

# **EFFECT OF ADDITION OF CHEMICAL ADMIXTURE ON THE PHYSICO- MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF A FLY ASH-SLAG BLENDED GEOPOLYMER COMPOSITE**

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**ABSTRACT.** The world is facing rapid infrastructural growth while it still needs to keep a balance on the sustainability in the construction industry. The adverse effects on environment due to the manufacture of Ordinary Portland Cement can be substituted by alkali activated composites. This project deals with the effect of addition of superplasticizer on blended Geopolymer composite. Pure fly ash (FA) which normally takes long time to set on the action of the alkali activator, was blended with ground granulated blast furnace slag (GGBS). The superplasticizer content was suitably changed to control the workability of the Geopolymer composite. The admixtures were changed keeping the proportions of Geopolymer composite constant. The subsequent effects on workability were investigated by flow table values. The steps were repeated for Geopolymer mixes containing different composition of FA: GGBS with ratios of 70:30, 90:10, 100:0. The impact in the physical properties was studied by the changes in bulk density, apparent porosity, water absorption whereas the mechanical properties were measured by the change in compressive strength. Microstructural analysis of the specimens were also done through scanning electron microscopy.

**Keywords:** Superplasticizer, Geopolymer, Workability, Bulk Density, Apparent Porosity

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## INTRODUCTION

The production of Ordinary Portland cement is resource exhausting, energy intensive process. It involves emission of huge greenhouse gases into the atmosphere [17]. This results in extreme adverse effects in the environment and maintaining sustainability issues in the construction industry is the requirement of the hour. In order to lower the massive CO<sub>2</sub> emissions in the atmosphere, alternative binding materials such as alkali-activated composites or Geopolymers are being increasingly used. The main source materials of alkali-activated composites comprises of Fly ash and blast furnace slag. Fly ash contains reactive silica and also possesses good acid neutralization properties but it takes longer duration to set on the action of alkali activator solution.

Blended precursors on the other hand have proved to yield much better results in terms of strength, workability and durability [18, 19]. Slag additionally used in the composite improves the reactivity of the Geopolymer mix to a greater extent thereby leading to a better workability and high early strength. The experimental programs mostly involved water curing at ambient temperatures. Addition of alkaline solution to slag leads to disintegration of calcium and formation of aluminum precipitates which leads to the formation of a C-A-S-H type gel [1-3] which functions as a major binding agent thereby increasing the mechanical strength, decreasing the porosity and increasing the durability.

Numerous studies [9–12] have been performed to understand the effect of superplasticizers on the properties of cement matrix with respect to mechanical and microstructural properties[13, 14]. The action of superplasticizers (SP) to cement concrete, mortar, gel has been studied and reported by several authors leading to extensive research and findings, whereas the research on the effect of SPs on fly ash based geopolymers have lacked such extensive research investigations.

## EXPERIMENTAL PROCEDURE

### Materials Preparation

The Geopolymer precursors used in this investigation were a fly ash, classified as class F according to ASTM C 618, from Kolaghat thermal power plant, West Bengal, India, and a Ground Granulated Blast Furnace Slag (GGBS) supplied by Durgapur steel plant, West Bengal, India. The alkali activator was prepared by dissolution of sodium hydroxide pellets in water and then adding sodium silicate (49.1 wt. % SiO<sub>2</sub> and 50.9 wt. % Na<sub>2</sub>O) in the mixture of sodium hydroxide and sodium silicate solution, which was taken permitted to cool to room temperature before being used for the preparation of specimens.

All samples were formulated with a fly ash to slag ratio of 70:30, 90:10,100:0. Water/binder ratio of 0.38 was used in the preparation of the mix specimens. The flow diameter of the fresh paste was measured on a miniature flow table and then the sample was casted into 50mm x 50mm x 50mm steel moulds and vibrated for 2 minutes to remove entrapped air. Following vibration, the specimens were kept at room temperature for 4 hours, following which it was kept in an oven and cured at 85°C for 48 hours. The tests were conducted on the 3<sup>rd</sup> day. The study is based on the workability of the Geopolymer concrete specimen.

