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INFLUENCE OF SODIUM HYDROXIDE CONCENTRATION ON THE STRENGTH OF FLYASH BASED GPC

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ABSTRACT

Substitute for cement is the global research need and apart from high volume flyash concrete. The recent research on the bulk utilisation of flyash is the development of GPC to promote the green concrete avoiding the CO2 emission from cement production and finds its way in a most typical means of development. This article brings out the development of low calcium flyash based GPC to achieve the required equivalent characteristic strength of 30MPa. GPC with different molarity of sodium hydroxide in the activating solution is produced by both hot and ambient curing methods for comparison. The activator/ flyash ratio by mass is taken as 0.35 and the liquid ratio as 2.5. It is concluded that, ambient curing is adequate for low calcium flyash based GPC.

KEYWORDS: Substitutes for Cement -flyash- alkaline solution-activator-geopolymer concrete-hot and ambient curing.

INTRODUCTION

Geopolymer concrete (GPC) is mostly obtained by alkali-activation of pozzolanic materials and found to possess excellent properties as concrete. GPC consists of a source material similar to cement and activating solution instead of water to act as a binder with common aggregates as conventional concrete. In its typical formation, GPC required hot steam curing (Joseph Davidovits, 1994) to attain high early strength. One ton of low-calcium flyash can produce 2.5 cubic metres of high quality geopolymer concrete, and the bulk cost of chemicals needed to manufacture this concrete is cheaper than the bulk cost of one ton of Portland cement (Hardjito and Rangan, 2005). Geopolymer chemistry is totally different from hydration process (Joseph Davidovits, 2011). Extensive studies conducted on Australian flyash based geopolymer concrete showed high early strength, low drying shrinkage and high freeze and thaw resistance (Rangan, 2008). Mix design procedure has also been developed for different grades of GPC (Rangan, 2008: Rajamane et al, 2012 and Anuradha et al, 2012). Qualitative information is available and it is possible to practically formulate the alkali activating solution for flyash to achieve required strength and other mechanical properties (Rajamane and Jeyalakshmi, 2014).

As a high quantum of flyash is available as waste, its utilization is limited and storing of flyash is a hectic problem, there is a need for high volume utilization flyash for structural purpose. However, research has to be focused on user friendly GPC. Therefore an experimental study is initiated for promoting a viable way of producing low calcium flyash based GPC here.

EXPERIMENTAL INVESTIGATION

For conventional concrete, OPC 43 grade is used and low calcium flyash (ASTM Class F) from Mettur Thermal Power Station for GPC. The chemical composition of cement and flyash used is presented in Table 1. The sodium hydroxide (pellets later dissolved in water) and sodium silicate solution in combination are used as the activator solution. Mix design for M30 grade concrete (IS: 10262-2009) and equivalent (GM30) grade GPC (Rangan 2008) is made based on the material properties. The constituent materials used for alkaline solution are shown in figure 1.

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Table 1 Chemical composition of flyash and cement used

No	Elements	Mass (%)	
		Class F flyash	OPC 43 grade
1	Silicon dioxide (SiO_2)	54.40	22.60
2	Aluminum oxide (Al_2O_3)	25.64	04.30
3	Ferric oxide (Fe_2O_3)	11.32	02.40
4	Calcium oxide (CaO)	02.03	64.40
5	Magnesium oxide (MgO)	00.92	02.10
6	Sulphur trioxide (SO_3)	01.70	02.30
7	Sodium Oxide (Na_20)	00.41	00.04
8	Potassium oxide (K_2O)	00.73	00.02
9	Titanium dioxide (TiO_2)	01.53	-
10	Loss on Ignition	01.32	02.20

Fig.1 Constituents of alkaline solution for GPC

The liquid ratio is taken as 2.5 and activator/flyash ratio by mass as 0.35. Mass of NaOH solids is obtained as 320, 400, 480 and 560gm/litre of NaOH solution and also as 262, 314, 361 and 404gm/kg respectively for 8M, 10M, 12M and 14M molarities of NaOH (Rangan, 2008) considered. The Sodium hydroxide solution is prepared 24 hours prior to use, because after dissolving the solids in water, the temperature of solution can go up to 80oC, hence it is necessary to cool it at room temperature before use.

Conventional river sand (specific gravity 2.64) and 12.5mm maximum size coarse aggregates (specific gravity 2.7) are used. The Sodium hydroxide solution thus prepared is mixed together with Sodium silicate solution to get desired alkaline solution. The mix proportions for the trial mix and the quantities for one meter cube of concrete are given in Table 2.

