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INFLUENCE OF NaOH CONCENTRATION ON THE PROPERTIES OF CLASS C FLYASH BASED GPC

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ABSTRACT

Geopolymer concrete is a recent development in the concrete research aiming for an alternate for the conventional cement concrete. As the rate of emission of CO_2 from cement and concrete industries is increasing day by day, more more researchers are diverted to investigate an alternate binder to conventional Portland cement. Geopolymer in its most effective development process involve the utilisation of a source material with sodium based alkaline activator and hot curing at 60^{o}C-100^{o}C.However, it is still in the laboratory level due to many constraints like, typical constituents, casting procedure, hot curing and compatibility with the reinforcing or prestressing steel. Also, most of the works reported are based on low calcium flyash and onlya few studies using high calcium flyash. Therefore, being more cementitious, development of GPCusing high calcium flyash with sodium based activating solution having liquid ratio of 2.5 isdealt. The influence of Molaity on the workability and strength of three grades of GPC equivalent to conventional M20, M30 and M40 grades of cement concrete are studied.It is observed that the expected strength of GPC can be achieved for specific molarity of NaOH by hot curing.

***Keywords**: Class C flyash, alternative binders, Geopolymer concrete, activating solution, hot curing*

I. INTRODUCTION

Geopolymer concrete (GPC) utilises the waste materials like flyash, GGBS, rice husk ash, red mud or metakaolin as a source material (Joseph Davidovits, 1994 and 2011). These source material can be activated using alkaline solution comprising of sodium or potassium based combinations of hydroxide and silicates in certain proportions. For its common availability and less expensice, the Sodium based solution is always preferred over potassium based solution. The variable involved in the proportioning of the GPC are the alkaline solution to flyash ratio, the molar concentration of the hydroxide and the liquid ratio between the hydroxide and silicates. The hot curing in a steam chamber or hot oven for 6-24 hours at higher temperature hardens the concrete attributing strength earlier by the process of polymerisation. Ambient or exposed curing have also been recommended.In the development of GPC, The preparation of required quantity of activating solution is typical.

The hot curing method has been varied by many studies as, 30°C to 90 °C steam curing in 6 to 96 hours (Djwantoro Hardjito et al, 2004), hot oven curing at 60^{o}C for 24hours (Vijai et al, 2012), steam curing at 85^{o}C for 5hours (Palomoa et al, 1999 and oven curing at 80°C, 90°C and 100°C for 12 and 24hours (Mohammed Rabbani, et al, 2014) and reported the achievementof higher strength. Ambient curing was also implemented by Bhosale and Shinde (2012), Krishnan et al (2014) and Kumaravel (2014) stating that a longer curing time under elevated temperature significantly did not affect the strength of geopolymer paste (Daniel et al, 2006) and rapid curing and curing at high temperature resulted in cracking and can impose negative effects on the physical properties of GPC and the water content is also critical for polymerization(Van Jaarsveld et al, 2003).

Of all the the source materials considered, flyash has been found abundantly available. In India, flyash generation is expected to increase to 300 million tons per annum by 2017 and 900 million tons per annum by 2031-32 (Joshi, 2014). Most of the works reported even by the pioneers are related to the low calcium flyash but very few about the high calcium flyash. Investigations on the use of class C (high calcium) flyash as source material for developing GPC (Shankar and Khadiranaikar,2012; Ashley Russell et al, 2015 and Prinya Chindaprasirt et al, 2013) indicated that the heat-cured fly ash based GPC to result in a dense composite and strong bonding between the fly ash and the geopolymer matrix leading to high strength gain and had an excellent resistance to acid and sulphate attack when compared to conventional concrete.

Neyveli Lignite Corporation (NLC) is a lignite based Thermal Power Station, annually 1.20 million tons of high calcium flyash is produced. As the utilization is only about 20 percent and storing and disposal of ash is also a problem for the corporation. Therefore, there is a need for bulk utilization of this flyash for structural purpose. Being high in calcium content class C flyash is more cementitious less pozzolanic in reaction compared with low calcium flyash. An ideal solution for these problems is to promote the potential use of the waste flyash as a sorce material and developing GPC by totally replacing the conventional cement in concrete.GPC has been attracted as an alternative to cement concrete in order to reduce the ill effects of cement production causing atmospheric pollution. But the technology is still in the laboratory levels ith out a data base and the development process needs to be simplified

II. EXPERIMENTATION

The OPCC grades M20, M30 and M40 (using OPC 43 grade cement) and similar equivalent grades of GPC designated as GM20, GM30 and GM40 are designed respectively. The chemical composition of cement and flyash is presented in Table 1.

