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Partial Replacement of Cement in the Geopolymer Quarry Rock Dust Concrete under Different Curing Conditions

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Abstract: *OPC is the commonly used binder for the production of concrete. Manufacturing of OPC requires quite an amount of natural resources and magnitude of carbon dioxide emitted to atmosphere is well known. It is high time to find an alternative binder to reduce the impact to environment and make concrete environmental welcoming. Geopolymer Concrete is an inorganic alumino-silicate composite consists of fly ash and geopolymer binders activated by alkaline liquids. As the production of geopolymer concrete require heating up to 60^0 to 90^0 C for activation of Alkaline liquid, the addition of cement in to geopolymer concrete might reduce heating requirement for curing of Geopolymer concrete. On this point of view present study was carried out by replacing Fly ash & Alkaline activator in Geopolymer with OPC 43 grade cement. The cement has been replaced by 0%, 10%, 30% and 50% with fly ash and alkaline activator. At each replacement level, samples were kept under three types of curing condition such as Oven Dry heating at 60^0 C, Steam curing at 60^0 C and 50% relative humidity, and normal atmospheric curing as given to normal concrete. In this study Crusher dust was used instead of sand for production of concrete. Around 156 samples were cast with different combination. It was observed that Oven dry Curing provides highest Compressive strength in comparison with Steam and Normal curing. The Maximum Compressive strength was found in Combination in 70% FA + 30% C in all three curing conditions. It was observed that hot air curing could be avoided by Geopolymer concrete is replaced by 30%*

Keywords: *Geopolymer Concrete, Fly ash, Quarry Rock Dust, curing condition*

1. Introduction

Concrete is one of the widely used materials all over the world. The demand of concrete is increasing day by day for the future need of development of infrastructure facilities [1]. It is well known that the production of OPC not only consumes significant amount of natural resources and energy but also releases substantial quantity of carbon dioxide into the atmosphere [2]. Geopolymer is an alternative material for alternatively developing Geopolymer concrete without use of cement. It is an inorganic alumino-silicate compound, synthesized from fly ash. Many literatures were suggested use of fly ash as a concrete binder and It is activated with using alkaline solutions at the temperature between 60^o C to 90^o C. With increasing temperature in the range of 60^o C to 90^o C, the compressive strength of the geopolymer concrete is also increased. The Geopolymer paste with NaOH concentration of 12 M produced maximum compressive strength. [1]. [2] A.M.Mustafa et al [3] Shankar H. Sanni [4] observed that Compressive strength is much affected by curing method and curing temperature. The average compressive strength of heat cured was 34% more than steam Curing. Prakash R. Vora [1] found that compressive strength increases with increase in the curing time, curing temperature, rest period, concentration of sodium hydroxide solution and decreases with increase in the ratio of water to Geopolymer solids by mass & admixture dosage, respectively.

As in all these studies were based on Alkaline liquid and curing heating temperature goes up to 90^0C. However, the maintaining of heating temperature of 90^0C for cast in situ product is quite impossible. Where as Popularity of geopolymer concrete among precast industry is scarce. The partial replacement of geopolymer concrete with Cement would build confidence among precast industry for use in their product. Hence present study proposed partial replacement of cement with geopolymer concrete. In this paper, an attempt is made to partially replace fly ash and alkaline liquids with cement in Geopolymer concrete in replacement levels of 0%, 10%, 30% and 50% using Ordinary Pozzolana Cement of 43 grades to evaluate the effect of various parameters affecting compressive strength. Curing to the specimen was carried in three ways viz. Hot air curing, Steam curing & Normal curing to find out in which type of curing condition would development maximum strength.

2. Experimental Programme

2.1. Materials:

In the present experimental work materials such as Flyash, OPC 43 grade Cement, Alkaline Liquid, Super Plasticizer, Quarry Rock dust, Coarse Aggregate were used as constituent of geopolymer concrete and it has been tested with relevant IS code. Low calcium fly ash was procured from the Khaperkheda thermal power plant, Nagpur. It physical and chemical properties is given in Table 1. As flyash consist of large percentage of silica instead of Calcium oxide, it is categories as Class F Fly ash. Cement was used as OPC 43 grade of Ultratech cement brand. The physical test were performed on cement as per IS 1489-1991[5] which is given in Table 2. Industrial grade alkaline liquids such as Sodium silicate solution and sodium hydroxide flakes were used. The chemical composition of the sodium silicate solution was Na_2O=15%, SiO_2=31.5%, and water 53.5% by mass as per manufacturer specification. To improve the workability of the fresh Geopolymer concrete, a polycarboxylic ether hyper-plasticiser, of Master Glenium ACE30 was used. Quarry Rock dust was used for the experiment had procured from locally available quarry in nearby area. Various tests were carried out according to IS 383-1970[6] reaffirm 1997 and IS 2386-1963[7] reaffirm 2002 to find out the properties of crusher dust as shown in Table 3 .

