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INFLUENCE OF FUSED SILICA AND CASTING DIRECTION ON ASR EXPANSION

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Abstract: Alkali-silica reaction is a prevalent type of deterioration in concrete infrastructure. In laboratory testing, prisms are cast horizontally and subsequently tested for expansion in the vertical direction (ASTM C1293). This may not adequately relate to actual cast-in-place concrete structures. In this research, prisms were cast in horizontal and vertical directions. Both axial and transverse expansions were measured. Spratt aggregate and fused silica were used to hasten reactions leading to clear monitoring for the influence of fused silica and casting direction. Results showed that the vertical casting was seen to increase the measured expansion by about 5-8% depending on the age of measurements. Moreover, the higher the fused silica, the higher the expansion regardless of the casting direction.

Keywords: Alkali-silica reaction, Expansion, Fused silica.

Introduction

Alkali-silica reaction (ASR) is defined as a chemical reaction between reactive silica and alkalis (Na_2O and K_2O) in concrete mixtures, that produces alkali-silica gel (ASG) that can absorb water and expands. As a result, inducing internal stresses causing cracks. (Nevillie 2002, and Mehta et al., 2006). The deterioration of concrete affected by Alkali-silica reaction (ASR) (i.e. expansion) has been evaluated in many studies following the standards that require measurements up to 2 years. Some studies have investigated materials to accelerate ASR as; opal, fused silica (FS), and quartz. These studies reveal the specimens incorporating 4.5% opal expanded more than specimens contains 15% FS (Gaskin 1955). In addition, 15% FS was evaluated by (Ahmed et al., 2003). A 7.5% FS replacement was used to trigger ASR in concrete columns (Abdullah 2012, Kubat et al., 2014, and Kubat et al. 2016). In addition, long-term monitoring is needed to determine concrete expansion using the prismatic specimens, but the expansion has been found to be affected by the casting direction (Smaoui et al., 2004). The defected concrete structures (i.e. columns) cast vertically and evaluated in the same cast direction, while the prisms cast in the horizontal direction and evaluated vertically. Moreover, studies conducted on evaluating the effect of specimens shape on ASR expansion exhibited that cylindrical specimen showed higher expansion than that of the prismatic specimens (Smaoui et al., 2004, Multon et al., 2005, Latifee et al., 2014, and Matthew Piersanti, 2015). For instance, the cylinder mold of Ø50mm×285mm showed an increase in expansion than prisms 50mm×50mm×285mm as exposed to a different degree of temperature (Latifee et al., 2014).

1 Experimental program

1.1 Materials Properties and mixtures

Six different mixtures were prepared using general use cement (GU) with 0.7% Na_2O_{eq}. Sodium hydroxide solution (NaOH) was prepared and added to meet requirements of ASTM C1260 "Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)". The concrete mixtures were prepared by using coarse reactive aggregate from the Spratt quarry, sieved prior mixing to meet the requirements of ASTM C1293" Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction". Mortar mixtures prepared using reactive fine aggregate meeting ASTM C1260 requirements. All mixtures contain fused silica (FS) of size fraction 10/20 and total silicon dioxide (SiO_2) 99.80.

Fused silica added to the mixtures as a replacement fine aggregate by weight at 6 different rates as follow; 0.0%, 5%, 7.5%, 10%, 15%, and 20%. Each concrete mixture included; six prisms 75×75×285mm, three cylinders Ø75×285mm, and three mortar bars 25×25×285mm to evaluate the expansion.

1.2 Exposure conditions and measurements

All concrete specimens were stored in an environmental chamber under 38 °C and 100% RH to meet ASTM C1260 requirements. The mortar bars were immersed in 1M NaOH solution and placed in an oven at 80°C satisfying the requirements of ASTM C1260. Expansion measurements were conducted on concrete and mortar specimens using a digital comparator of accuracy 0.002mm as represented in Fig. (1).

