

Role of class-C fly Ash in the Development of Strength & Microstructure of Fly Ash-GGBS Geopolymer

Sasui, Sasui* Kim, Gyu Yong** Lee, Sang Kyu* Son, Min jae* Hwang, Eui Chul* Nam, Jeong Soo***

Abstract

The class-C fly ash (FA) and ground granulated blast-furnace slag (GGBS) based geopolymer activated in NaOH (4M) was studied regarding compressive strength, porosity, microstructure and formation of crystalline phases. The class-C FA and GGBS blends resulted in reduced strength and increased porosity of the matrix with the increase in FA content. The unreactivity of calcium in blends was observed with increasing FA content leading to strength loss. It is evident from XRD patterns that calcium in FA did not contribute in forming CSH bond, but formation of crystalline calcite was observed. Furthermore, XRD analyses revealed that reduction in FA leads to the reduction in crystallinity and SEM micrographs showed the unreactive FA particles which hinder the formation of denser matrix.

Keywords : FA/GGBS, geopolymer, strength, microstructure

1. Introduction

The combined effects of low-calcium fly ash (class-F) and GGBS on the strength development and microstructure of geopolymer mortar have been explored by many studies. Some authors revealed that class-F FA doesn't contribute in improving strength and microstructure of blends as it reduces reactive Ca from GGBS and prevents the formation of C-S-H or C-A-S-H bond^{1,2)}. While some author reveals that increasing amount of GGBS above 50% in FA/GGBS blends reduces the strength due to the development of micro-cracks with excessive Ca in a blend^{3,4)}. However, the role of high calcium FA (Class-C) on FA/GGBS blended geopolymer have been less explored. Therefore, this paper investigated and reports the combined effects of class-C fly ash and GGBS at different mass ratios on strength and microstructure of the geopolymer composites. The obtained results would benefit the future applications of composite class-C fly ash and GGBS.

2. Materials, Geopolymer Synthesis & Test Methods

In this Study the GGBS and FA used as a solid material composed of elements shown in Table 1 and consists of about 80% of its particle size below 75 μm . NaOH of 4M concentration was used as an alkali activator after 24 hours of its preparation. The FA/GGBS was mixed for 10 minutes in a dry form in the following ratio; 100/0, 85/15, 70/30, 50/50, 30/70, 15/85 and 0/100 with given ID; F100S0, F85S15, F70S30, F50S50, F30S70, F15S85 and F0S100 respectively. Alkali solution was poured in a mix at constant Alkali/Solid ratio of 0.4 with the additional water and mixed it for additional 15 minutes. 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. Apparent porosity was determined using archimedes principle as per ASTM C-20. SEM-EDS was performed using FIB-SEM, model LYRA3 XMU on Pt. coated samples and XRD was performed at 2θ from range for 5° to 100° using X-ray Diffractometer (D/Max-2200 Ultima/PC).

Table 1. Element composition of solid materials

Solid	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	-	-
FA	43.44	2.01	0.65	10.33	18.16	2.38	1.53	18.72	1.50	0.82

* Graduate student, Department of Architectural Engineering, Chungnam National University

** Professor, Department of Architectural Engineering, Chungnam National University

*** Associate Professor, Department of Architectural Engineering, Chungnam National University(j.nam@cnu.ac.kr)

3. Results & Discussion

3.1 Compressive strength

From the graph (Figure 1–A), it can be clearly seen that, With the decrease of FA from 100% to 0% in a blend, increases the compressive strength from 7.35 Mpa to 30.34 Mpa. Although the FA used in the blend is rich in Ca content but yet observed the abrupt increase in strength with decreasing FA indicating the unreactivity of FA.

3.2 Apparent porosity and water absorption

The results revealed in Figure 1–B supports the compressive strength result, suggesting the matrix with reducing FA content leads to the reduced porosity and so the percentage of water absorbed was also reduces. This indicates the presence of undissolved FA particle which left the open voids within the matrix.

3.3 SEM Micrographs & XRD

SEM micrographs in Figure 2–A showing undissolved FA particles for the matrix containing 100% FA. With decreasing FA the matrix become denser with maximum gel and less undissolved particles as shown for samples F50S50 and FOS100 in Figure 2–B & C. While the XRD is showing more crystalline phases for samples containing 100% and 50% FA and turns to maximum amorphous phases as GGBS completely replaced FA in a matrix as shown in Figure 2–C. Furthermore, with the addition of GGBS, the XRD showing CSH traces with calcite peak (C) indicating the Ca in GGBS was reactive.

4. Conclusion

In conclusion, the class–C FA, when activated remained unreactive/partially reactive which limits the leaching of major elements such as Si, Al and Ca and thus formed less gel and more crystalline phases in a matrix. This results in strength loss and maximum porosity. The GGBS on the other hand was more reactive, which developed the CSH gel in a matrix, improved the strength and reduced the porosity.

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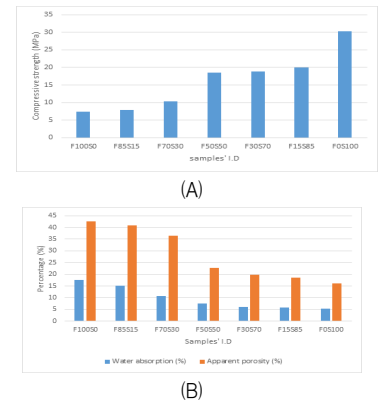


Figure 1. Compressive strength test result (A) and apparent porosity & water absorption test result (B)

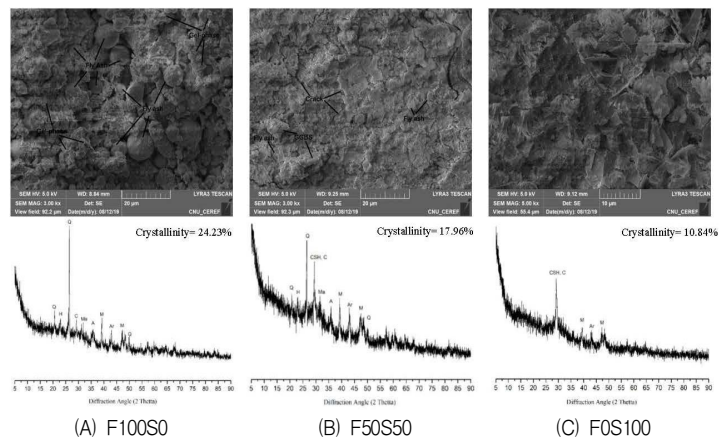


Figure 2. SEM & XRD; Q=Quartz; Ma=Magnetite, M=Mullite, CSH=Calcium Hydrate Silicate, C=calcite, Ar=Aragonite; H=hydrosodalite, A=Albite