TABLE I: Composition of Class F Fly Ash

SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	CaO	LOI
55.5%	**28.3%**	**11.2%**	**0.69%**	**0.44%**	**1.18%**	**1.10%**

TABLE II: Physical Properties of Quarry Rock Dust

Particulars	Specific Gravity	Water Absorption
Quarry Rock Dust	2.65	0.84%

TABLE III: Sieve Analysis of Quarry Rock Dust

IS SIEVE DESIGNATION	PERCENTAGE PASSING (CRUSHER DUST)	IS 383-1963 REQUIREMENTS FOR ZONE I
10 MM	100	100
4.75 MM	98.05	90– 100
2.36 MM	71.5	60 – 95
1.18 MM	49.8	30 – 70
600 MICRON	30.5	15 – 34
300 MIICRON	17.45	5– 20
150 MICRON	12.25	0– 20
75 MICRONS	7.05	Max 15
ZONE	**ZONE I**	**ZONE I**

2.2. Concrete Mixes

The mixing procedure used for geopolymer concrete is similar to that of conventional OPC concrete. The testing plan for mixing is given in Table 4. Mixing of all the materials have been done in the laboratory at room temperature. The alkaline activator solution is prepared at least one day prior to its use. The fly ash with different percentage of cement, aggregate were mixed together in a pan mixer for about 3 to 4 minutes. The alkaline solution that was prepared 1-day prior was added along with water and super-plasticiser. Then, Wet mixing is again continued for 4 to 6 minutes. For compaction of the concrete specimens, each layer was given 25 to 35 manual strokes using 20 mm rod. Concrete specimens were vibrated using vibration table for another 10 to 15 seconds. After the casting, the concrete specimen was kept at room temperature for one day rest period.

TABLE IV: Comparison of Different Geopolymer Concrete Mixes

Ingredients	**Unit**	**Mix 1 100% FA+0%C**	**Mix 2 90% FA+10%C**	**Mix 3 70% FA+30%C**	**Mix 4 50% FA+50%C**
Fly Ash	Kg/m^3	375	337.5	262.5	187.5
Cement (43 Grade)	Kg/m^3	0	37.5	112.5	187.5
10 mm aggregate	Kg/m^3	489	489	489	489
20 mm aggregate	Kg/m^3	733	733	733	733
Crusher Dust	Kg/m^3	650	650	650	650
Alkaline Liquids	Kg/m^3	153	137.7	107.1	76.5
Na2Sio3	Kg/m^3	102	91.8	71.4	51
NaoH	Kg/m^3	51	45.9	35.7	25.5
Molarity		14	14	14	14
Super Plasticizer	Kg/m^3	5.6	5.6	5.6	5.6
Water	Kg/m^3	50	68	83	98
Curing Temperature	^OC	60	60	60	60
Humidity (Steam Curing)	%	50	50	50	50
Rest Period	Hours	24	24	24	24
Curing Period	Hours	24	24	24	24
Water-Binder Ratio		0.3-0.35	0.3-0.35	0.3-0.35	0.3-0.35

FA : Fly Ash C: Cement

2.3. Curing Of Concrete Specimen

After casting of specimen, specimens were kept for rest period of 24 hours in ambient temperature. In this studies, the concrete specimens were cured under three different curing conditions such as Hot air, Steam curing and Normal curing. For Hot air, the temperature was set to 60^OC for 24 hours. For steam curing temperature was set to 60^OC and humidity was set to 50% RH for 24 hours. In case of normal curing, specimens were kept at ambient temperature for 24 hours. After the curing period specimens were de-moulded and sent to curing tank for water curing.

3. Results and Discussion

3.1. Compressive Strength with Different Curing Conditions

The test result of 37 and 28 days compressive strength of concrete under different curing condition is given in Table 5.