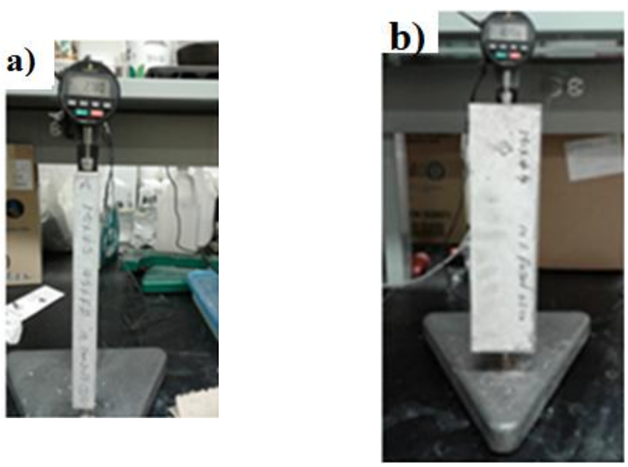


Figure (1) Expansion measurements
(a) Mortar bars, and (b) Concrete prisms

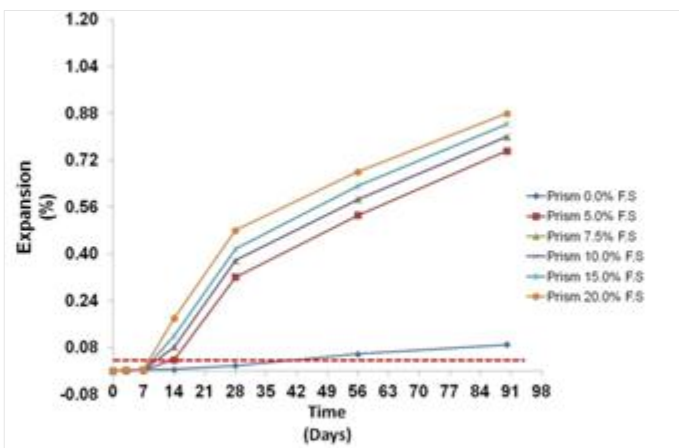
2 Preliminary results and discussion

2.1 Effect of fused silica

Expansion for all concrete specimens was measured according to ASTM C1293 and represented in **Fig. (2)**. Expansion for all mixtures containing reactive aggregate with and without FS increased with time. Mixtures containing FS showed an increase in expansion more than mixture incorporated reactive Spratt aggregate only. The expansion of prismatic specimens containing 7.5% and above of FS surpass the specification limit after two weeks only, while the mixture containing Spratt aggregate had an expansion greater than the specification limit after 56 days. For instance, the prismatic expansion at 56 days were 0.058, 0.532, 0.560, 0.586, 0.632, and 0.680 for mixtures contains 0.0%, 5%, 7.5%, 10%, 15%, and 20% FS, respectively. It is obvious; the expansion was influenced by the different portions of FS replaced in the concrete mixtures.

The increase in expansion at early ages resulting in an increase in the internal stresses produced, while the concrete tensile strength still low. As a result, the cracks developed quickly appear on the concrete surface.

Figure (3) represents the expansion of mortar bars mixtures measured following ASTM C1260. All mixtures exhibited a significant increase in expansion following the same trend as concrete expansion. However, mixtures containing FS showed an extreme increase in expansion more than mixture incorporated fine reactive Spratt aggregate only. Moreover, the effect of FS replacement in mortar mixture did not have the same trend in concrete mixtures, which indicates that the measurements should have continued for more than 14 days. The expansion of mortar bars with all FS portions exceed the specification limit after one day, while the mixture containing fine reactive Spratt aggregate had an expansion greater than the specification limit at the third day. For instant, The expansion of mortar bar were 0.330, 0.780, 0.691, 0.648, 0.722, and 0.728 for mixtures contains 0.0%, 5%, 7.5%, 10%, 15%, and 20% FS at the fifth day, respectively. Moreover, the expansion were 0.793, 1.126, 1.045, 1.073, 1.178, and 1.324 for the same mixtures at 14 days.



Figures (2) Expansion of concrete prism specimens contains Spratt aggregate and a different portion of fused silica FS

