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Comparative analysis of fly ash effect with three different method in mortars that are exposed to alkali silica reaction

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ABSTRACT

Many researchers agree that the ASR expansion values that are made on mineral and chemical additive concrete and mortar samples give more rational results.

In this study, the potential ASR reactivity of aggregates in Sakarya province is determined. The fly ash's effect, that is used as mineral additive in ASR, is determined in three different test method one in long term and the others in accelerated test methods.

As it can be seen when the fly ash's contribution that are used in each of the three test methods are used over 25%, we find out that they fall below ASR standard values.

Although the long term expansion results are observed below the 6 month standard values it is observed that the 12 month results agree with those results of accelerated mortar bar method.

In terms of autoclave method provides results as soon as possible the mixture of pure water samples has showed us that they have been in a good correlation on the basis of 12 month results and 28 day results.

1. Introduction

Damage due to alkali aggregate reaction in concrete starts with the chemical reactions between the alkali hydroxides that emerge as a result of reactive components of aggregate grains and cement hydration. There are 2 known formations of alkali aggregate reaction.

(1) Alkali-carbonate reaction (ACR).
(2) Alkali-silica reaction (ASR).

Different types of reactions may occur for each classes of these two reaction formations. But a negative impact may not occur in all of these reactions [1].

The most common of these two types of reactions is alkali-silica reaction (ASR) that is the result of alkali in cement, moisture and active silica in aggregate. The active silicas in aggregate are minerals contain of active silica such as rhyolite, opalit, and tridymite.

Alkali silica forms alkali silicate consistency of gel by reacting together with alkali and moisture. These compounds swell in the concrete and causes concrete cracks. ASR is a closed reaction that forms between hydroxyl (OH^-) ions in concrete pore water and some of the on-site concrete aggregate materials containing reactive silica reaction.

$$\begin{array}{llll} SiO_2 + 2NaOH + H_2O \Rightarrow & Na_2SiO_3 \cdot 2H_2O \\ \text{Silica} \quad \text{Alkali} \quad \text{Water} & \text{Alkali} - \text{Silika Gel} \end{array} \qquad (1)$$

In some cases, the swelling (expansion) in concrete reaches up to 2–3% by volume. Such as many other alkali aggregate reactions, ASR is also under the effect of many factors. Typically, ASR is a kind of reaction that emerges slowly as the other reactions and so the damage of the internal structure of concrete due to expansion becomes visible after a few years (Fig. 1).

Significant and visible impact of ASR, is the external crack formation. However, it has been revealed by petrographic investigations that some of the physical and micro structural properties of the concrete have also been affected by ASR. These effects come out as formation of reaction zones at surface of aggregate grains spaces filled with reaction products, cracks on aggregate grains and the loss of bond between the aggregate and cement paste [4].

Although it is sufficient for many applications, it is not guaranteed that cement that has low alkali can prevent the damage alone due to ASR and the probability alkali from aggregate is also not guaranteed. Cements that have 0.6% equivalent to Na_2O or cements that have less alkali are considered as low alkali cements. By using these kinds of cements and similar cements can prevent damage formation due to ASR in normal circumstances. Besides, the en-

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Fig. 1. Severe map cracking on the wing wall of 30 year old bridge structure affected by ASR [2], Highway Protection Barrier [3].

trance of external source alkali such as de-icing salt improves the damage formation due to ASR. These types of alkalis damage the hardened concrete through penetration from outside [5].

When the cement that we used is calculated with Na_2O equivalent ($Na_2O + 0.658\ K_2O$), Na_2O equivalent is found as 0.52. It can be understood from this result that the cement that we used is in the low alkali group [3].

The effect of ASR that causes damage in concrete structures is its expansion deformation. Therefore, the reaction rate and the total elongation expansion amount are the critical parameters of concrete structure. Both of these depend on the type volume and grain size of reactive aggregate and various factors mentioned before. Because of its size, location and exposure conditions in order to keep ASR's damage below harmful level the alkaline level may be kept at acceptable levels generally at 'Safe Level' less than 0.6% [5].

According to the standards of using ASTM C 618 fly ash and natural puzzolanas in concretes, they are divided into two by looking at the content of lime. When it is higher than 10%, it is C class, and it is F class, when it is less than 10%. Since the fly ash shows puzzolanic and binding properties, it is used in cement and concrete production. It also increases the workability of the fresh concrete and increases the strength of the hardened concrete at later ages.

It is identified that when the cement mass changes place with the fly ash at 20–30% rate for aggregates which show slow reactions, the expansion that may be occurred on the concrete due to ASR is reduced [6].

Ramyar ve Andiç, used two types of fly ash instead of cement at five different rates and three different fineness in order to identify the fly ash's usage rate and the fineness effect on ASR expansion. According to the results of the study, when both of the fly ash are used over 20% their expansions reduced below the limit value [7].

In parallel with these information the mortar bar method (ASTM C 227), accelerated mortar bar method (ASTM C 1260) and autoclave testing method are used on mortar types that are prepared with aggregates that are used in experimental studies in our region.

According to the results obtained from three different methods, it is observed that the experimental studies reduce ASR. The autoclave test method to be among new methods reveals the importance of our study in terms of proving the usability of the method.

2. Test methods of alkali silica reaction

There are two main possibilities to select the test procedures in aggregates. First, the test is made whether the aggregate that is used in the test contains potentially alkali silica or not. The second alternative is made to see ASR development by exposing the mortar samples to negative conditions and to see in which mix rates the expansion values are reduced.

Theoretically, the second approach can be preferred but these tests could lead to the development of cracks in the structure of mortars and creates a real danger because of late perception of aggregates that are expanding slower.

Many tests are now widely used which will give results in a few days or in a few weeks. Short delivery time and rapid test results are needed for many construction projects. Thus, the accelerated mortar bar test, that gives results in 16 days is used frequently because it is simple and gives satisfactory results.

The China autoclave test, though it is useful for research purposes is probably considered as an acceptance test for concrete aggregates because of its small sample size.

The satisfactory correlation between the accelerated mortar bar test results and the autoclave test method results that are developed on mortar bars by Nishibayashi, Tamura and Fournier, is the reason for gaining importance for the development of these methods.

Autoclave test, chemical test (ASTM C 289), accelerated mortar bar method and the ultra-accelerated concrete prism test have been developed in the last 15 years and considered in the evaluation.

3. Experimental study

3.1. Materials

3.1.1. Aggregate

The aggregate used in the experimental study was obtained from Sakarya River sand gravel quarry near the town of Geyve and in the range of 0–7 mm.

Primarily, active silica amount on aggregate was found with the method of chemical analysis method in accordance with ASTM C289, TS 2517 and it was found that it was in the harmful region (Table 1), [8,9].

3.1.2. Cement and the fly ash

CEM I 42.5 type cement and the fly ash chemical analysis values that used in the experimental study are given in Table 2.

Table 1
Chemical ASR report made in accordance with TS 2517.

Consumed NaOH	350 (mmol/L)
Solved SiO_2	700 (mmol/L)
Result	III. Zone (hazardous aggregate)