Waste Glass as an Activator in Class-C fly Ash/GGBS based Alkali Activated Material

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Abstract

An alkaline activator was synthesized by dissolving waste glass powder (WGP) in NaOH-4M solution to explore its effects on the Class-C fly ash (FA) and ground granulated blast furnace slag (GGBS) based alkali-activated material (AAM). The compressive strength and porosity were measured, and (SEM-EDX) were used to study the hydration mechanism and microstructure. Results indicated that the composition of alkali solutions was significant in enhancing the properties of the obtained AAM. As the amount of dissolved WGP increased in alkaline solution, the silicon concentration increased, causing the accelerated reactivity of FA/GGBS to develop Ca-based hydrate gel as the main reaction product in the system, thereby increasing the strength. Further increase in WGP dissolution led to strength loss, which were believed to be due to the excessive water demand of FA/GGBS composites to achieve optimum mixing consistency. Increasing the GGBS proportion in a composite also appeared to improve the strength which contributed to develop C-S-H-type hydration.

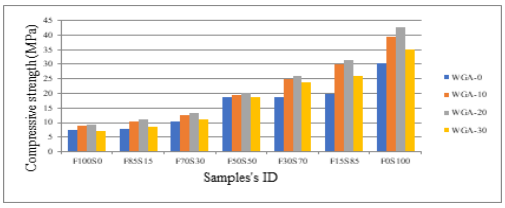
Keywords : soda-lime glass powder, GGBS, geopolymer

1. Introduction

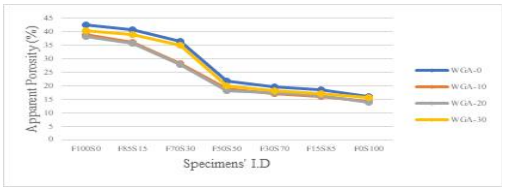
Use of amorphous soda-lime glass as a source of Si is one of the sustainable approaches. This glass, with a chemical composition of SiO_2 (65-75 wt.%) and Na2O (12-15 wt.%), is available as a waste and a potential source of Si. Glass rich in alkalis can be used in conjunction with NaOH instead of sodium silicate to produce an alkali activator with moderate environmental impact due to greenhouse gas emission and energy consumption.

2. Materials, Geopolymer Synthesis & Test Methods

In this study, High calcium Class-C fly ash (FA), and ground granulated blast furnace slag (GGBS) were used as precursor materials. For synthesizing the waste glass-based alkaline solution (WGA), 0g, 10g, 20g and 30g soda-lime waste glass powder (WGP) of particle size below 75 μm was dissolve in 100 ml NaOH-4M solution using hot plate stirrer for 4hr at 60 0C. The Si content in prepared solution was analyzed using ICP technique. The FA & GGBS, was mixed for 10minutes in a dry form in the following FA/GGBS ratio; 100/0, 85/15, 70/30, 50/50, 30/70, 15/85 0/100 with given ID; F100S0, F85S15, F70S30, F50S50, F30S70, F15S85, F0S100 respectively. Prepared WGA Alkali solution was poured in a mix at constant L/S ratio of 0.4 with the additional water (see sec 3.2). Prepared pastes were poured and compacted in a molds then sealed with plastic wraps and left for 2hours in indoor temperature. It was then unsealed and unmolded after curing it for 24hours in oven at 600C, then further cured for 28days in room temperature. Compression test was conducted in accordance to ASTM C109. Archimedes principle as per ASTM C-20 was used to determine apparent porosity. SEM-EDS was performed using FIB-SEM, model LYRA3 XMU on Pt. coated samples.



