

Effect of activator solution on compressive strength of flyash geopolymer blended with slag

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ABSTRACT

The influence of the composition of activator solution on the strength of fly ash geopolymer blended with slag was investigated. The research variable include % Na₂O and sodium silicate under typical controlled parameters like curing profile, water content, base material and supplementary material. In this study, the monitoring response variable was compressive strength. Finding suggests that activator solution combination has a significant effect on the properties of the GP (non-blended geopolymer) and GB (geopolymer blended with 15% slag). The experiment concludes that higher percentage of Na₂O gives lower strength for GB specimens but corresponding higher strength for GP specimens. Silicate modulus has similar impact on GP and GB. Both for GP and GB specimens compressive strength is increase with higher silicate modulus.

Keywords—Geopolymer, Slag, Fly ash, Compressive Strength, Activator.

I. INTRODUCTION

A geopolymer is a kind of alkali aluminosilicate cementitious material having superior mechanical, chemical and thermal properties as compared to Portland-based cements, and with significantly lower CO₂ production [1]. Any pozzolanic compound or source of silica and alumina that is readily dissolved in the alkaline solution is a well known source of geopolymer acting as geopolymer precursor species and contributes itself in geopolymerization [2]. In last decade, a positive research outcome is low calcium fly ash based geopolymer cement and concrete [3–5]. Its preparation includes activation in an alkaline medium and curing at moderate temperatures. It is the fact, that Low-calcium ash is more as a source material of geopolymer rather than that containing high calcium. High calcium in fly ash as base material may disturb the polymerization process or change the microstructure [6]. Research has been done on slag a supplementary material in fly ash based geopolymer to have a favorable effect.[7]. Addition of calcium compound to a fly ash system has been proved that it brings quick setting behavior and enhance strength [8]. In chemical terminology, it shows that calcium compound subjected to alkaline medium forms geopolymer and C-S-H component [9,10]. As we know, excessive presence of calcium creates highly unstable calcium hydroxide which is extremely prone to carbonation [10]. Mechanism of geopolymers involves the polycondensation reaction of geopolymeric precursors i.e. aluminosilicate oxide with alkali polysilicates yielding polymeric Si–O–Al bond [11,12,13,14]. The basic polymeric formula can

be expressed as $M_n[-(Si - O_2)_z - Al - O]_n \cdot wH_2O$ where M is the alkaline element, z is 1,2, or 3 and n is the degree of polycondensation [13]. Now any alkali cation can be used as (M) in the polymeric reaction but most of the study has entertained on sodium or potassium [7,9-11]. The incorporation of calcium is much important to consider as an alkali cation which may act as a charge compensator of aluminium to form an amorphous geopolymeric gel rather than any part of a basic geopolymeric structure. It is already found that in higher value of pH the alkali activation of metakaoline in presence of calcium hydroxide form complete amorphous sodium aluminosilicate which is similar to that when metakaoline was activated in absence of Ca(OH)₂ [12, 13]. In this type of geopolymer, C-S-H can be treated as the secondary product. The aim of the study is to find out the effect of activator solution on slag blended fly ash geopolymer.

II. EXPERIMENTAL

A. Materials

Class F fly ash used in the research was collected from Kolaghat Thermal Power Plant near Kolkata, India. About 75% of particles were finer than 45 micron and Blaine's specific surface was 380m²/kg. The chemical composition of fly ash is given in Fig. 1. The blast furnace slag used was in powdered form having specific gravity 2.8, bulk density 1236 kg/m³, consisting of 39.07% CaO. The average particle size of blast furnace slag was varied between 35μ to 65μ. The chemical composition of blast furnace slag is given in Fig. 2.