Table 1 Chemical Composition of low calcium flyash and cement

Material	Mass of elements (%)									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	TiO_2	MgO	SO_3	LOI
Flyash	47.60	21.40	07.80	11.90	00.70	00.82	01.88	01.80	02.80	03.30
Cement	22.60	04.30	02.30	64.30	00.05	00.04	-	02.20	02.10	02.10

The schematics of the experimental work is shown in figure 1. Fine aggregate (river sand) having specific gravity of 2.64 and fineness modulus 2.62 and coarse aggregate (hard granite stone of 12.5mm) of maximum siz having specific gravity of 2.7 and fineness modulus 6.12 are used for both OPCC and GPC. Based on the experience of the preliminary study and requirements, the sodium based alkaline solution with liquid ratio of 2.5 is considered. The molarity of NaOH is varied as 8M, 10M, 12M and 14M. For preparation of alkaline solution, Sodium silicate (Na_2SiO_3) with Na_2O = 12%, SiO_2 = 30%, and water = 58% by mass and Sdium hydroxide with 98% purity are used. The mass of the solids obtained based on the Perry's Chemical Engineer's Hand Book (Rajamane and Jeyalakshmi, 2014) is given in Table 2. The alkaline liquid and the mixture are prepared 24 hours before use for concrete. The constituents of alkaline solution is shown in figure 2. For brevity, only the constituent details of GPC are given in Table 3.

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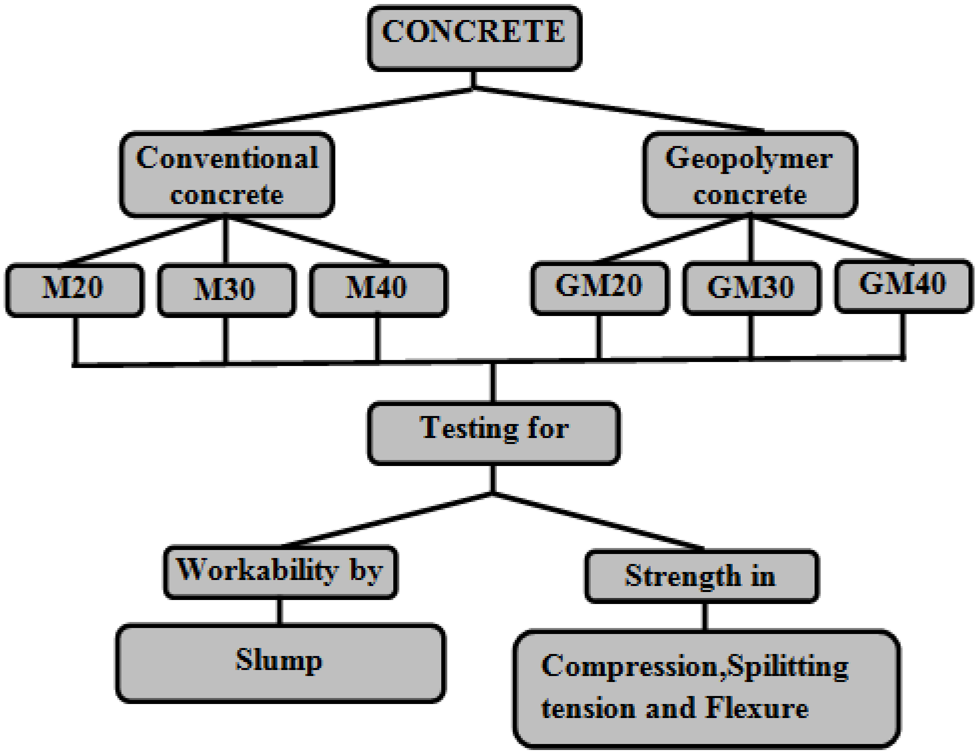

Fig. 1 Schematics of the experimental programme

Workability Characteristics

Workability is an indication of the quality of concrete with respect to consistency, cohesiveness and possibilities to segregation. The constituents for a particular batch of required quantity of concrete are got by weigh batching. OPCC is prepared in the standard way of mixing and GPC also is prepared conventionally. Flyash and the aggregates are first mixed together dry for about three minutes. The alkaline liquid component prepared 24 hours in advance is then added to the dry materials and the mixing continued for another four minutes. With the prepared concrete, the slump test is conducted and the results are compared in figure 3.

