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

THE BACKGROUND OF AAR PREVENTIVE MEASURES ADOPTED BY THE JAPANESE MINISTRY OF CONSTRUCTION

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1. INTRODUCTION

Since around 1982 in Japan, many concrete structures in which alkali aggregate reaction (referred to as AAR) has been taking place have been found, and the Ministry of Construction issued a notification for AAR preventive measures in 1986[1]. It requests that the durable concrete structure has to be taken one of the following four methods.

1) To use only inocheous aggregate.

2) To use low-alkali cement.

3) To use pozzolan blended cement.

4) To limit the total amount of alkali (Na_2Oeq) in concrete to 3 kg/m^3 or less.

This paper describes briefly the experimental background for the proposed methods of 3) and 4).

2. PREVENTION BY GROUND GRANULATED BLASTFURNACE SLAG [2]

It is well known that ground granulated blastfurnace slag (referred to as ggbs) has a preventive effect against AAR reaction. However, no established view has been proposed about whether all kinds of ggbs in Japan have this preventive ability and at what mixture ratio ggbs is suitable for preventing AAR.

Therefore, we conducted a study to examine the AAR preventive ability of all kinds of Japanese ggbs (12 brands) by ASTM C441[3]. The results of the tests are shown in Figure 1. It indicates that the AAR preventive ability is uncertain for almost all of the tested ggbs, unless the slag content is 65% or more. However, we could not understand clearly the reason why the experimental results obtained with very sensitive and reactive pyrex glass have to be adopted.

Then we performed mortar bar tests using deleterious andesite aggregate, which is produced in Japan in large quantities, using different slag substitution ratios, slag brands, and amounts of alkali in base portland cement. The following results were obtained:

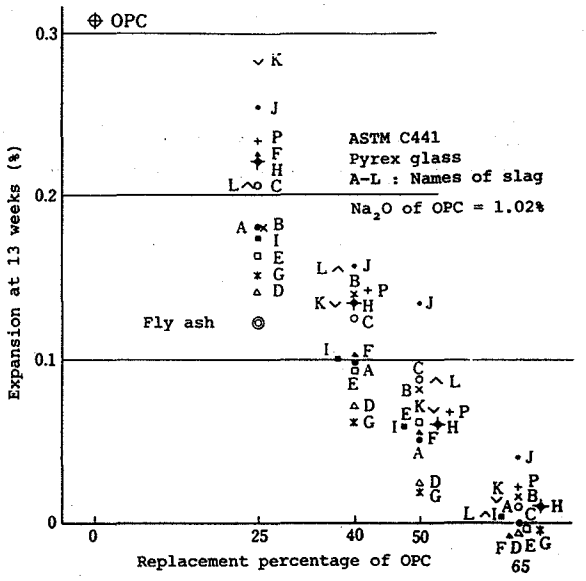

Figure 1 ASR Preventing Effects of ggbs [2]

1) When the base portland cement is replaced with 50% of ggbs, the expansion of the mortar bar is below 0.1%, even when the alkali content of the cement is approximately 2% and J-brand ggbs, which has the least preventive ability, is used.

2) When the alkali content in the cement is 1.2%, the expansion of the mortar bar is below 0.1%, even when the replacement ratio is 30% and the J-brand is used. Figure 2 shows a part of the experimental result.

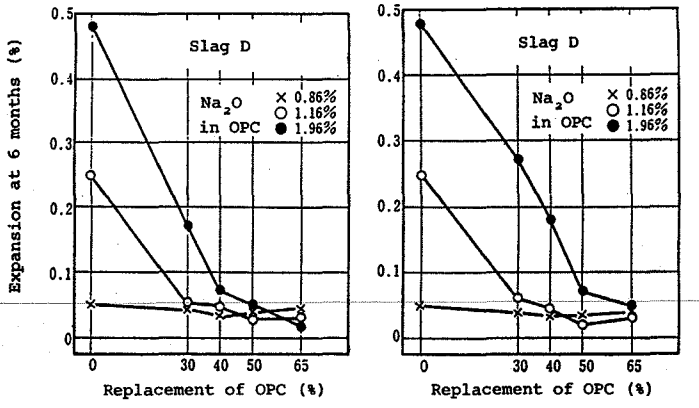

Figure 2 Examples of Percentage Replacement and Expansion of Mortar Bars with the Andesite Aggregate [2]

Based on these results, we concluded that AAR can be prevented sufficiently if blastfurnace slag cement containing more than 50% ggbs is used and if the alkali content in base portland cement is less than 0.8%, the required minimum ggbs content is decreased to 40%.

