

Geopolymer composite binders of soda-lime glass (GP) & Ground Granulated Blast Furnance Slag (GGBS): The strength & microstructure

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Abstract

This study investigated the possibility of strength development by incorporating the slightly coarser soda-lime glass powder (GP) with 0–100 wt.% of Ground Granulated Blast Furnance Slag (GGBS) to synthesis GGBS based geopolymer. Compressive strength, water absorption & apparent porosity, were experimentally determined. To determine the homogeneity of mix, the microstructure & elemental composition of samples were studied using SEM-EDS. Study reveals the improvement in strength and reduction in porosity for the samples containing up to 30% GP. Furthermore, the microstructure analyses confirmed the development of denser and compact structure with the incorporation of glass powder up to 30%.

Keywords : Soda-lime Glass powder, GGBS, geopolymer

1. Introduction

Nowadays, achieving the sustainability is one of the crucial challenge in a construction sectors. Thus to reduce the use of portland cement which is not environmentally viable, the research on waste materials is in trend. Soda lime Glass is one of the urban waste material, globally, 2.01 million tons of solid waste is generated annually and glass contribute 5% of the total waste¹⁾. This material have shown the immense gain by the construction industry as it contains the specification of pozzolanic material such as high silica content²⁾³⁾⁴⁾. Whereas GGBS is an industrial by product waste and is widely used as construction material as it is rich in calcium content. Geopolymer is an alternate of PC as it utilize the waste products and the work in this research is at initial stage aiming to recycle slightly coarser GP in a GGBS based geopolymer cement.

2. Materials, Geopolymer Synthesis & Test Methods

In this Study the GGBS (Calcium rich) and GP (Silica rich) is used as a solid material (S) to compensate the chemical composition (refer Table 1 for element composition of both material). Particle size of GP is in a range of 150 μm to 75 μm and 80% GGBS particles are below 75 μm . For alkali solution; (Al) NaOH (4M) 24 hours old mixed with Na_2SiO_3 solution at 1.5 $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio to avoid excessive silicates in mixture⁵⁾⁶⁾. To activate the solid materials the GP & GGBS was mixed for 10 minutes in a dry form in the following GGBS/GP ratio; 100/0, 85/15, 70/30, 50/50, 0/100 with given ID; S100G0, S85G15, S70G30, S50G50, S0G100 respectively. Alkali solution was poured in a mix at constant Al/S ratio of 0.4 with the additional water. The pastes containing GP was mixed for 4 Hours to let the silica dissolve from GP. Prepared pastes were poured and compacted in a molds to cast 50 mm³ samples then sealed with plastic wraps and left for 2 hours in indoor temperature. It was then unsealed and unmolded after curing it for 24 hours in oven at 60 °C, then further cured for 28 days in lab condition. Compression test was conducted in accordance to ASTM C109. Archimedes principle as per ASTM C-20 was used to determine apparent porosity and water absorption. SEM-EDS was performed using FIB-SEM, model LYRA3 XMU on Pt. coated samples.

Table 1. Element composition of solid materials

S	Element By Weight percentage (%)									
	O	Fe	Na	AL	Si	Au	K	Ca	S	Cl
GGBS	35.43	0.51	0.47	7.37	14.57	1.38	0.35	39.92	-	-
GP	41.7	0.68	11.6	1.53	32.11	2.26	0.93	0.60	0.23	0.36

3. Results & Discussion

3.1 Compressive strength

From the graph (Figure 1-A), it can be clearly seen that, incorporation of GP up to 30% in GGBS contributed in slight gain

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in compressive strength from 56,43 Mpa to 57,03 Mpa, Strength reduced with further increase of glass powder in matrix. The reduction of Ca from GGBS source is a reason behind strength loss which leads the matrix to lose its binding, as observed in the sample containing 0% GGBS dropped the strength to 18,37 Mpa,

3.2 Apparent porosity and water absorption

The Apparent porosity and water absorption results (Figure 1–B) supports the compressive strength result. As observed in the graph, the percentage of pours reduce with the increase of GP to 30 wt.%. With the GP above 30% the matrix becomes porous due to the reduction in Ca which resist the undissolved glass particles to hold in matrix, Graph indicating the results of water absorption in compliance to porosity percentage of samples,

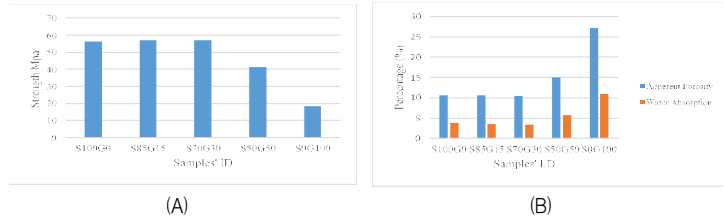


Figure 1. Compressive strength test result (A) and apparent porosity & water absorption test result (B)

3.3 SEM-EDS

SEM micrographs showing the denser matrix for sample without GP (Fig 2–A). However the nonreactive particles can be seen in a samples with 15 & 30 % GP but the particles are embedded in a reactive GGBS due to adequate Ca content in a matrix showing the homogeneity in a matrix (Fig. 2–B & C). With GP above 30%, samples loose its matrix due to the reduction or/ eradication of Ca rich GGBS (Figure,2–D & E).

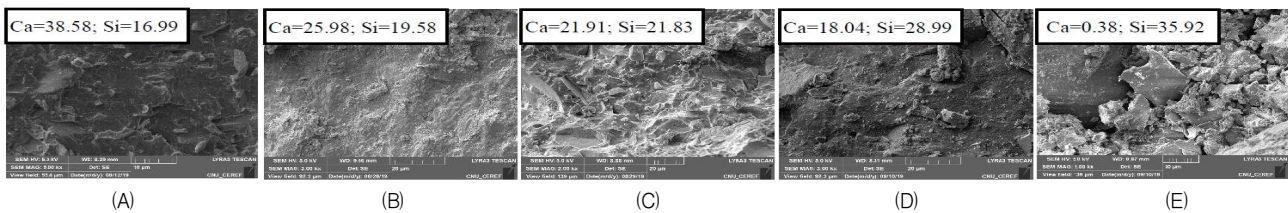


Figure 2. SEM Micrographs S100G0 (A), S85G15 (B), S70G20 (C), S30G50 (D), S0G100 (E)

4. Conclusion

In conclusion, the slightly coarser GP (i.e 150 μm to 75 μm) cannot contribute in the major gain in strength regardless of mixing time as the nonreactive particles were visible. These nonreactive particles did not lead to strength loss due to the presence of Ca from GGBS source, which embedded the particle and developed the homogeneous mixture. Thus the adequate Ca content in a glass composite is beneficial in strength gain.

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