Fig. 1 CHEMICAL PROPERTIES OF FLY ASH

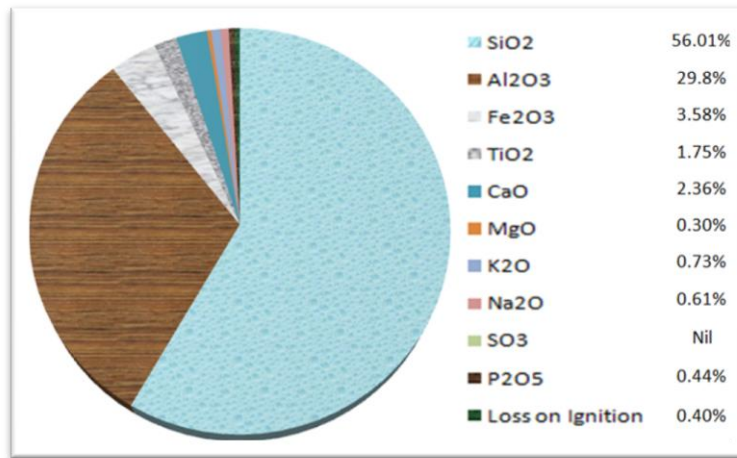
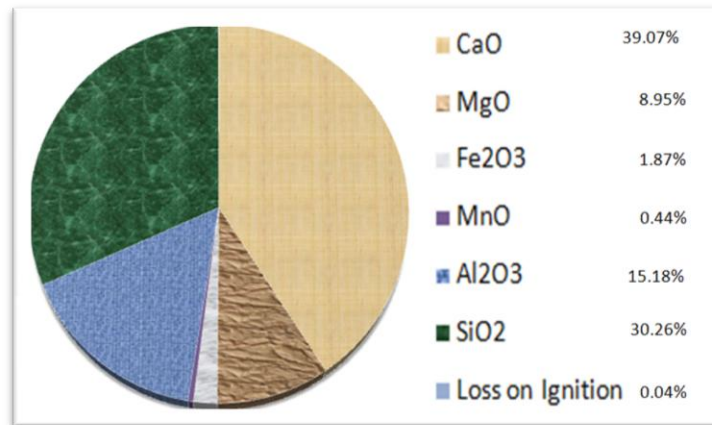


Fig. 2 CHEMICAL ANALYSIS REPORT OF BLAST FURNACE SLAG



Laboratory grade sodium hydroxide in pellet form (98% purity) and sodium silicate solution (Na₂O= 8%, SiO₂ =26.5% and 65.5% water) with silicate modulus ~ 3.3 and a bulk density of 1410 kg/m³ was

supplied by LobaChemie Ltd, India. Scanning electron micrographs of fly ash and Blastfurness slag is given in Fig. 3 and Fig. 4.

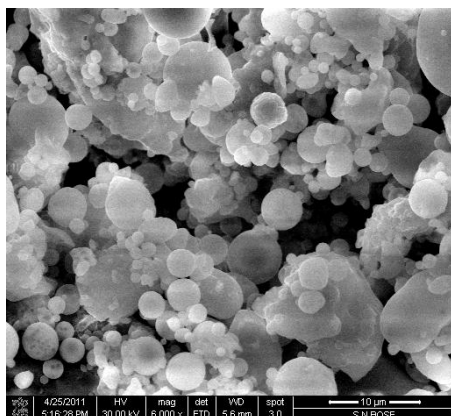


Fig. 3 SEM of Fly ash at 6000x zoom

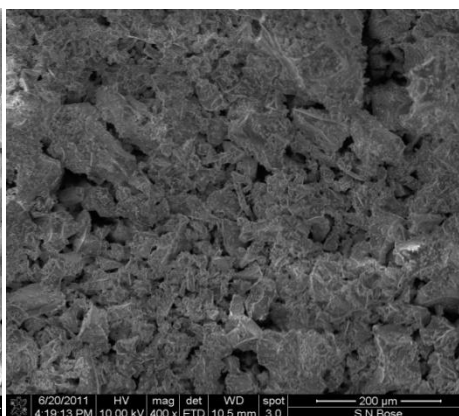


Fig. 4 SEM of Blastfurness slag at 400x zoom

B. Preparation of Solution, Specimens and

The alkaline activating solution was prepared by dissolving required quantity of sodium hydroxide pellets directly into water .The activator solution (sodium hydroxide and water) was left at room temperature for 24 hours after that predetermined quantity of sodium silicate solution was added 3 hours before casting of geopolymer specimens.

In a Hobart mixer, fly ash, with or without blast furnace slag (according to Table 1) was mixed

Testing

with predetermined quantity of activator solution for 5 minutes. The mix was transferred into 50 x 50 x 50 mm cubes followed by table vibration for 2 minutes to expel any entrapped air. After 60 minutes of air dry, the cubes were cured in a hot air oven for a period of 48 hours at 85°C and then allowed to cool inside the oven [15]. Specimens were removed and stored at ambient temperature in a dry place before testing. Geopolymer paste mixture composition and curing environment is given in Table 1.