3. PREVENTION BY FLY-ASH [4],[5]

Some published papers say that pulverized fuel ash (referred to as pfa) has the ability to prevent AAR, while other papers doubt pfa's preventive ability. This is because some brands of pfa have a very high alkali content and some reports indicate that AAR took place even though pfa was used.

We conducted tests for mortar bars made from deleterious andesite aggregate produced in Japan and all types of pfa produced in the country. Figure 3 shows amounts of expansion after 6 months when the replacement ratio of pfa was 10, 20, or 30% with an alkali content of 1.2% in the cement.

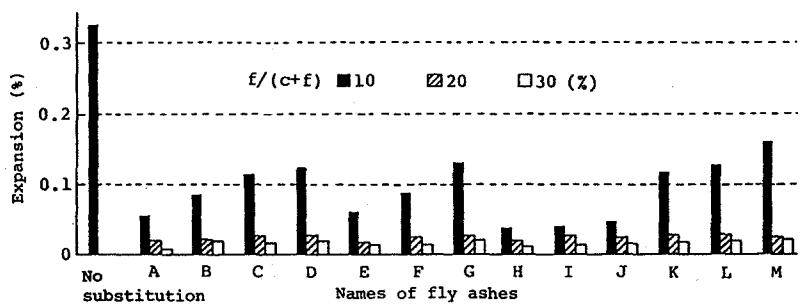

Fig. 2 f/(c+f) and Expansion of Fly Ashes (R_2O = 1.2%)

Figure 3 f/(c+f) and Expansion of Fly Ashes (R_2O = 1.2%) [4]

The Figure indicates that when mixed at 10% some brands of pfa have a higher expansion preventive ability. All types of pfa, when mixed at more than 20%, showed satisfactory preventive ability. We conducted a factor analysis for pfa components and the amount of expansion and found that Na^+ in pfa is a primary factor in mortar bar expansion, while SiO_2 is a factor in preventing expansion.

Based experimental results, we concluded that fly-ash cement can prevent the expansion caused by AAR, if the equation below is met:

$$\Sigma CA + 0.83\Sigma FA - 0.046\Sigma F \leq 4.2 \ (kg/m^3) \qquad (1)$$

where ΣCA, ΣFA: total alkali content in cement, in pfa, by Na_2Oeq
ΣF: total amount of pfa

Taking account of the fact that the maximum alkali content in pfa and portland cement are 4% and 1.2% at the most, we concluded that if fly-ash cement with a pfa content of more than 20% is used AAR can be prevented, and if the alkali content in the cement is less than 0.8%, the requested minimum pfa content is decreased to 15%.

4. PREVENTION BY LIMITING TOTAL ALKALI AMOUNT IN CONCRETE [6]

AAR prevention by controlling the total amount of alkali in concrete is a method which was proposed and has been used in the United Kingdom.

We conducted mortar bar and concrete prism tests in order to know whether there is any amount of alkali in which expansion does not take place even when a reactive aggregate is used.

Figure 4 shows the results of mortar bar tests in which the total amount of alkali varies.

