

As shown in *Fig.* 7, the expansions of mortar bars with slag cement and fly-ash added cement were less than with type 1 portland cement at equal alkali contents. Therefore, slag cement and fly-ash added cement can prevent the damages by ASR in the case of using crushed stone in Cheju island.

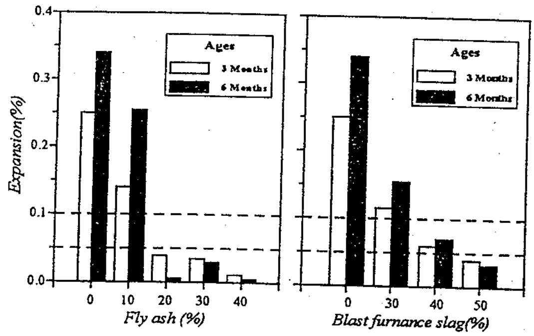

Fig. 7 Expansion of pozzolanas added mortar bar

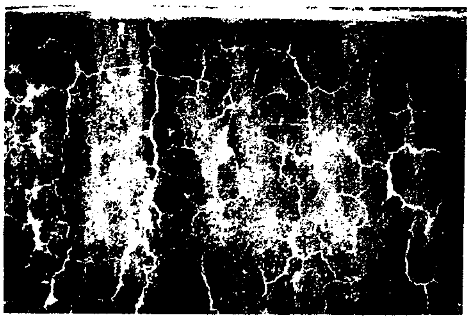

Photo 3a Damages of a concrete by AAR on the wall of a building in Cheju university

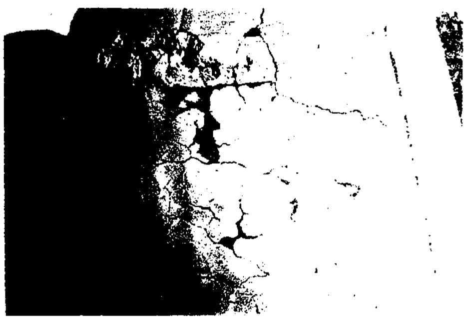

Photo 3b Damages of a concrete by AAR on tetraport in Cheju island

FIELD INVESTIGATION

Field investigation was performed on the concrete structures in Cheju island where alkali-silica reactive volcanic rocks have been used as aggregates for ready-mixed concrete. Crushed coarse aggregates are supplied by 10 makers being located in west, northwest, east and northeast in Cheju area. All fine aggregates are water-washed sea sand.

As shown in *Photo* 3, concrete cracks which is thought to be due to ASR were found in university buildings, hospitals, bridges, and offshore structures. There are not so old concrete structures enough for the occurrence by ASR in Cheju island. Because of the small amount of rainfall and the porous volcanic ground let the water flows under ground level, ASR in field concrete structures may proceed slowly.

However, only alkali-silica reactive aggregates and sea-sand are available as ready mixed concrete aggregates in Cheju island. Therefore, there can be more damages by ASR in the future.

CONCLUSION

There are numerous reports on the damage of concrete structures caused by using alkali-silica reactive aggregates in many parts of the world after the report of T. E. Stanton. However, the presence of alkali-silica reactive aggregates has not been yet reported in Korea.

Forty different aggregates commonly used in the ready-mixed concrete plants in Korea were tested for their alkali-silica reactivity by petrographic examination, chemical bar and mortar bar method, respectively. Test results indicate that several aggregates be alkali-silica reactive. ASR products were observed in the cement composites of these aggregates by using SEM and EDS.

Concrete structures in this area, where these seemingly reactive aggregates have been used in producing ready-mixed concrete, were thus investigated. It is found in this investigation that several structures seem to have been deteriorated by ASR, indicating the presence of alkali-silica reactive aggregates in Korea.

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