TABLE 1.1Dry mix combination

Sample Id	Base Material (Bm)	Supplementary Material (Sm)
GP	Fly ash	NIL
GB	Fly ash	GGBS (15% of base Bm plus Sm)

TABLE 1.2Activator Combinations

Sample ID	Activator	
	%Na ₂ O	Silicate Modulus
GP	6%	0.5
		1
		1.5
	8%	0.5
		1
		1.5
GB	6%	0.5
		1
		1.5
	8%	0.5
		1
		1.5

TABLE 1.3 Hot Curing Exposure regimes

Curing Regime	
Curing Duration	Curing Temperature
1 Day (24 Hours)	55°C
	65°C
	75°C
	85°C
2 Days (48 Hours)	55°C
	65°C
	75°C
	85°C

III. EXPERIMENTAL PROCEDURE

Compressive strength was evaluated according to ASTM C109 by using the digital compressive strength testing machine. Every specimen under different curing environment were taken out of oven and put in room temperature for 1 day. The compressive strength was carried out to evaluate the strength development for the samples. The samples were subjected to compression at 3 days.

IV. RESULT AND DISCUSSION

A. Compressive Strength

It is noticeable that for GP specimens (non-blended) the result is better with higher %Na₂O of fly

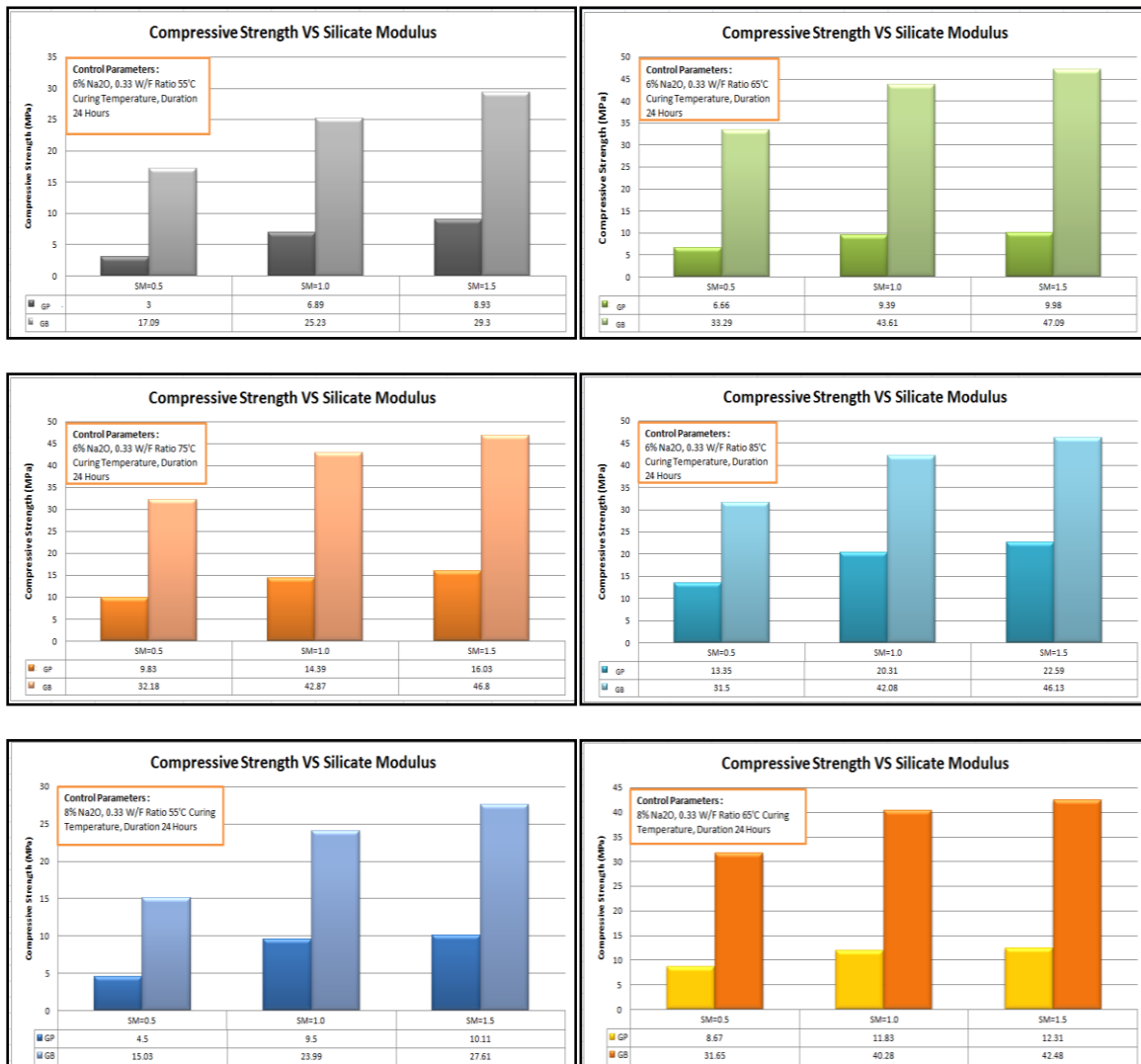
ash activated. For example, geopolymer sample activated by 8% Na₂O gives 32.33 MPa for a controlled parameter whereas the value is dropped to 22.59 MPa under the same condition when activated by 6% Na₂O of fly ash. Means 31.33% increment in compressive strength is observed due to the increment in %Na₂O in activator from 6 to 8. However, sample GB reciprocates the relation where higher percentage of Na₂O gives lower result in compressive strengths. That implies higher percentage of Na₂O in activator put a negative feedback in compressive strength for fly ash based geopolymer blended with GGBS (Ground Granulated Blast-furnace Slag).

