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Effect of Curing Profile on Fly Ash Geopolymer with Slag as Supplementary

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Abstract

The aim of this research is to evaluate the curing temperature at which the fly ash based geopolymer can achieve its best mechanical properties with the presence of supplementary calcium source. Wide range of curing temperature from 55ºC-85ºC was imposed to sample GP (without any calcium compound) and sample GB (with 15% of slag as supplementary material) to have their comparative performance. The prime objective is to find out the right curing temperature in a manner to obtain the optimized strength under compression.

Keywords: Slag, Geopolymer, Fly ash, Curing, Activator.

Introduction

In earlier study, the aim was inclined towards the effect of curing temperature as well as curing duration of fly ash and kaolinite based geopolymers which proves that higher temperature for more than a couple of hours seemed better for the development of compressive strength [1]. Proper parametric study on blended geopolymer has not yet done. Though literature review gives some data regarding optimal value of different mixing parameter. Before any further research or extension a detail understanding on the formation of fly ash geopolymer, it's control parameter and also the role of different supplementary material are needed. In last decade, a positive research outcome is low calcium fly ash based geopolymer cement and concrete [2–5]. 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 geopolymery 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 polysiliates yielding polymeric Si–O–Al bond [11,12,13,14].The basic polymeric formula can be expressed as $M_n[-(Si - O_2)_z - Al - O]_n .wH_2O$ 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 alumino silicate which is similer 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 present investigation is targeted towards the findings of the optimal curing profile to have the best mechanical properties like strength.

Experimental

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 380m^2/kg. The chemical composition of fly ash is given in Figure 1. The blast furnace slag used was in powdered form having specific gravity 2.8, bulk density 1236 kg/m^3, consisting of 39.07% CaO. The average particle size of blast furnace slag was varied between 35µ to 65µ. The chemical

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composition of blast furnace slag is given in Figure 2.

Figure: 1 Chemical properties of fly ash

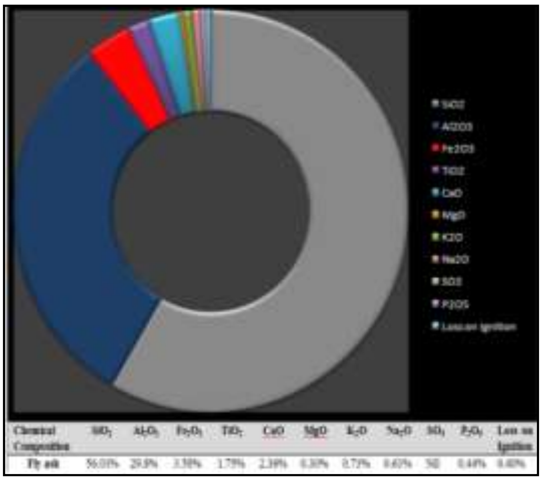
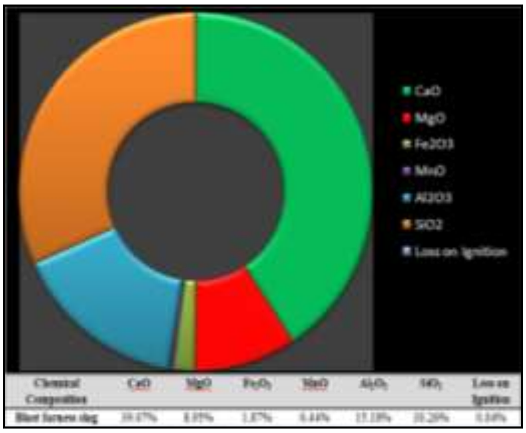


Figure: 2 Chemical analysis report of blast furness slag



Laboratory grade sodium hydroxide in pellet form (98% purity) and sodium silicate solution (Na_2O= 8%, SiO_2 =26.5% and 65.5% water) with silicate modulus ~ 3.3 and a bulk density of 1410 kg/m^3 was supplied by Loba Chemie Ltd, India. Scanning electron micrographs of fly ash and Blast furness slag is given in Figure 3 and Figure 4.

