Use of waste glass as an aggregate in GGBS based alkali activated mortar

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Abstract

This study incorporates fine waste glass (GS) as a replacement for natural sand (NS) in ground granulated blast furnace slag (GGBS) based alkali activated mortar (AAm). Tests were conducted on the AAm to determine the mechanical properties, apparent porosity and the durability based on its resistance to Na2SO4 5% and H2SO4 2% concentrated solutions. The study revealed that increasing GS up to 100 wt%, increased strength and decreased porosity. The lower porosity attained with the incorporation of GS, improved the resistance of mortar to Na2SO4 and thus increasing durability. However, the durability of mortar to H2SO4 solution was negatively impacted with the further reduction of porosity observed with increasing GS above 50 wt.% believed to be caused by the stress induced as a result of expansive reaction products created when the mortar reacted with acid.

Keywords : glass aggregate, GGBS, alkali activated mortar

1. Introduction

Owing to high amount of Ca in GGBS, the AAm produces Ca based hydration product which develops compact matrix resulting in increased strength. However the formation of Ca based hydration product makes the AAm susceptible to sulfate solution. The reaction mechanism of hydration products of mortar are significantly influenced by the type of aggregates. Therefore study explored incorporation of NS in GGBS based AAm.

2. Materials, Synthesis & Test Methods

GGBS (CaO= 55.85; SiO2= 31.17; Al2O3= 13.92) as a binder, NS and GS as an aggregate was used to produce AAm. The GS and NS with particle size in a range of 1-1.18 mm was used in this study. To produce AAm paste, the GS/NS ratio 0/100 (G-0), 20/80 (G-20), 40/60 (G-40), 50/50 (G-50), 75/25 (G-75) and 100/0 (G-100), GGBS/fine aggregate ratio 1:3, NaOH-4M, alkali to binder ratio of 0.4 and water to binder ratio of 0.3 was used in this study. The prepared paste was molded then sealed with plastic bags and cured for 24 hr in oven at 60 0C followed by 2 hr curing in indoor temperature. Samples were further cured for up to 28 days in room temperature. Compressive strength test was conducted in accordance to ASTM C109, porosity was measured as per ASTM C-20. Durability test of AAm against Na2SO4 5% concentrated solution (pH = 7 ± 0.5) and H2SO4 2% concentrated solution (pH = 2 ± 0.3) was setup in a controlled room temperature. Samples initially immersed in distilled water for 48 h dried for 2 h in the same environment were immersed in respective solution for 90 days. The mass of the samples immersed in both solutions for 0, 7, 14, 28, 56 and 90 day was measured after drying for 2 h. While the residual compressive strength of 0, 14, 28 and 90 days immersed samples was measured after drying the samples for 8 h. SEM-EDS was performed using FIB-SEM, model LYRA3 XMU on Pt. coated samples.

3. Results & Discussion

Compressive strength developed by GGBS in Figure 1(A) increased with increasing curing time and with increasing GS. Mortar containing 100 wt.% GS achieved highest strength suggesting the increased reactivity of GGBS with increasing GS in a mortar producing the strong binder aggregate bond forming the matrix homogeneous and compact by reducing porosity in a matrix (Figure 1(B)). SEM showing more compact matrix for sample containing