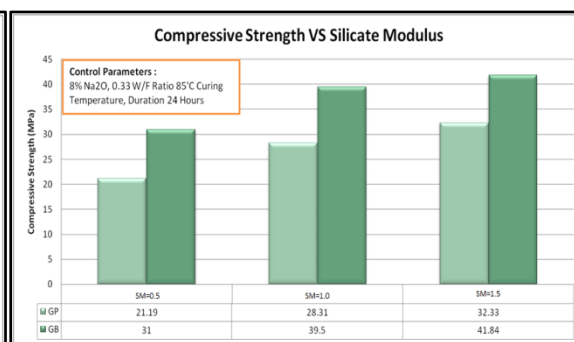
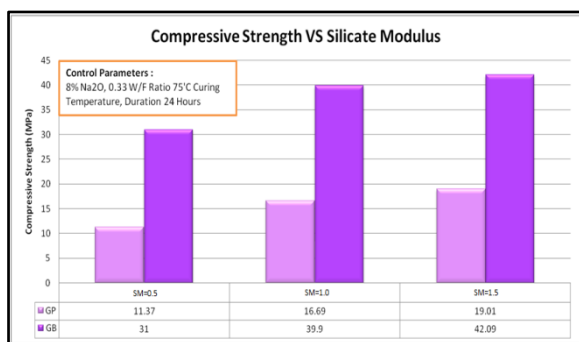
TABLE 2Compressive Strength of typical specimens

Sample	Activator	Compressive Strength (MPa) after 3 days from
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ID			Curing for 24 hrs @				Curing for 48 hrs @			
	%Na ₂ O	Silicate Modulus	55°C	65°C	75°C	85°C	55°C	65°C	75°C	85°C
GP	6%	0.5	3.0	6.66	9.83	13.35	4.87	9.89	15.67	18.09
		1	6.89	9.39	14.39	20.31	8.68	11.15	19.13	27.66
		1.5	8.93	9.98	16.03	22.59	10.32	13.01	22.7	29.22
	8%	0.5	4.5	8.67	11.37	21.19	7.80	12.35	17.88	26.90
		1	9.5	11.83	16.69	28.31	13.03	15.12	25.09	37.00
		1.5	10.11	12.31	19.01	32.33	13.82	15.79	26.50	40.00
GB	6%	0.5	17.09	33.29	32.18	31.50	17.62	33.46	32.01	30.73
		1	25.23	43.61	42.87	42.08	25.81	43.69	41.60	39.80
		1.5	29.30	47.09	46.80	46.13	29.56	47.17	46.80	46.09
	8%	0.5	15.03	31.65	31.00	31.00	15.89	31.87	30.13	29.65
		1	23.99	40.28	39.90	39.50	25.93	40.63	38.00	41.00
		1.5	27.61	42.48	42.09	41.84	28.17	42.70	42.00	40.44

