Strength & Microstructure of Class-C fly Ash Activated in Waste Glass Based Alkaline Solution

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Abstract

The soda lime waste glass powder was dissolved in NaOH-4M solution to synthesize an alkaline activator, which was used to activate Class-C fly ash (FA). Compressive and flexural strength tests were conducted to determine the mechanical properties. Archimedes' principle was applied to measure the porosity of samples, (SEM-EDX) and XRD was used to study the microstructure and phase changes of samples. Through Inductive Coupled Plazma technique, the solution was found to increase the concentration of Si as the amount of dissolved glass powder was increased. Owing to the increased concentration of Si in an alkaline solution, the reactivity of FA was accelerated resulting in an increased strength and reduced porosity. Additionally, the dissolution of FA was improved as well as the formation of amorphous phases in the matrix was also enhances with the concentration of increased Si in an alkaline solution.

Keywords : Soda-lime Glass powder, fly ash

1. Introduction

To activate FA, the combined use of Na2SiO3 and NaOH (in a certain ratio) is common to manufacture geo-polymer-type binders, as the incorporation of Na2SiO3, in NaOH solution, shows promising results in improving its mechanical properties of compared to NaOH-activated FA1). However, the use of Na2SiO3 together with NaOH for the synthesis of geopolymer increases the embodied energy, therefore, the alternative alkaline solutions need to be identified to have lower environmental impact. The soda-lime glass being rich in amorphous Si can be used to produce an alkali activator which can impose lower environmental impact.

2. Materials, Geopolymer Synthesis & Test Methods

The FA used is class-C as per ASTM C618-19, to synthesize alkaline solution, the soda lime glass of particle size below 75 μm was weighed 0 g, 10 g, 20 g and 30 g then stirred in 100 ml NaOH-4M solution using hot plate stirrer for 4 hr at 60 0C. The solution was then filtered and used as an alkaline activator. FA was activated in a prepared alkaline solutions at constant liquid to solid ratio of 0.4, and the additional water was added (water to mix ratio). With increasing glass powder in NaOH solution from 0 g to 30 g, the demand of water by each paste was increased from 0.075 to 0.113 to maintain the same consistency. 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 unmold then further cured for 28 days in room temperature. Compression and flexural strength test was conducted in accordance to ASTM C109 and ASTM C348-18 respectively. Archimedes principle as per ASTM C-20 was used to determine apparent porosity. XRD patterns were obtained using an X-ray Diffractometer (D/Max-2200 Ultima/PC), over the 2θ range 5° - 100° & SEM-EDS was performed using FIB-SEM, model LYRA3 XMU on Pt. coated samples.

3. Results & Discussion

3.1 ICP (Inductive Coupled Plasma)

The concentration of Si in a solution increased from 3508 to 8752 ppm as the amount of glass powder was increased from 10 to 30g in 100mL NaOH-4M solution.

3.2 Compressive & flexural strengths

The compressive and flexural strengths developed by FA in Figure 1(A) showing the increased trend as glass powder was increased from 0-20 g/100 ml NaOH solution. This is associated with the increase of Si in a solution, promoting

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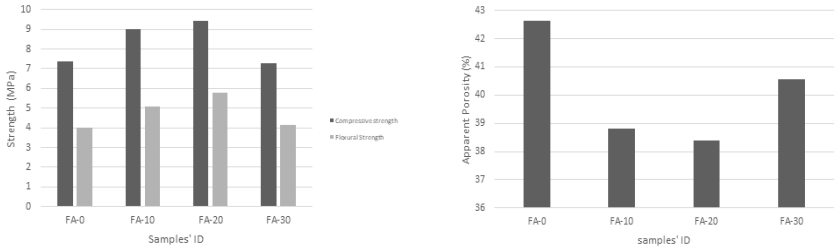
maximum leaching of elements from FA leading to more gel formation and improved strength. The strength was reduced when FA activated by solution containing glass 30 g/100 NaOH solution, which is believed to be due to the formation of porous gel resulting from the increased Si and increased water demand during mixing as the solution becomes viscous with the dissolution of 30 g glass in 100 ml NaOH solution.

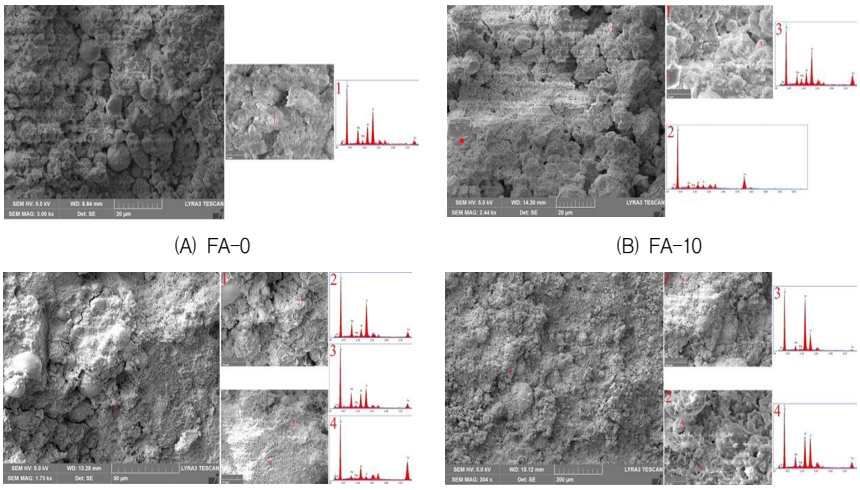
3.3 Apparent porosity

The apparent porosity of alkali activated FA Figure 1(B) showing the decreasing porosity with increasing glass dissolution from 0-20 g in 100 ml NaOH solution. Increasing the glass dissolution to 30 g/100 ml solution, the porosity of the sample was increased.



(A) (B)

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



(A) FA-0 (B) FA-10

(C) FA-20 (D) FA-30

Figure. 2. SEM Micrographs and EDS Spectra

3.4 SEM-EDS and XRD analyses

The micrograph of sample FA-0 shown in Figure 2(A) appeared less dense with maximum undissolved FA particles surrounded by the heterogeneous gel exhibits the lowest strength. While the EDX spectrum showing formation of N-A-S-H type reaction product. When the sample was FA-10 (Figure 2(B)) the amount of gel increased, suggesting increased dissolution of FA. Increased Si and formation of Ca-substituted N-A-S-H suggesting increased dissolution of FA. The matrix FA-20 (Figure 2(C)) appears to have a greater amount and denser gel than observed in FA-0 & FA-10 samples, filling the spaces between undissolved FA particles. The Si rich N-A-S-H gel, and increased Al and Ca rich C-A-H type gel can be observed in FA-20 samples. The sample FA-30 (Figure 2(D)) shows the porous matrix forming maximum amount of gel but disintegrated thus weakening the matrix. The porous gel is mainly composed of Al as high Al peak indicating the formation of Al rich zeolites responsible for reduced strength. Additionally, Si and Al rich N-A-S-H gel is also observed.

4. Conclusion

It is concluded that the presence of soluble Si in the solution Improved the reactivity of Fly ash resulting in increased strength and decreased porosity. Further increase of Si in the solution corresponded to the high water demand, due to which, the porous microstructure was developed responsible for strength loss.

Acknowledgment

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Reference

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