Table 1 Mix proportion of the geopolymer composites

SAMPLE DESIGNATION	% FLY ASH	% GGBS	TYPE OF ADMIXTURE	% ADMIXTURE
100-0 PC based	100	0	Polycarboxylic ether	0
			0.6	
			0.9	
			1.2	
100-0 Naptha based	100	0	Sodium naphthalene formaldehyde	0
			0.6	
			0.9	
			1.2	
90-10 PC based	90	10	Polycarboxylic ether	0
			0.6	
			0.9	
			1.2	
90-10 Naptha based	90	10	Sodium naphthalene formaldehyde	0
			0.6	
			0.9	
			1.2	
70-30 PC based	70	30	Polycarboxylic ether	0
			0.6	
			0.9	
			1.2	
70-30 Naptha based	70	30	Sodium naphthalene formaldehyde	0
			0.6	
			0.9	
			1.2	

## RESULTS AND DISCUSSIONS

### Compressive strength

Fig 1 shows the variation of chemical admixture percent (both naptha and PC based) on the three day compressive strength of the fly ash slag based geopolymer composite. Increase in the compressive strength is directly related to the increase in the slag content. This can be attributed to the formation of C-S-H gel, C-A-S-H gel, N-A-S-H gel, which increases the reactivity of slag particles.[1-3] This increased reactivity contributes to the enhanced mechanical strength properties. Previous authors have similar results. Garcia et al. reported an increase in the compressive strength with increasing slag content [4]. Yip et al. also suggested that the increase in the compressive strength could be correlated to the coexistence of the sodium aluminium silicate hydrate gel and the calcium aluminium silicate hydrate gel could enhance the mechanical properties of geopolymer samples [5, 6].

Fig 1 shows that the mortars fabricated with PC based geopolymers composites have a more positive effect on the early mechanical strengths than the mortars with naptha based admixtures. The difference between 1.2 % and control (0 %) mortars, in the case of 70-30 is 1.88 % for PC based and -4.8% for naptha based, while in the case of 90-10 is 15.38 % for PC based and -23.07 % for naptha based. The negative sign shows a decrease in the compressive strength of 1.2 % with respect to the control. In the case of 100-10, the naptha based mortars showed an increase in the compressive strength properties. From the graph it can be concluded that increase in admixture percent results in increase in compressive

strengths, except in some cases, where the higher admixture percent of 1.2% is detrimental to the compressive strength of the geopolymer mix. Many authors have cited that on increasing the admixture percent beyond 1% results in an overall decrease in compressive strength [7, 15].

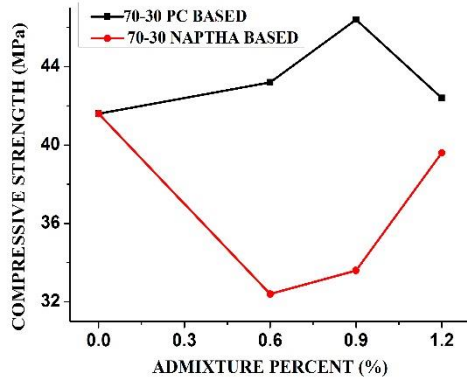


Fig 1a

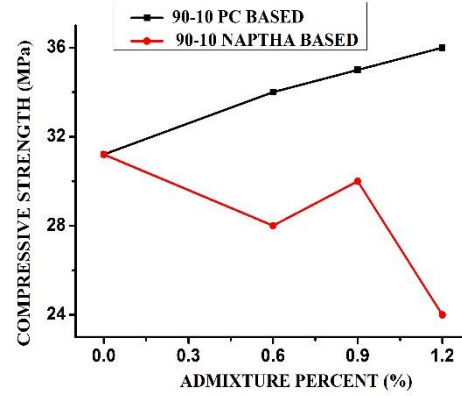


Fig 1b

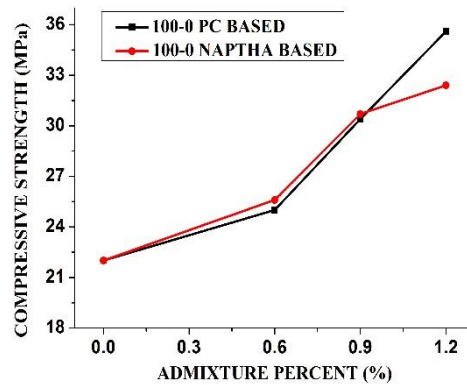


Fig 1c

Figure 1(a-c): Variation of chemical admixture percent (both naptha and PC based) on the three day compressive strength of geopolymer composite