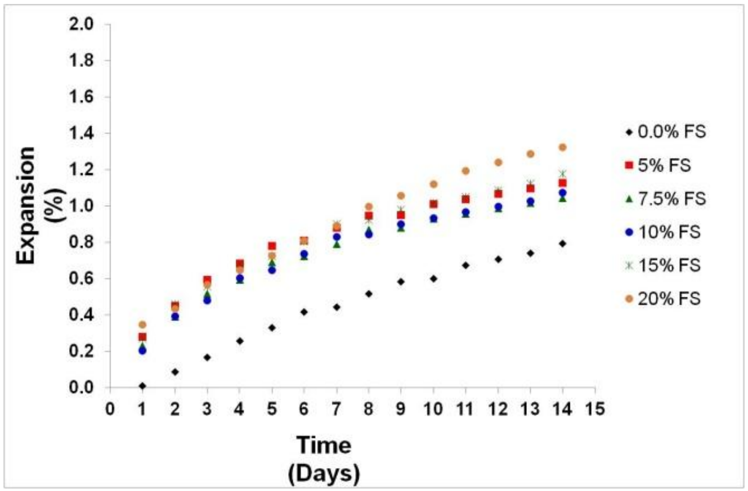


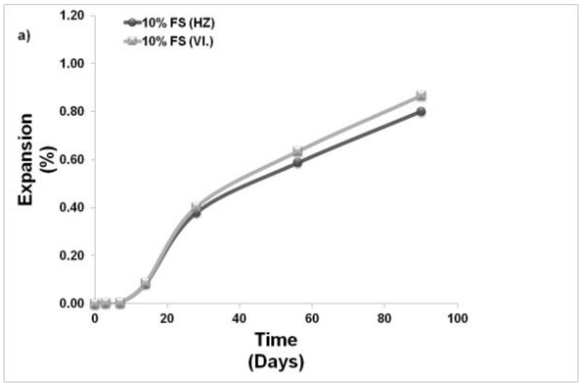
Figure (3) Expansion of mortar bars contains Spratt aggregate and a different portion of fused silica FS

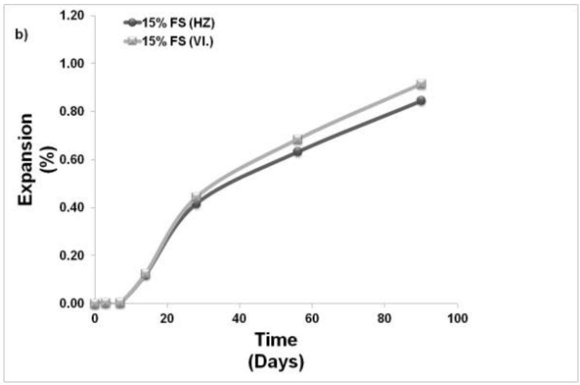
2.2 Effect of casting direction

The expansion was measured on prismatic specimens having the same dimensions to meet ASTM C1293 requirements. Expansion measured on prismatic casted vertically for all concrete mixtures containing reactive aggregate with and without FS showed an increase more than the prismatic casted in a horizontal direction by about 5-8% depending on the age of measurements.

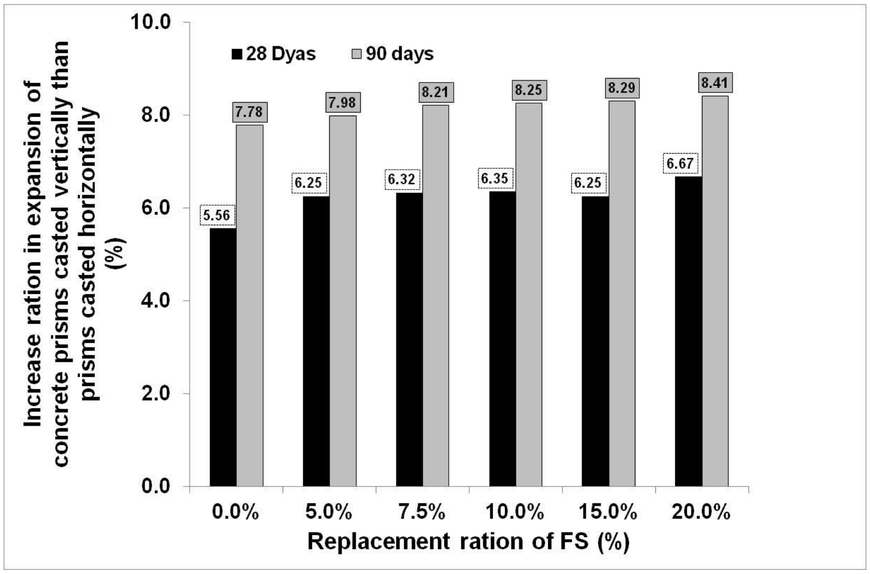
For an instant, **Fig.4 (a,b)** represented the expansion of mixtures contains 10% and 15%FS casted in both direction (i.e. vertical and horizontal). It is obvious that the prismatic casted in vertical direction had higher expansion than the prismatic casted in the horizontal direction.