TABLE V: Experimental Results (Compressive Strength)

Sr.	Geopolymer	Avg. Compressive Strength (MPa)		
		3 Days	7 Days	28 Days
1	100 % Fly Ash + 0 % Cement			
	Normal Curing	6.55	12.47	20.11
	Steam Curing	23.0	24.9	26.81
	Hot air Oven	24.5	26.32	28.13
2	90 % Fly Ash + 10 % Cement			
	Normal Curing	7.8	15	21.9
	Steam Curing	16.75	22.4	26.8
	Hot air Oven	20.6	24.6	30.2
3	70 % Fly Ash + 30% Cement			
	Normal Curing	12.45	20.62	29.2
	Steam Curing	18.57	25.3	34.1
	Hot air Oven	21.2	28.2	36.7
4	50 % Fly Ash + 50%Cement			
	Normal Curing	12.85	17.7	27.5
	Steam Curing	14.19	24.17	30.3
	Hot air Oven	16.1	26.48	33.9

Figures were plotted as shown in Fig. 1 to 4 for different percentage of cement with fly ash under different curing condition. It was observed that compressive strength of Geopolymer concrete under hot air oven has higher compressive strength in comparison with steam and normal curing. Hot air oven cured cubes have compressive strength of 30.2 MPa, whereas steam and normal cured have 26.8 and 21.9 MPa strength respectively at 28 days. The increase in compressive strength from 7 to 28 days under hot air and steam cured cubes where found to be 22% & 19% respectively whereas increase in strength of compressive strength from 7 to 28 days for normal cured was found to be 46%.