### Bulk Density, Water Absorption, Apparent Porosity, Flow diameter

Figure 2 illustrates the effect of chemical admixture percent on the variation of the dry bulk density. The minimum bulk density is observed in the case of 100-0 mix with Naptha 0.9 %, which is 1607 kg/m<sup>3</sup>. The 90-10 0.9 % Naptha mix was found to be 1738 kg /m<sup>3</sup> while the 70-30 0.9 % Naptha mix showed an increased bulk density of 1864 kg /m<sup>3</sup>. The increment in bulk density with the addition of slag is observed in all the cases, which can be attributed to the dense and compact microstructure on incorporation of slag. The compact microstructure can be clarified from the EDX/SEM analysis, which is discussed in section (please mention the section of SEM). Puligilla and Mondal (16) proposed that the simultaneous formation of the geopolymeric gel and the gel (formed in presence of Ca from Ca rich slag) helps to fill the gaps between the different hydrated phases and the unreacted particles, resulting in a more dense and homogeneous matrix.

The incorporation of superplasticizers led to the decrease in the bulk density. In the case of 70-30 Naptha mix, 1.2 % addition led to a decrease of dry bulk density by 1.38% compared to the control

(0 % admixture). Similarly for 90-10 Naptha mix, 1.2 % addition showed an overall decrement of 4.48 % in density than the control mix. Similar results are observed in all the mixes.

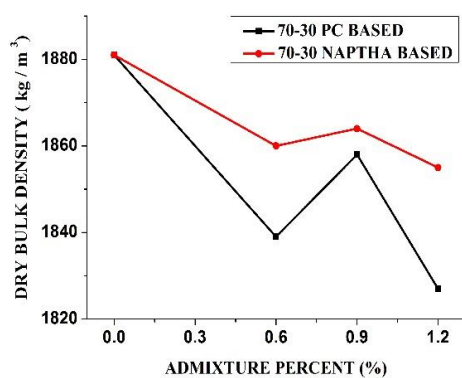


Fig 2a

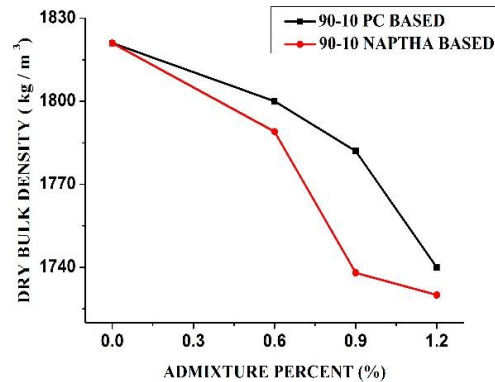


Fig 2b

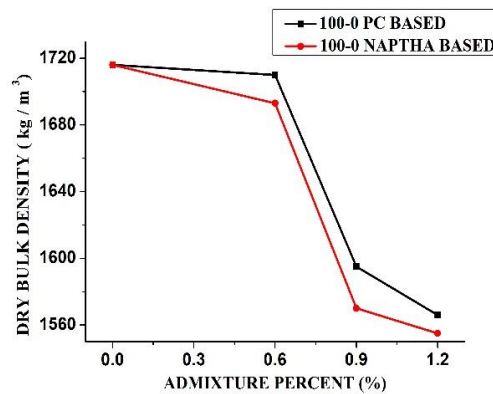


Fig 2c

Figure 2(a-c): Variation of chemical admixture percent (both naptha and PC based) on the three day bulk density of geopolymer composite

Figure 3 displays the effect of admixture on the flow of geopolymer composite. Figure infers the increment of flow diameter value up to 0.9 % for all the samples, after which it drops at 1.2 %. The flow diameter also increases with the increase in slag content. This can be attributed to the higher gel formation on the inclusion of slag. The gel makes the composite more workable and reduces the need for external mechanical vibration. The 100-0 mix was too stiff, thereby no significant change was observed in the flow diameter.