(A)



(B)

figure 1. Compressive strength test result (A) and apparent porosity test result (B)

3. Results & Discussion

3.1 ICP (Inductive Coupled Plasma)

From ICP analyses, it was observed that the leaching of Si from glass was increased with increasing glass content from

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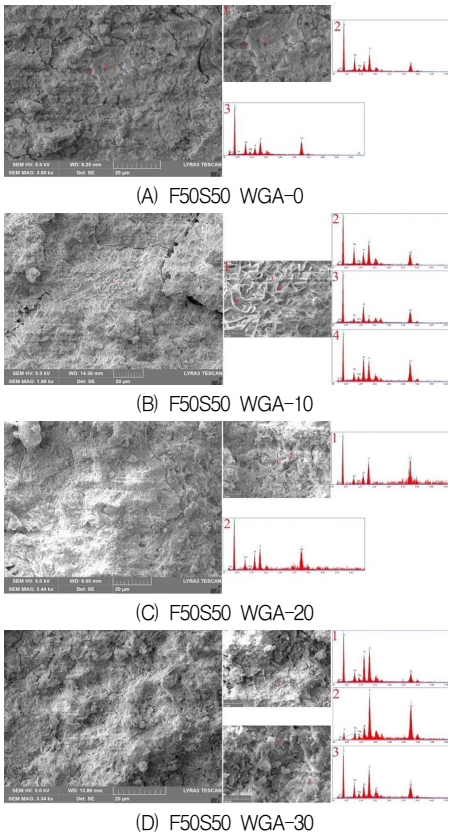
10g (3508 ppm) to 30g (8752ppm) in 100mL NaOH-4M solution. which promotes the leaching of elements from precursor materials, i.e., FA and GGBS, leading to more gel formation and improved strength.

3.2 Additional water

To obtain the same mixing consistency, water was added to the blend of FA/GGBS and alkaline solution according to the demand of each paste. Each FA/GGBS composite demanded more water with the increasing WGP content in NaOH solution. This can be attributed to the viscosity of the solution, which was observed to increase as the glass content added to NaOH was increased. Additionally the water demand of FA/GGBS composite in each batch increased with increasing GGBS indicating the high reactivity of GGBS used in this study.

3.3 Compressive strength & apparent porosity

From the graph (figure 1-A), it can be clearly seen that, With increasing glass powder from 0 to 20g/100mL NaOH the compressive strength increased is believed to be due to the increase of Si in the solution, which promotes the leaching of elements from precursor materials, i.e., FA and GGBS, leading to more gel formation and improved strength. The decrease in strength on activation with WGA-30 solution is believed to be due to the formation of porous gel resulting from the increased water demand during mixing as the viscosity was increased with increased concentration of Si. Additionaly, the GGBS is far more reactive than the FA for all alkali solutions trialed. The greater reactivity and associated composition of the GGBS resulted in improved strength compared to FA. The results revealed in figure1-B supports the compressive strength result, suggesting the matrix with increasing glass powder in WGA leads to the reduced porosity, Similarly, the reduced porosity can be observed for the matrix containing high GGBS content.



(A) F50S50 WGA-0

(B) F50S50 WGA-10

(C) F50S50 WGA-20

(D) F50S50 WGA-30

figure 2. SEM Micrographs and EDS Spectra

3.4 SEM-EDS analyses

SEM micrographs of samples F50S50 (Figure 2) showing the matrix becomes denser as the amount of GP was increased in NaOH solution. Additionally, EDS analyses showed the high leaching of elements from the precursors with increasing WGP content i.e. from 0 g-30 g in NaOH solution forming more Ca and Si based hydration products making the matrix denser and homogeneous. However, the microstructure of sample WGA-30 F50S50 in Figure 2D compared to WGA-20 F50S50 in Figure 2C appears coarser indicating the formation of loose matrix due to excessive water in the system resulting in lower compressive strength and high porosity.

4. Conclusion

It was revealed that, as the quantity of WGP in the NaOH solution increased, the Si concentration increased, which significantly enhanced the reactivity of the FA and GGBS precursor materials. When the FA/GGBS composites were synthesized using WGA-10 and WGA-20 solutions, the presence of soluble silica in the solution along with adequate water supplied to the system, accelerated the geopolymerization resulting in increased strength and decreased porosity. Further increase in Si in the NaOH solution i.e. WGA-30, corresponded to an even higher water demand, which led to the development of a more porous microstructure. Owing to its amorphous nature, the GGBS was found to be superior to FA for improving the strength and reducing the porosity of the matrix. The presence of reactive Ca supplied from GGBS along with the alkaline solution containing dissolved silica, a homogeneous and compact matrix was developed with low porosity and high mechanical strength.

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