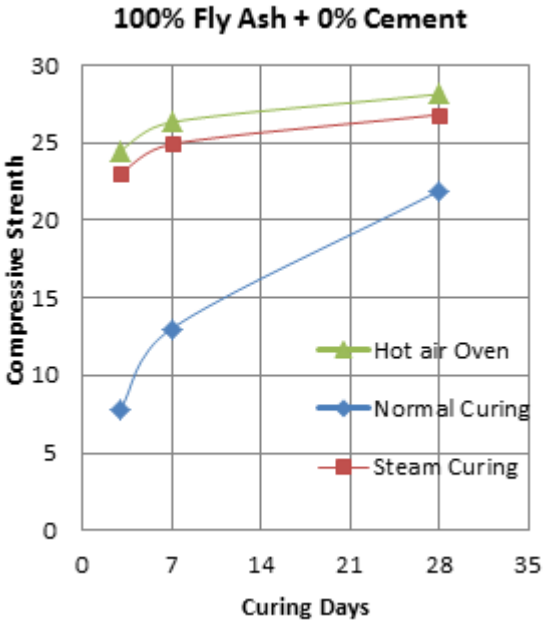

Fig. 1: Comparison of compressive strength of 100 % Fly Ash + 0% cement GPC

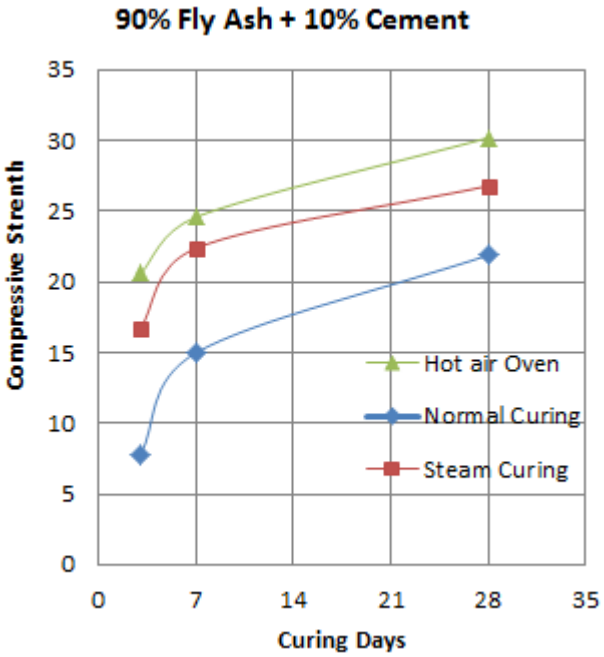

Fig. 2: Comparison of compressive strength of 90 % Fly Ash + 10% cement GPC

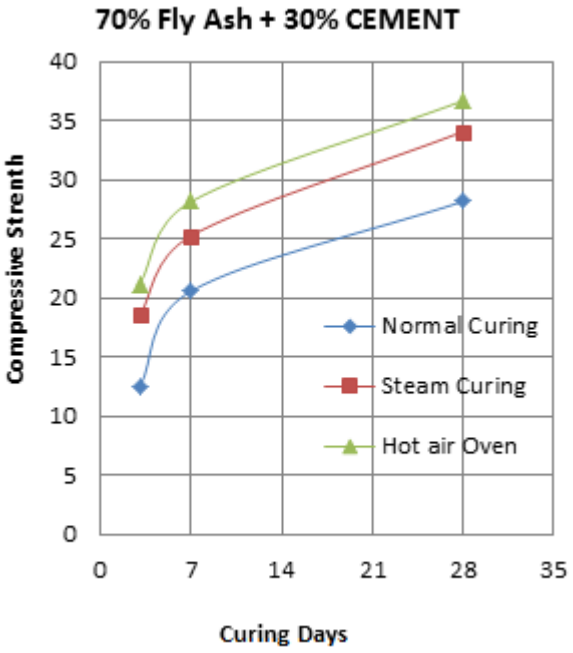

Fig. 3: Comparison of Compressive Strength Of 70 % Fly Ash + 30% Cement GPC

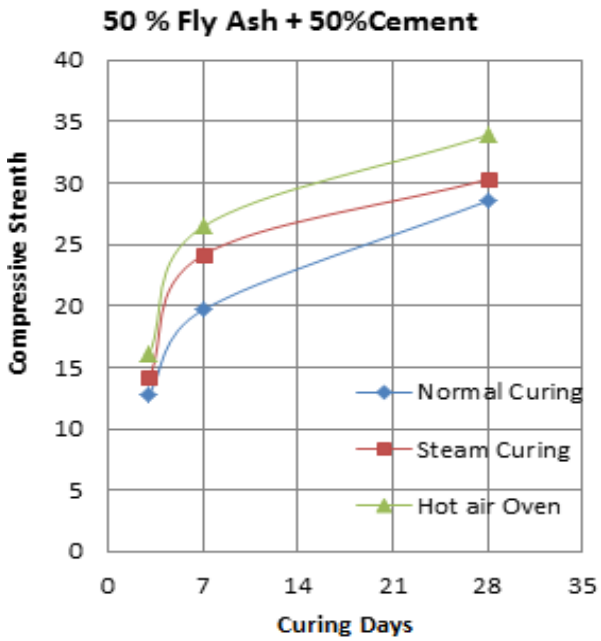

Fig. 4: Comparison of Compressive Strength Of 50 % Fly Ash + 50% Cement GPC

3.2. Compressive Strength with % by Weight of Cement Replacement

Comparative graph were plotted between compressive strength and percentage by weight of cement replacement in geopolymer concrete as shown in Fig 5 to Fig 7. It was observed from the Fig 5 that at 3 days of testing, 100% FA + 0% C condition gives maximum compressive strength when compared to other replacement levels. In this case normal curing condition strength is increasing with increase in addition of % of cement. From the Fig. 5, at 28 days strength test, the 30% replacement level gives highest compressive strength under Hot curing condition. With the 30% replacement of cement, the compressive strength has increased from 28 MPa to 36.7 MPa (around 32%) in case of hot cured concrete. It is also observed that at 0% replacement of cement the compressive strength is 28.1 MPa under hot air curing and with 30% replacement of cement, the compressive strength is 28.2 MPa under normal curing condition. Hence hot air curing would be avoided if geopolymer concrete is replaced with 30% of cement.

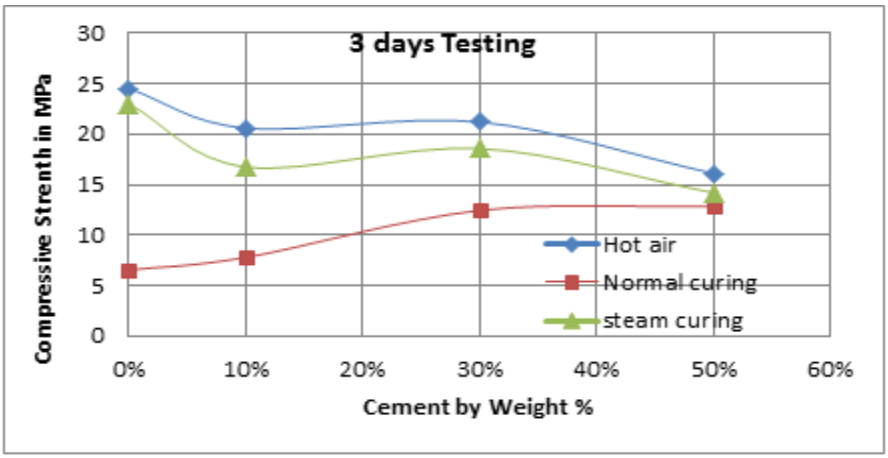

Fig. 5: Comparison of compressive strength of GPC cubes with increase in cement by weight % (3 Days)