Fig. 5 Elementary exhibition of Table 2 in graphical format to evaluate the effect of Silicate Modulus on the compressive strength of geopolymer under different control features





The source of Na₂O in activator solution is sodium hydroxide and sodium silicate. So higher silicate modular is definitely increase the amount of sodium silicate which partially contribute to the amount of Na₂O in activator. Here for every cases there is an increment in compressive strength with the increase in silicate modular. Though both the sodium hydroxide and sodium silicate have contribution to Na₂O content but result suggests that higher value of Na₂SiO₃ is much appreciable rather NaOH to maintain a particular % Na₂O in activator solution even for GB specimens. The result concludes the silicate modulus affects the compressive strength of GP and GB in the same manner but the magnitude of compressive strength of GB is far high than that of GP.

V. CONCLUSION

- Higher percentage of Na₂O is not suitable for fly ash based geopolymer blended with blast furnace slag. The compressive strength of GB specimens activated under 8% Na₂O concentration is poor than that obtain under 6%. The result is completely opposite for GP specimens.
- For both GP and GB specimen's silicate modulus exhibits the same impact. Better compressive strength is obtained for every cases with the increments of silicate modulus.

REFERENCES

- P. Duxson, J.L. Provis, G.C. Lukey, J.S.J. van Deventer, "The role of inorganic polymer technology in the development of 'Green concrete'", Cement and Concrete Research 2007, 37(12), 1590–1597p.
- Xu H, Van Deventer JSJ (2000) The geopolymerisation of aluminosilicate minerals Int J Miner Process 59:247-266(2000).
- A.Palomo, M.W. Grutzeck, M.T. Blanco, Alkali-activated fly ashes: a cement for the future, Cement Concrete Res. 29 (1999) 1323–1329.
- B.V. Rangan, Low-calcium fly ash-based geopolymer concrete, in: E.G. Nawy(Ed.), Concrete Construction Engineering Handbook, second edition, CRC Press, New York, 2007.
- P. Duxson, A. Fernandez-Jimenez, J.L. Provis, G.C. Lukey, A. Palomo, J.S.J. van Deventer, Geopolymer technology: the current state of the art, J. Mater. Sci. 42(2007) 2917–2933.
- J.T. Gourley, Geopolymers; Opportunities for Environmentally Friendly Construction Materials, Presented at the Materials 2003 Conference: Adaptive Materials for a Modern Society, Sydney.
- Z. Li, S. Liu, Influence of slag as additive on compressive strength of fly ash based geopolymer, J. Mater. Civil. Eng. 19 (6) (2007) 470–474.
- S. Antiohos, S. Tsimas, Activation of fly ash cementitious systems in the presence of quicklime Part 1. Compressive strength and pozzolanic reaction rate, Cement Concrete Res. 34 (2004) 769–779.
- C.K. Yip, J.S.J. van, Deventer, Microanalysis of calcium silicate hydrate gel formed within a geopolymeric binder, J. Mater. Sci. 38 (2003) 3851–3860.
- C.K. Yip, G.C. Lukey, J.S.J. van, Deventer, The coexistence of geopolymeric gel and calcium silicate hydrate at early stage of alkaline activation, Cement Concrete Res. 35 (2005) 1688–1697.
- Davitovits J (1991) J Therm Anal 37:1633.
- Van Jaarsveld JG S. Van Deventer JSJ. Lorenzen L. "The potential use of geopolymeric materials to immobilise toxic metals: Part I. Theory and applications [J]. Miner. Eng., 1997. 10: 659 — 669.
- Hardjito D, Wallah SE, D.M.J Sumajouw, Rangan BV In: George Hoff Symposium, ACI, Las Vegas USA, 2003.
- A. Palomo and F. P. Glasser, "Chemically-Bonded Cementitious Materials Based on Metakaolin," Brit. Ceram. Trans. J., 91, 1992., 107–12 p.
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