Figure (5) represents the increased ratios in expansion occurred in vertical prisms than the horizontal prisms for all concrete mixtures (i.e. six mixtures) incorporating FS and reactive Spratt aggregate. The results exhibit, all concrete mixtures reveal the same trend of increased in expansion in vertical prismatic than the horizontal. For example, for a mixture incorporating 10% and 15% FS at 28 Days showed an increase in prismatic casted vertically by about 6.35% and 6.25%). This ratio increased to be 8.25% and 8.29% for the same mixtures at 90 days. Form the above; it is clear that the cast direction affected the measured expansion





Figures (4) Expansion of concrete prisms casted in vertical and horizontal directions
(a) 10% FS, (b) 15% FS



Figures (5) Increase ratios in the expansion of concrete prisms casted vertically than prisms casted horizontally

2.3 Effect of Shape

The expansion was measured on the standard prismatic specimens met ASTM C1293 (2018) requirements and cylindrical specimens prepared using plastic cylinder molds prepared for that purpose by Ø75mm×285mm as shown in **Fig. (6)**. For an instant, **Fig. (7)** represented the expansion of mixtures contains 15%FS casted in both molds (i.e. cylindrical and standard prismatic shapes). It is obvious that the cylindrical specimens showed a higher expansion than the prismatic specimens by about 12.3% at 90 days. In addition, all FS level of replacement showed a similar trend.

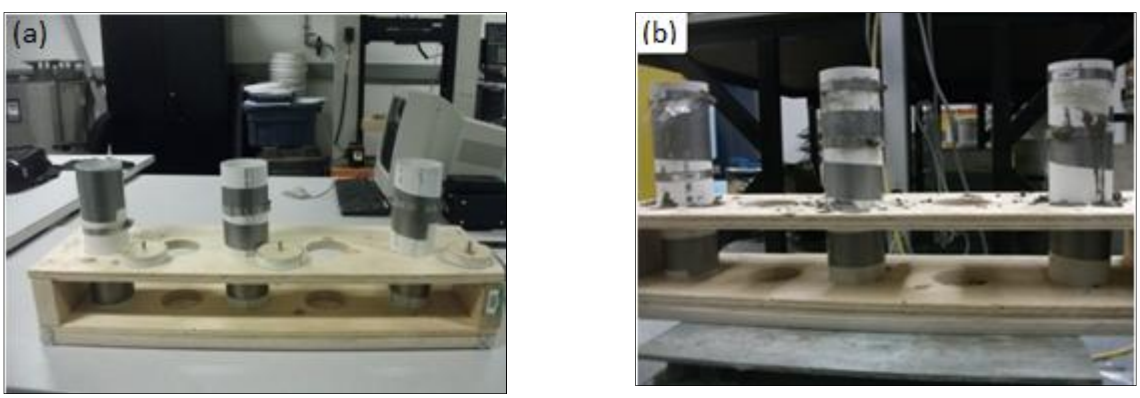


Figure (6) Preparation of concrete cylinder specimens (Ø75mm×285mm)
(a) Mold of cylinders Ø75mm×285mm, and (b) Mold after casting concrete

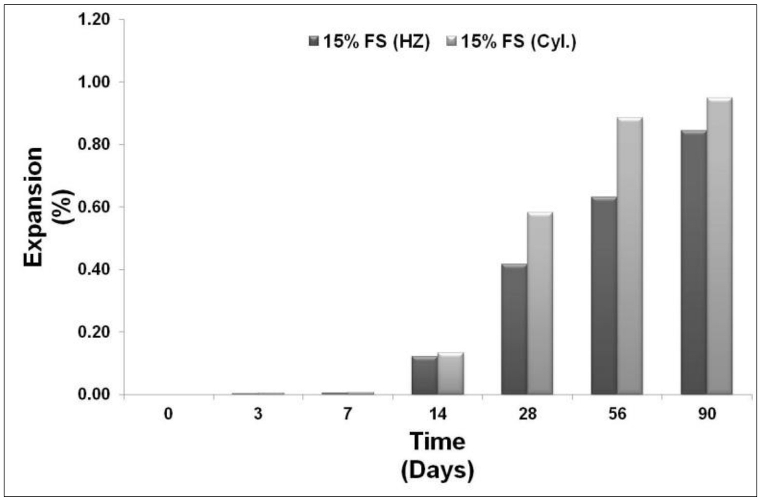


Figure (7) Expansion of concrete prism specimens incorporated 15%FS

3 CONCLUSION

Six concrete and mortar mixtures were cast and differentiate based on the %FS replacement to evaluate the effect of FS, specimens shape, and cast direction on the expansion.

1. FS caused a significant increase in expansion over time,
2. The optimum percentage of FS will differ from one type to another,
3. The expansion increased by about 5-8% for vertical cast specimens,
4. Cylindrical specimens expanded more than prismatic specimens.

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