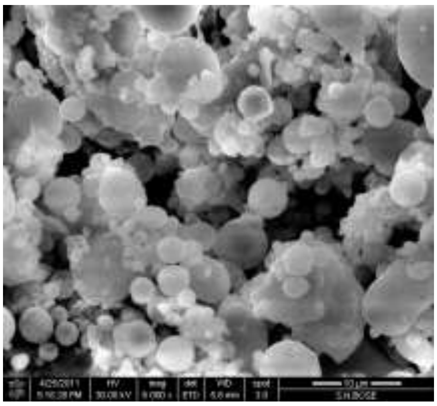


Figure: 3 SEM of Fly ash at 6000x zoom

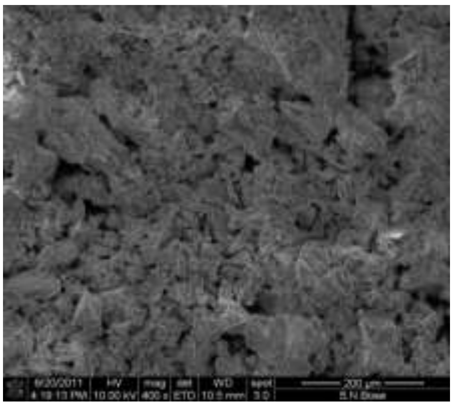


Figure: 4 SEM of Blast furness slag at 400x zoom

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Preparation of Solution, Specimens and Testing

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 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 85ºC 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(a). Dry mix combination

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

Table 1(b). Activator Combination

Sample ID	Activator	
	$\%Na_2O$	Silicate Modulus
GP	6%	0.5
		1
		1.5
GP	8%	0.5
		1
		1.5
GB	6%	0.5
		1
		1.5
GB	8%	0.5
		1
		1.5

Table 1(c). Hot Curing Exposure regimes

Curing Duration →	24 Hours				48 Hours			
Curing Temperature →	55ºC	65ºC	75ºC	85ºC	55ºC	65ºC	75ºC	85ºC

Moto of the present work

The motto of the work is to find out the impact of different curing period on the mechanical property like compressive strength for slag-blended fly ash based geopolymer composite. To determine the optimal curing period the other parameters influencing geopolymerisation were kept controlled.

Result and discussion

Compressive Strength

The compressive strength of the cube specimens were evaluated according to ASTMC109 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. Fly ash based geopolymer needs sufficient time for the geopolymerization process to happen, and therefore, in order to increase the dissolution of reactive species sufficient amount of heat influx is needed for strength gain. Here the term heat influx indicates the product of curing temperature and curing time. The graphical demonstration depicts the successive increments in compressive strength with prolong curing. The incorporation of supplementary slag in fly ash based geopolymer upto 15% of fly ash brings better chemistry in

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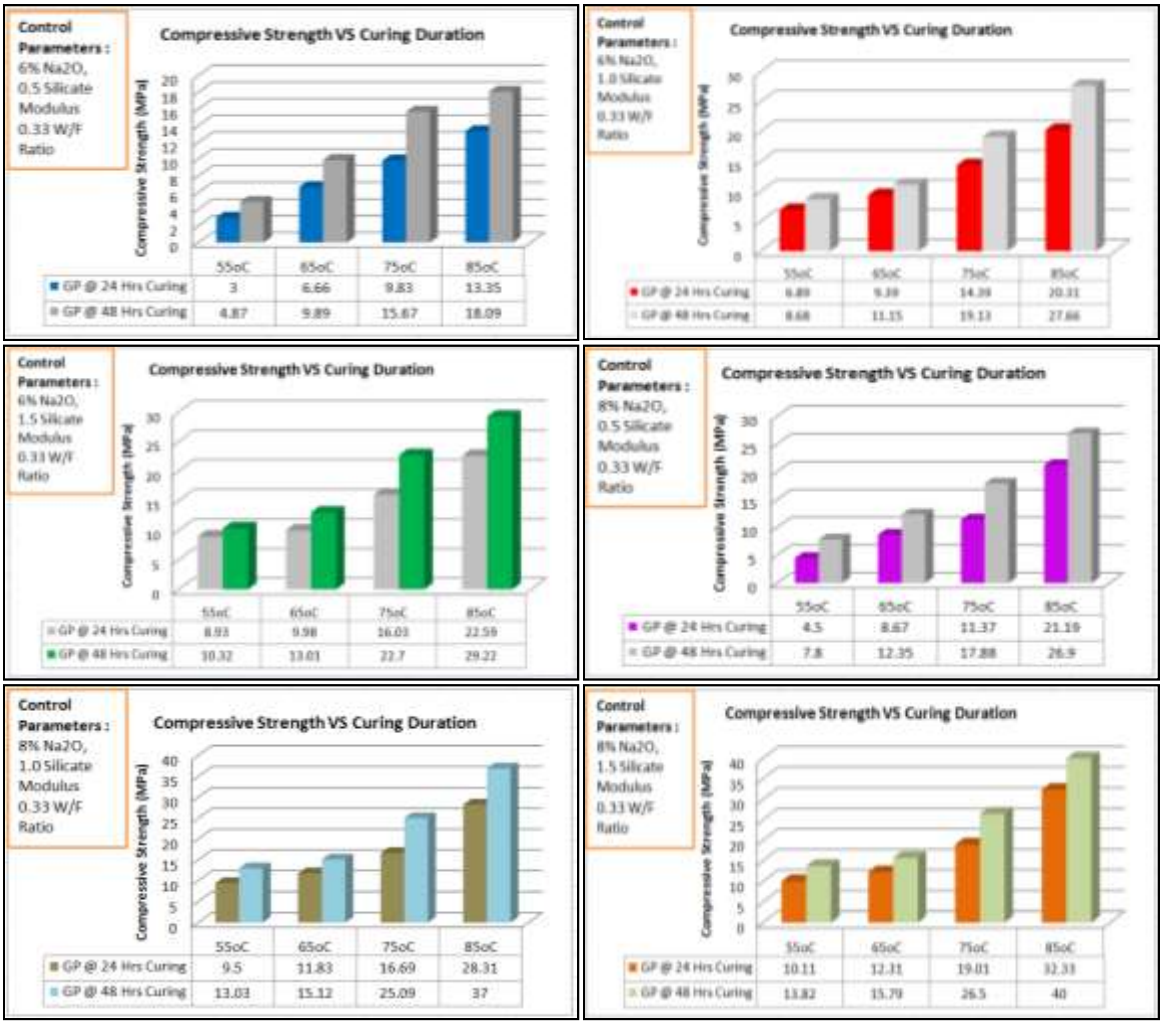
geopolymerization. Here calcium plays better role in geopolymerization than sodium.