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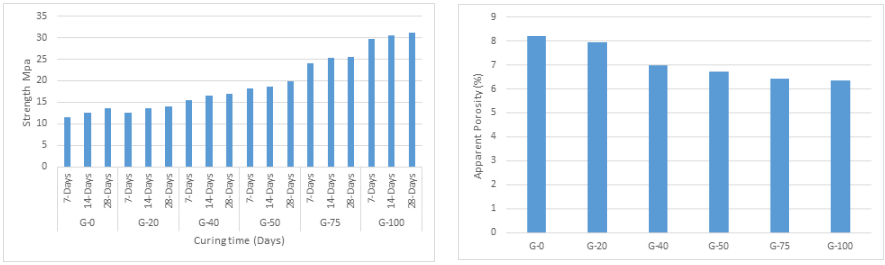
100% GS (G-100), while EDS spectrum showing more leaching of Ca suggesting improved reactivity of GGBS while the increasing peak of Si suggesting the dissolution of GS (Figure 2). On exposure to H2SO4 Figure 3 (A), the samples G-0 to G-50 after 7 days of immersion gained mass which then reduced with increasing immersion period to 90. While the samples G-40 to G-100 showed increased strength indicating improved resistance. With increasing GS to 75 and 100 wt.% the mass gain after 7 days of immersion was reduced significantly and samples continued to gain mass for up to 56 days and continued strength gain for sample G-100 was observed up to 28 days. After 90 days of immersion, mass and strength was dropped for G-100. The mass gain in this sample is associated to the formation of soluble salt caused by acid base reaction and the mass loss is associated to the cracking of sample observed visually and is a result of induced stresses from the expansion of insoluble salt. Samples exposed to Na2SO4 showing gain in mass Figure 3(C), which reduced with increasing GS in samples from 0 to 100 wt.% indicating improved resistance. The residual compressive strength Figure 3(D), was observed to be improved for samples G-0, G-20, G-40 and G-50 with increasing immersion time to 28 days and for sample G-75 and G-100 with increasing immersion time to 90 days. The mechanical strength resistance observed is related to the GS, which reduced the porosity of sample allowing the sample to resist the penetration of aggressive ions from sodium sulfate.



(A) (B)

Figure 1. Compressive & flexural strength (A) and apparent porosity (B)

4. Conclusion

It is concluded that GS compared to NS improved the mechanical performance and microstructure of GGBS based AAm. AAms, formed expansive products as the matrix was rich in Ca. Increasing GS up to 50 wt% improves it resistance to acidic environment as the sample was porous enough to allow the reaction products to expand. Whereas increasing GS above 50 wt% produced samples more compact providing limited space for the expansive products, which induced stress resulting in the formation of cracks and strength loss. As anticipated, the resistance of mortars against sodium sulfate highly depends on the sample porosity as GS showed the greatest resistance to sulfate attack.

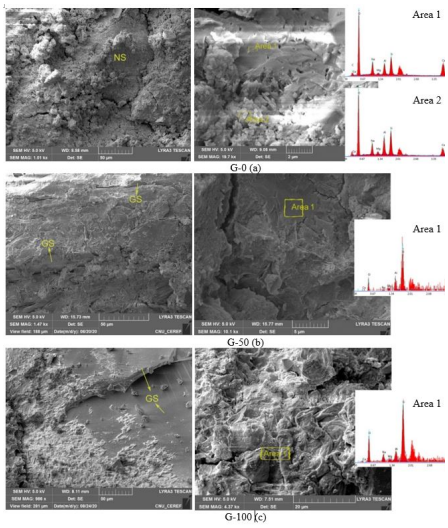
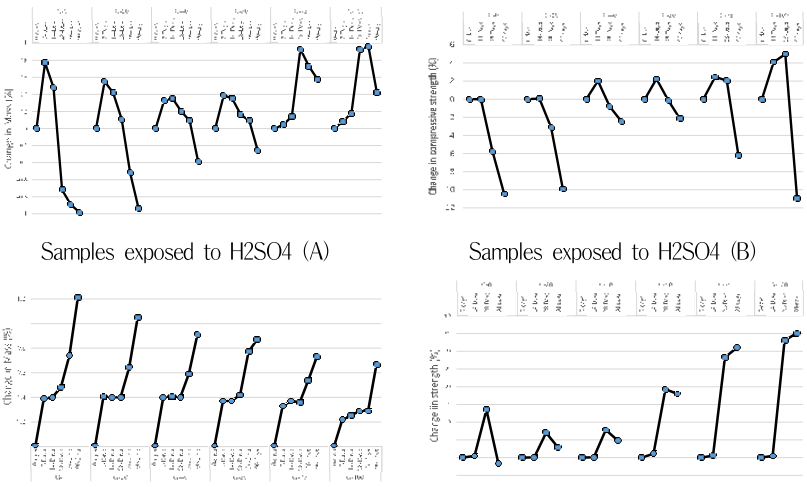


Figure 2. SEM-EDS



Samples exposed to H2SO4 (A) Samples exposed to H2SO4 (B)

Samples exposed to Na2SO4 (C) Samples exposed to Na2SO4 (D)

Figure 3. Durability test results

Acknowledgment

This work was supported by Korea Environmental Industry and Technology Institute (KEITI) and funded by the Ministry of Environment (No. 20190027500031).