International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 2, Issue 2, February 2014)

Comparative Study of the Effect of using Different types of Portland Cement and other Additives on Alkali-Silica Reaction of Concrete Aggregates

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***Abstract*—Alkali silica reaction is potentially a very disruptive reaction within concrete in which silica reacts with alkalis to form a gel which expands and disrupts its mechanical properties. Dilution of alkalis by increasing silica content using Portland pozzolana cement or Portland slag cement or some mineral additives like flyash, micro silica, metakaolin etc. retards rate of Alkali silica reaction. The aim of the current study was to determine the effect of using Portland pozzolana cement, Portland slag cement, and different percentage of silica fume on Alkali silica reaction expansion. The outcome of the study is presented in this paper.**

***Keywords*— Accelerated Mortar Bar; Alkali-Aggregate Reactions; Portland Pozzolana Cement; Portland Slag Cement; Silica Fume; Gel; Expansion.**

I. INTRODUCTION

Alkali silica reaction (ASR), is potentially a very disruptive reaction within concrete. When silica reacts with alkalis a gel is produced within the aggregates. This gel absorbs pore water causing expansion which disrupts the mechanical properties of concrete. Presence of pore fluid, alkalis and ASR reactive aggregate in concrete will initiate such process of deterioration. It is observed that reactivity is greatest for a pessimum content of reactive aggregate. The ratio of reactive alkalis to reactive silica surface area is crucial in ASR. However, dilution of alkalis by increasing silica content by using Portland pozzolana cement (PPC) portland slag cement (PSC), silica fume (SF) retard the rate of ASR. The aim of the current study was to determine the effect of using PPC, PSC, different percentage of SF on ASR expansion.

II. REVIEW

Portland cement is the main source of the alkalis. Adding fly ash (IS 1489 Part 1, 1991) induces dilution of the alkalis which disrupts ASR. Ensuring sufficient surface area by varying the percentage (BS 3892 Part 1) and type of FA provides an efficient method to prevent ASR. Small quantities of fine FA ash with low-reactivity aggregates and sufficient alkalis may be more susceptible to ASR, if the pessimum silica alkali ratio is approached.

Even when total alkalis within the concrete are as high as 5 kg/m^3, FA has been found effective in preventing ASR (Alasali and Malhotra, 1991). The addition of fly ash reduces the pH of the pore solution to below 13 which prevents ASR. Researchers have categorized FA for usage for arresting ASR (Fournier and Malhotra, 1997). It is however suggested that to restrict ASR FA must comply with ASTM C618 (ACI *Manual of Concrete Practice*, 1994). Laboratory research [1] and field experience [2] supports that appropriate use of fly ash can prevent expansion due to ASR in concrete. FA from bituminous coal sources (ASTM Class F) which is characterized by relatively low calcium contents (i.e. <10% CaO) is most effective in controlling expansion instead of those obtained from sub-bituminous or lignite coals [3–4]. The inferior performance of FA with calcium contents in excess of 25% may be largely ascribed to the pore solution chemistry. Such FAs are not as effective in reducing the pore solution alkalinity of cement paste systems [5]. Greater proportions of the alkalis are available for ASR in these FAs [6].

III. MATERIALS & METHODOLOGY

A. Materials

1. Aggregates:

Coarse aggregate samples have been obtained from quarry in north eastern region of India (Figure 1). These have been reduced to crushed sand sizes.

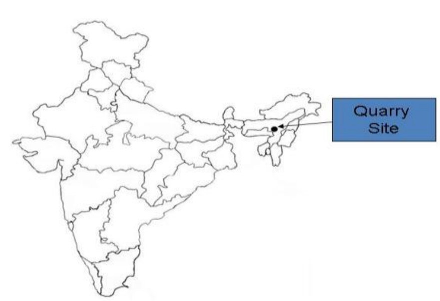

Fig 1: Location of Quarries

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2. Different type of Cements

Three different types of cements viz. Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) have been used with aggregate for studying ASR. Alkali Content and Water Cement Ratio of these cements are presented in Table 1.