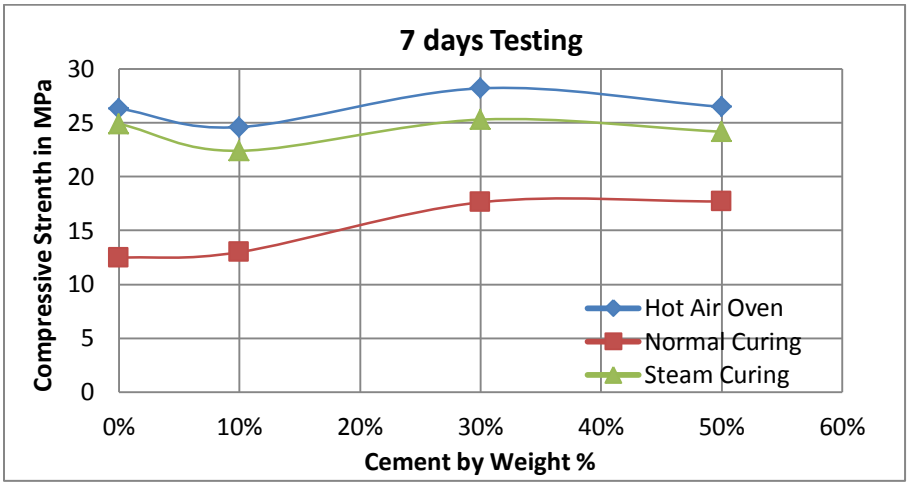

Fig. 6: Comparison of Compressive Strength of GPC Cubes with Increase in Cement By weight % (7 Days)

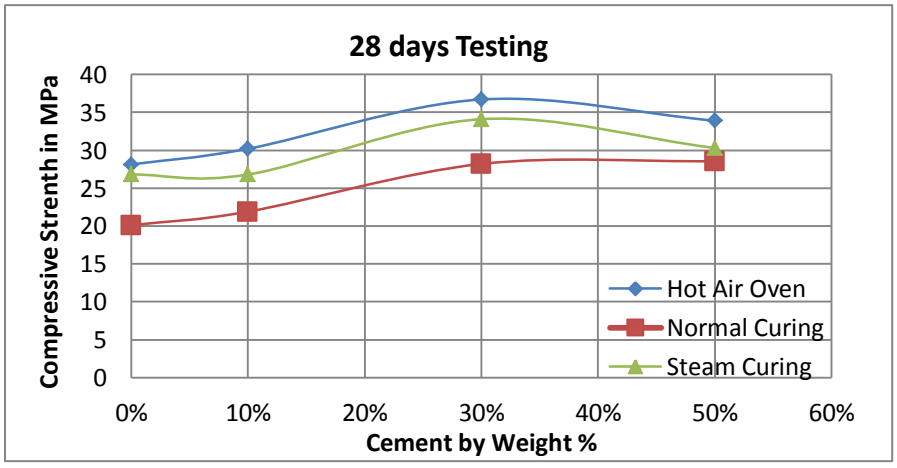

Fig.7: Comparison of Compressive Strength of GPC Cubes with Increase. In Cement By weight % (28 Days)

4. Conclusions

Based on above results of the experimental investigation, following conclusions could be drawn are as follows

1. Hot Air Curing provides highest Compressive strength in comparison with Steam and Normal curing.
2. Maximum Compressive strength was found in Combination of 70% FA + 30% C in all curing conditions.
3. It is also observed that at 0% replacement of cement the compressive strength is 28.1 MPa under hot air curing and with 30% replacement of cement, the compressive strength is 28.2 MPa under normal curing condition. Hence hot air curing would be avoided if geopolymer concrete is replaced with 30% of cement.
4. Steam curing (60^{o}C and 50% Humidity) condition could be relatively better option than the Hot air curing condition (60^{o}C). The presence of humidity condition in the concrete reduces compressive strength.

5. For Normal curing condition, with increase in amount of cement by weight %, Compressive & Flexural strength increases.
6. The Compressive strength of Geopolymer concrete was found to be increasing with replacement of fly ash by cement. It is found that replacement of 30% of fly ash by cement provides highest compressive strength.

5. References

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