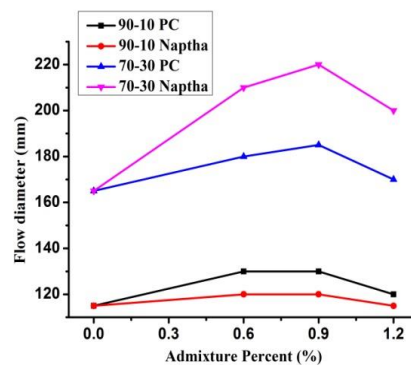


Figure 3: The effect of chemical admixture on the flow diameter of fly ash slag geopolymer composite

Fig 4 shows the variation of chemical admixture percent (both naptha and PC based) on the water absorption of the fly ash slag based geopolymer composite having FA:GGBS. Water absorption percentages for the different mixes of both naptha and PC based admixtures followed similar trend with PC based specimens recording the highest value.

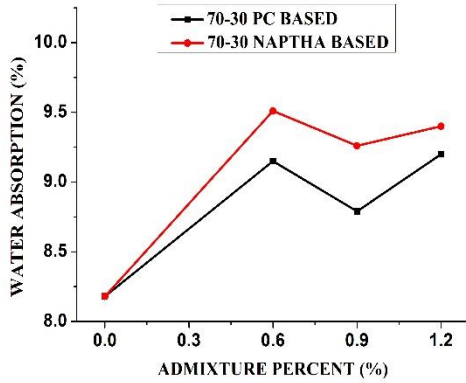


Fig 4a

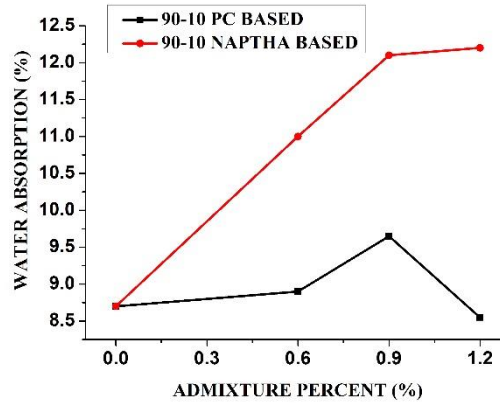


Fig 4b

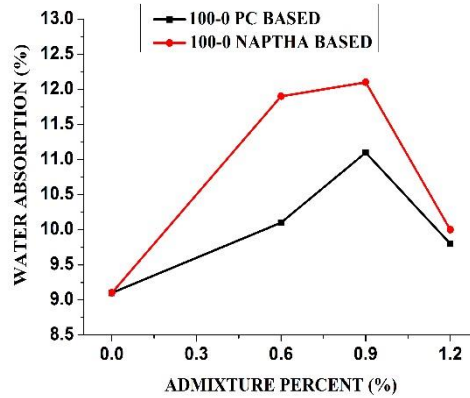


Fig 4c

Figure 4(a-c) : The effect of chemical admixture on the water absorption of fly ash slag geopolymer composite