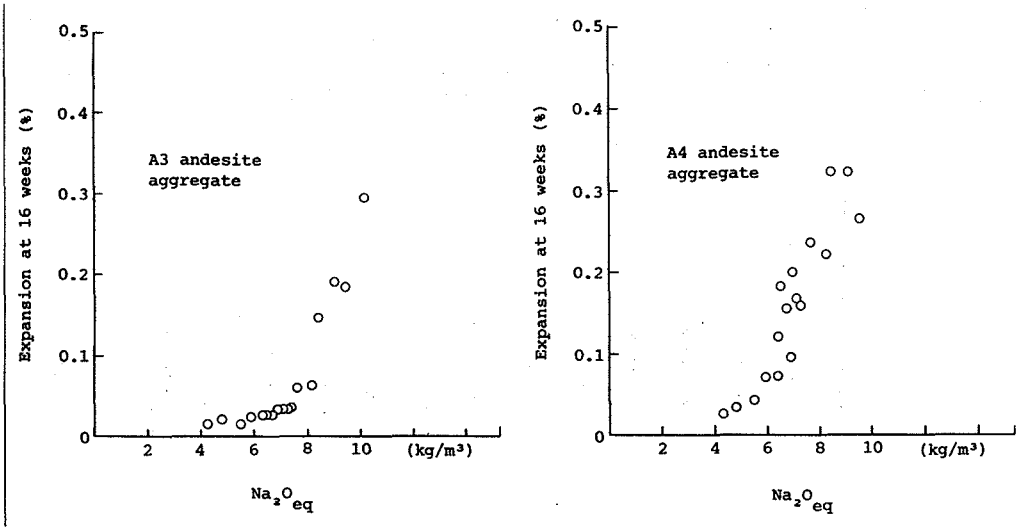

Figure 4 Expansion of Mortar Bar and Amount of Na_2Oeq [6]

Figure 5 shows the results of concrete prism tests. The specimens were made at different ratios of inactive aggregate to harmful aggregate in consideration of the affection of the pessimum, using only coarse aggregate as a reactive aggregate, and then cured at 40°C in moist conditions for 6 months.

In all the tests, expansion did not take place when the total amount of alkali in concrete or mortar was less than 3 kg/m³. Therefore, the authors concluded that AAR can be prevented when the total amount of alkali (Na_2Oeq) in concrete (including soluble Na^+ in the admixture and aggregate) is below 3 kg/m³. According to this theory, AAR takes place if the total amount of Na_2Oeq has increased even when low alkali cement is adopted. This was also proved in other experiments.

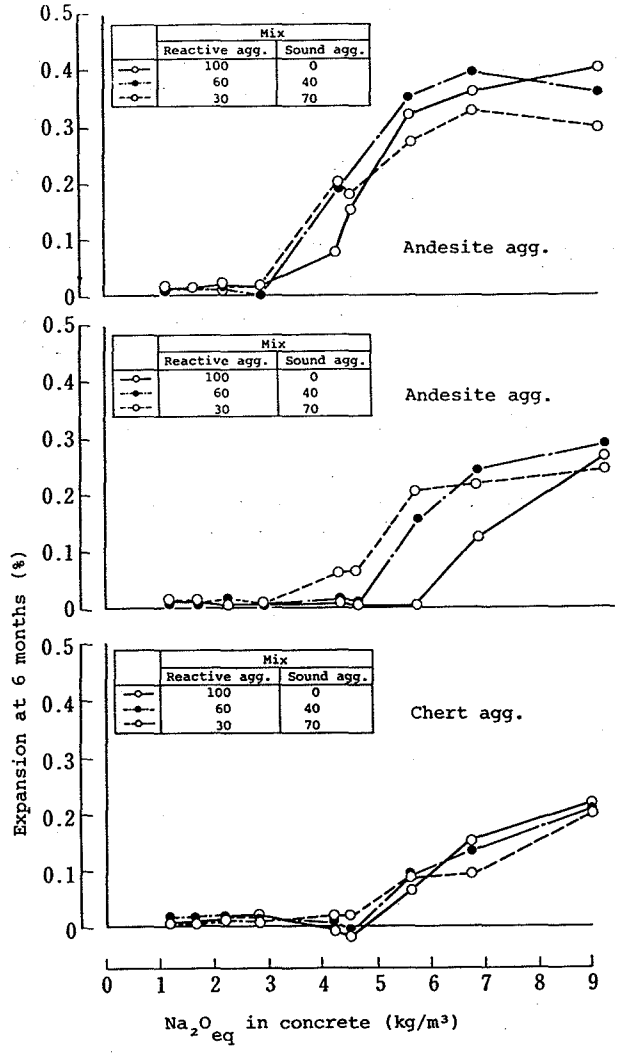

Figure 5 Expansion of Concrete Prism and Amount of Na_2Oeq in Concrete [6]

5. ACKNOWLEDGEMENT

This series of tests was performed as a joint research project by the Public Works Research Institute of the Ministry of Construction, the Japan Cement Association, the Japan Slag Association, and the Japan Fly-Ash Association. The authors deeply acknowledge Professor Kiyoshi Okada, Chairman of the Commitee for Improving the Durability of Concrete, and other members of the Committee for their learned advice.

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