Table 2. Compressive Strength of typical specimens

Sample ID	Activator		Compressive Strength (MPa) after 3 days from									
	Silicate Modulus	%Na_2O	Curing for 1 Day @	55ºC	65ºC	75ºC	85ºC	Curing for 2 Days @	55ºC	65ºC	75ºC	85ºC
GP	0.5	6%		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
GP	0.5	8%		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	0.5	6%		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
GB	0.5	8%		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

Figure: 5 Elementary exhibition of Table 2 in graphical format to evaluate the effect of Curing Duration on the compressive strength of geopolymer under different control features



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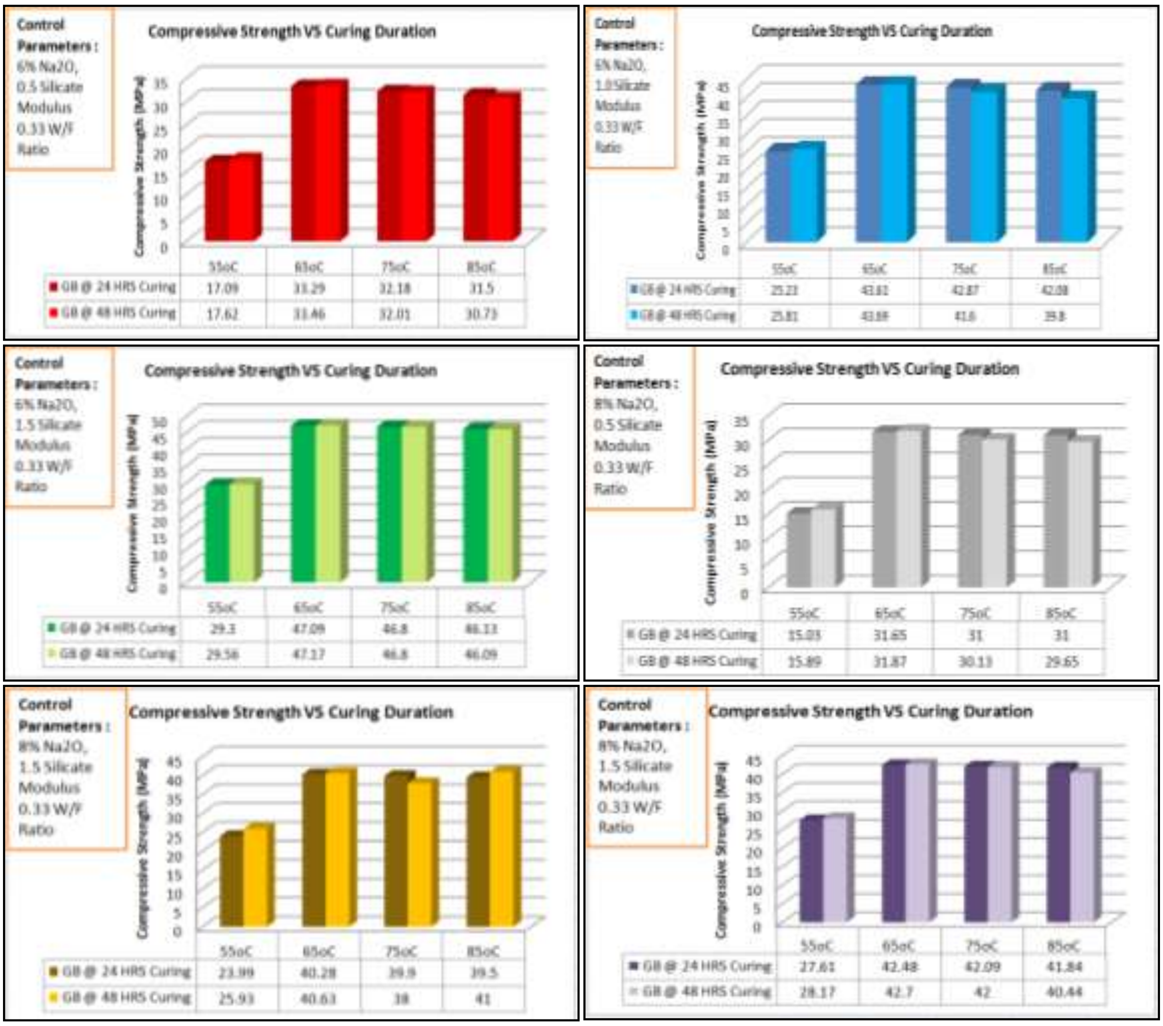

Actually, Ca^{++} acts as charge balancer of aluminum which emphasis the faster formation of amorphous geopolymeric structure. It may be assume that optimal presence of calcium increases the rate of polycondensation by influencing the resolution of reactive species. It could be observed that GP sample shows corresponding increment in compressive strength for longer curing period, whereas blended geopolymer specimens does not influence in that way. It is also noticeable that few of the GB sample exhibits little drops in strengths due to longer curing duration. It is because of excessive pressure on the hardened geopolymer structure caused by the water trying to be extruded. It can be concluded from the compressive strength data that one day curing duration is sufficient for fly ash geopolymer blended with 15% slag of fly ash.

Conclusion

1. Specimen GB shows very small percentage of increment in compressive strength for longer curing duration for a curing temperature upto 65ºC, but every case this increment is not greater than 1% even. Furthermore a curing duration of 48 hours for a curing temperature greater than 65ºC gives poor result in connection in compressive strength.