Table 1: Alkali Content and Water Cement Ratio of the Cements used in the study

Type of Cement	Cement alkalis (Na_2O equivalent)	Water-Cement Ratio
OPC	0.63	0.50
PPC	0.86	0.50
PSC	0.77	0.50

3. Silica Fume

OPC blended with SF in fixed proportion have also been used to conduct the ASR observations.

B. Methodology

1. Accelerated Mortar-Bar Test (ASTM C 1260 and ASTM C 1567):

The accelerated mortar-bar (AMBT) test is quick, reliable and can characterize the potential reactivity of slow as well as fast reactive aggregates. Aggregates are crushed to sand sizes for mortar-bar expansion test. The mortar bars are stored in a 1N NaOH solution to provide an immediate source of sodium and hydroxyl ions to the bars. Temperature is maintained at 80°C to accelerate the ASR. Comparator readings are taken over a period of 14 and 28 days [7, 8]. The test conditions are more severe than most field service environments. Categorized the aggregate based on 14 days expansion observation in AMBT is presented in Table 2.

Table 2: Categorized the aggregate based on 14 days expansion

Average Expansion	Reactivity
Less than or equal to 0.10%	innocuous
Greater than 0.10% but Less than 0.20%	susceptible to reactive
Greater than 0.20 %	deleteriously

2. Tests Conducted

The study has been carried out using different cements and additives. The details of the test are presented in Table 3.

Table 3: Details of Various Tests

Test	Material Combination
1	Aggregate + OPC
2	Aggregate + OPC + 5% SF
3	Aggregate + OPC + 7% SF
4	Aggregate + OPC + 10% SF
5	Aggregate + PSC
6	Aggregate + PPC

IV. Discussion Of Result

The reactivity of these aggregate with different ingredients have been measured with the help of accelerated mortar bar test method. The observations are presented in fig. 2. Based on 14 days expansion the cement-aggregate combination is classified for various tests (Table 4).

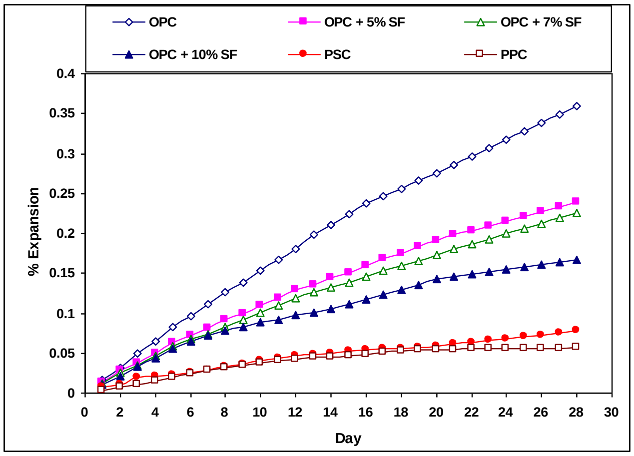

Fig. 2: Aggregate Reactivity using Different Cements and Ingredients

Table 4: Reactivity of cement-aggregate combination

Test	Material Combination	% expansion after 14 days	Classification
1	Aggregate + OPC	0.211	Deleterious
2	Aggregate + OPC + 5% SF	0.144	Susceptible
3	Aggregate + OPC + 7% SF	0.132	Susceptible
4	Aggregate + OPC + 10% SF	0.106	Susceptible
5	Aggregate + PSC	0.050	Innocuous
6	Aggregate + PPC	0.045	Innocuous

V. Conclusion

The OPC-aggregate combination is found to be deleterious. On addition of SF the reactivity reduced. The percentage expansion as observed after 14 days gradually reduced as % of SF was increased however the aggregate-OPC-SF combination showed susceptible behavior. With PSC and PPC the aggregates combination shows innocuous character.

Acknowledgement

The authors extend their sincere gratitude to Director CSMRS for being a constant source of inspiration. Sincere thanks are extended to all the authors whose publications provided us directional information from time to time.

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