Table 2 Mix proportions for OPCC and GPC

No	Constituents	OPCC (M30)		GPC (GM30)	
		Ratio	Wt/m^3	Ratio	Wt (kg/m^3)
1	Cement /Flyash	1	475	1	550
2	Sand	1.25	594	1.1	605
3	Jelly 12.5mm	2.25	1068.8	1.5	838
4	Water / Activator		190	2.5	225/90

5	w/c ratio/ Activator/FA	0.40	-	0.68	-
6	Admixture	Supaflo special 1 %			
7	Slump	50mm		Made to 50mm	

CASTING OF SPECIMENS

Five specimens are cast out of OPCC of grade M30. For GPC for each molarity of sodium hydroxide ten specimens are cast, out of which five are kept for hot curing and five for ambient curing. Actually five specimens of OPCC and 4×2×10 = 80 specimens of GPC and thus, totally 85 specimens are cast. The flyash and aggregates are mixed in a pan mixer for few minutes and the activating solution premixed with admixture is then added to the dry mixture, and mixing continued for few more minutes. Immediately after discharging from the mixer machine, slump test is conducted for workability (IS: 1199 -1959) and the slump values are compared in figure 2.

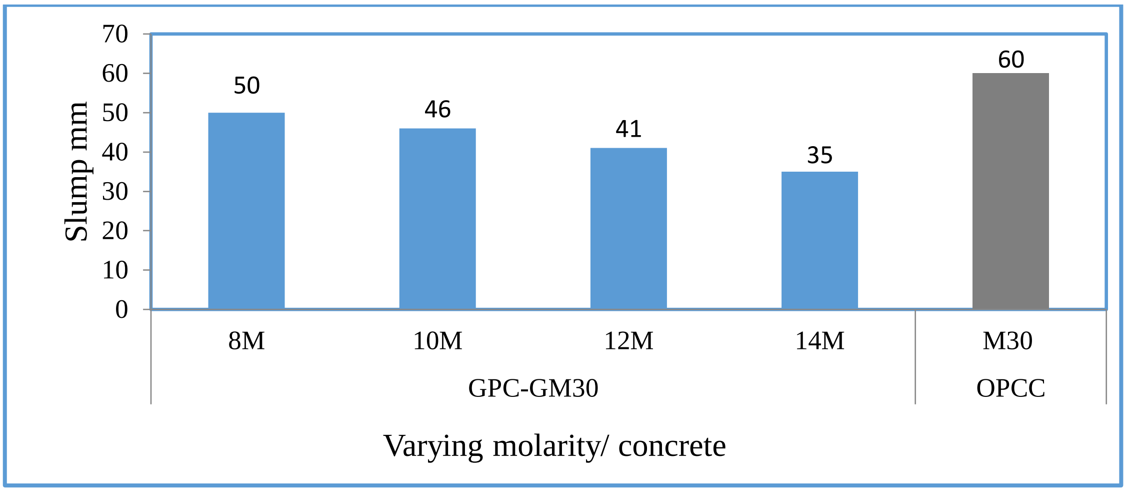

Fig.2 Comparison of workability of GPC and OPCC

The concrete is poured in the cube moulds of 100mm size in three layers and compacted by placing on the table vibrator. After finishing the top, the specimens are wrapped by placing a lid on the mould. Hot curing in the laboratory oven at 65°C for 24 hours as well as ambient curing (at room temperature of 29±1°C for 28 days exists are adopted separately. Appropriate curing days, the specimens are tested for compressive strength as per standards (IS: 516 -1959) and the results are presented in Table 3 and the comparison of the average values is shown in figure 3.

Table 3: Comparison of compressive strength

No	Compressive strength of concrete								
	M30	Molar concentration for GM30 by Oven*/ Ambient** curing							
		8M		10M		12M		14M	
1	40.2	35.6	34.4	36.4	34.9	39.1	37.5	41.1	39.6
2	38.7	34.7	35.3	36.3	36.3	41.3	38.5	42.3	42.6
3	40.6	34.3	33.1	37.1	34.6	41.2	38.3	42.1	39.8
4	39.1	34.4	31.1	37.4	35.2	40.4	37.8	42.4	41.8
5	39.8	35.1	33.2	36.3	35.3	40.6	38.7	40.9	39.5
Average	39.68	34.82	33.42	36.70	35.26	*40.52*	*38.17*	41.76	*40.66*
Fraction of M30		0.878	0.842	0.925	0.889	1.021	0.962	1.052	1.025