2. Non-blended geopolymer GP undergoes to sufficient increments in compressive strength with prolong curing duration. Maximum compressive strength is obtained by a typical GB specimens subjected to 65ºC curing temperature for 24 hours. While the highest value of compressive strength for GP specimens is 40 MPa for a curing profile of 85ºC at 48 hours.

3. The geopolymerization chemistry is much effected by the introduction of 15% GGBS with fly ash. This supplementation brings optimal strength in shorter time period of curing. It is because of the higher rate of polycondensation in the presence of Ca^{++} cation as charge balancer of aluminiuam.

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Dr. Ghosh has demonstrated his skill by providing technical advice on a number of occasions and the same has been implemented very successfully in practice. Repair and restoration techniques adopted for the earthquake damaged structures of the Kandla special economic zone (SEZ) through his expertise deserve a special mention. Another noteworthy contribution is the restoration of Assembly building at Sikkim. His skill in computer aided analysis of structure has been demonstrated through the design of a Buddha statue of 52m tall, on the top of a hill at Namchi, Sikkim and a cricket stadium in Guwahati. His selection as the Country Head of a division in a multinational company in Nigeria speaks about his skill and expertise. During this period, Dr. Ghosh has successfully guided a good number of students for their Ph.D and Master's degree. He has acted as expert member on several occasions for CSIR, AICTE, UGC, IIT, NIT & other Universities. Dr. Ghosh has contributed immensely both in academics as well as in practice through his activities.