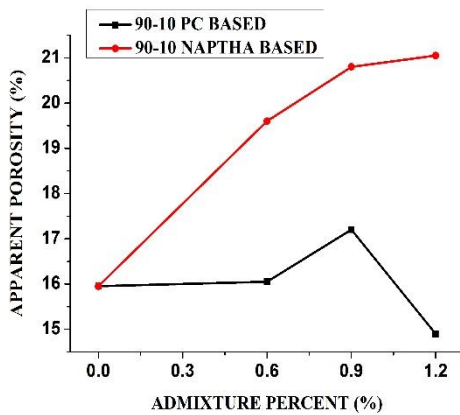


Fig 5a

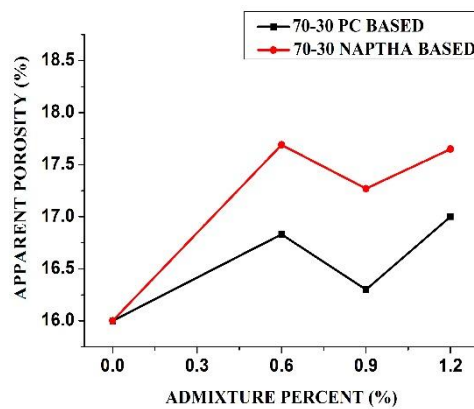


Fig 5b

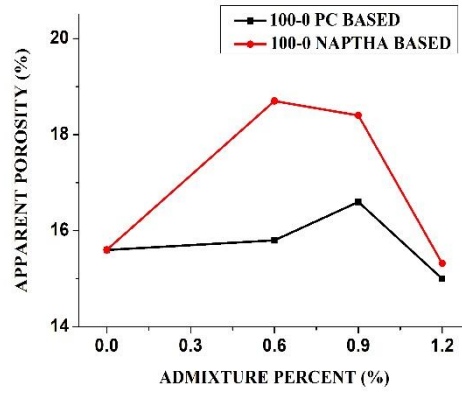
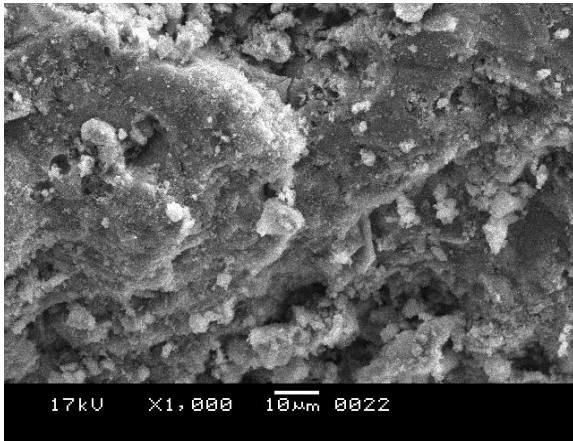


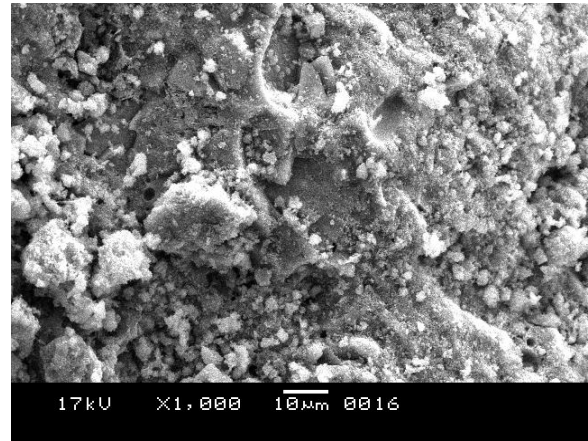
Fig 5c

Figure 5(a-c): The effect of chemical admixture on the apparent porosity of fly ash geopolymer composite

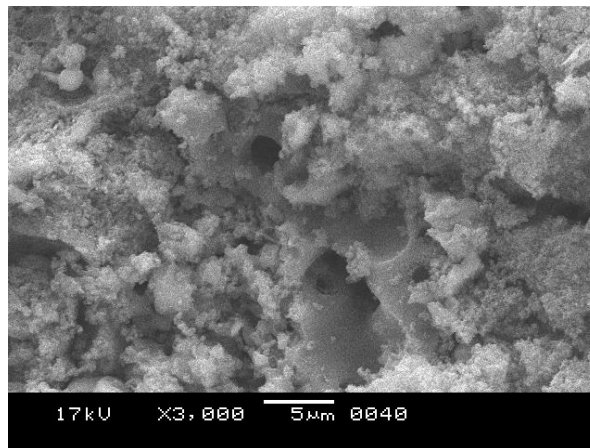
### Scanning Electron Microscopy Analysis



70-30- 0.6% PC based admixture



70-30- 0.9% PC based admixture



70-30- 1.2% PC based admixture



It can be seen from the above sem images that the 70-30 mix with 0.9% PC based admixture has a more cohesive microstructure than the 70-30 mix with 0.6% PC based admixture. But the mix with 1.2% PC based admixture has the presence of multiple voids and microcracks which can be attributed to incomplete geopolymerisation. Increasing the admixture beyond an optimum percentage of 0.9% hinders the reaction process which affects the various stages of geopolymerisation viz dissolution, gelation, polycondensation and crystallisation.

## **CONCLUDING REMARKS**

1. It was seen that upon addition of optimum level of slag resulted in increasing of mechanical properties of the geopolymer composite like compressive strength, bulk density, apparent porosity and water absorption.
2. It was seen that variation of slag changes the microstructure of the geopolymer composites. Slag addition leads to formation of two prominent gel phases: N-A-S-H gel and C-A-S-H gel with N-A-S-H gel being the primary load bearing phase.

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