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Fraction of HC#	-	0.960	-	0.961	-	0.942	-	0.974
* For 24 hours at 65ºC: ** at 28 days: # strength of hot cured concrete								

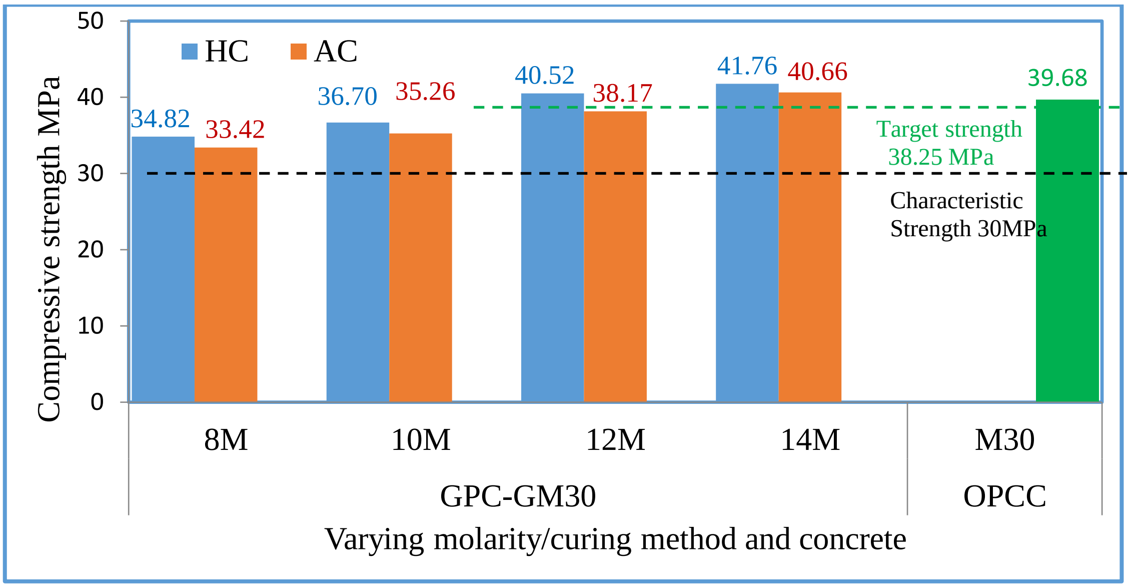

Fig. 3 Comparison of average compressive strength

DISCUSSION

- The slump of GPC decreases for the increase in molarity of NaOH and that is why extra water is added to make the slump to virtually 50mm for 12M and 14M based concrete. The slump of OPCC is more than that of GPC meaning that the OPCC is more workable than GPC.
- The actual strength of OPCC is 3% more than its target strength for M30 grade concrete.
- Extra water is required for concrete with higher molar concentrations of sodium hydroxide solution like 12M and 14M to make them workable with a slump of 50mm in case of GPC.
- The compressive strength of GPC increases gradually for oven curing for all molar concentrations considered (8M-14M) and the same trend is observed for ambient curing also. Thus the compressive strength is directly proportional to the concentration of NaOH irrespective of the type of curing.
- The strength of ambient cured specimens is always less and about 95% to 97% of the hot cured concrete irrespective of the molarity of NaOH solution. But the characteristic of the M30 grade of concrete is reached even in 8M molar based GPC.
- However, the equivalent target strength of GPC is reached by hot curing for NaOH molar concentration of 12M and above. In case of ambient cured concrete the equivalent compressive strength is just reached for 12M molarity based concrete but, to be on the safer side it shall be stated for M14 based concrete only.

CONCLUSION

Based on the experimental investigation in developing low calcium flyash based geopolymer concrete (GM30) of equivalent M30 grade, it is concluded that,

- The higher concentration of NaOH reduces the slump value and extra water is needed for workability.
- OPCC is more workable compared to GPC
- The equivalent characteristic strength of GPC even 3% more than that is easily obtained with the lowest molarity (8M) of NaOH both in hot and ambient curing.
- But the equivalent target strength is reached only at 12M concentration in hot curing which is also almost equal in ambient curing
- Ambient curing yields about 95-97% of the hot cured strength.
- The compressive strength is directly proportional to the concentration of NaOH irrespective of the type of curing for GPC.

- Under specified concentration of NaOH, the required strength of GPC can be achieved by ambient curing itself and hot curing is not at all required under laboratory condition. Hot curing may be employed in case of fabrication of precast units

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