Table 2 Mass of NAOH solids by Perry's Chemical Engineer's Hand Book

Molarity	NaOH(gm) for 1kg solution		Concentration of NaOH solution	
	NaOH solid	Water	Ws mass/mass	%
8M	255	745	2.55	25.5
10M	306	694	3.06	30.6
12M	354	646	3.54	35.4
14M	400	600	4.00	40.0

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Fig.2 Ingredients of alkaline solution

Table 3 Constituent quantities for one m^3 of GPC

Grade	M	NaOH			Na_2SiO_3			Fly ash	Aggregates	
		Solid/ Water/Solution			Solid/ Water/Solution				Fine/Coarse	
GM20	8M 10M 12M 14M	09.41 11.29 13.07 14.77	27.50 25.62 23.85 22.15	36.91	40.70	51.59	92.29	230.8 (1)	612 (2.65)	1428 (6.19)
GM30	8M 10M 12M 14M	13.39 16.07 18.59 20.99	39.11 36.43 33.91 32.50	52.50	57.86	73.35	131.21	296.3 (1)	576 (1.95)	1344 (4.54)
GM40	8M 10M 12M 14M	17.23 20.67 23.91 27.02	50.32 46.87 43.63 40.52	67.55	74.47	94.39	168.86	363.6 (1)	540 (1.49)	1260 (3.47)

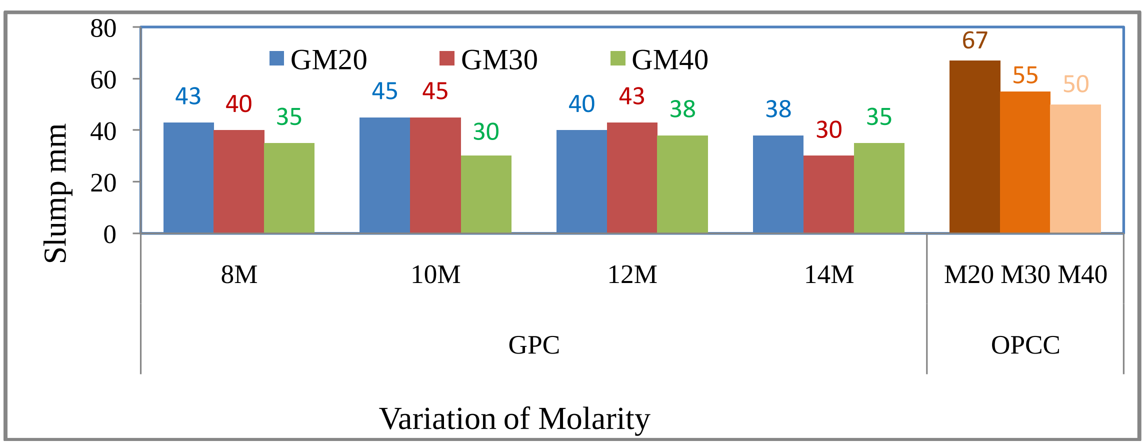

Fig.3 Comparison of workability characteristics

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III. STRENGTH PROPERTIES

The concrete is cast in oiled steel moulds and compacted over table vibrator. The cast OPCC specimens are demoulded after 24 hours of casting and then put for pond curing for 28 days. The GPC specimens are cast and kept inside a polythene coverage. The next day, once set of specimens are kept inside the hot oven at 60°C for 24 hours and then kept for further curing at room temperature.Specimens like 100mm cubes for compression, 100×200mm cylinders for splitting tension and 100×100×500mm prisms for flexure (moulus of rupture) are cast respectively. These specimens aretested in three days of casting for their properties in a standard manner uniformly in accordance with IS 516-1959.Modulus of rupture test is conducted by two point loading system. The test results are compared in figures 4, 5 and 6 respectively for their variation.

IV. ANALYSIS OF RESULTS

The slump values decrease as the grade levels increase from M20 to M40 for OPCC and the expected range of 50-100mm is maintained. But for GPC the slump values are always less compared to OPCC and the variation with respect to the molarity of NaOH is not significant.

The compressive strength increases for increase in the molarity of NaOH irrespective of the grades of GPC and also it increases as the grade level rises. Equal grade strength of GPC is reached incase of GM20 for 8 molarity, GM30 for 10 molarity and GM40 for12 molarity itself.

The splitting tensile strength also increases for increase in the molarity of NaOH irrespective of the grades of GPC and also it increases as the grade level increases. Equivalent grade strength of GPC is reached in case of GM20 for 8M, GM30 for 10 M and GM40 for 12M of NaOH. The same trend is also experienced in case of modulus of rupture of GPC.

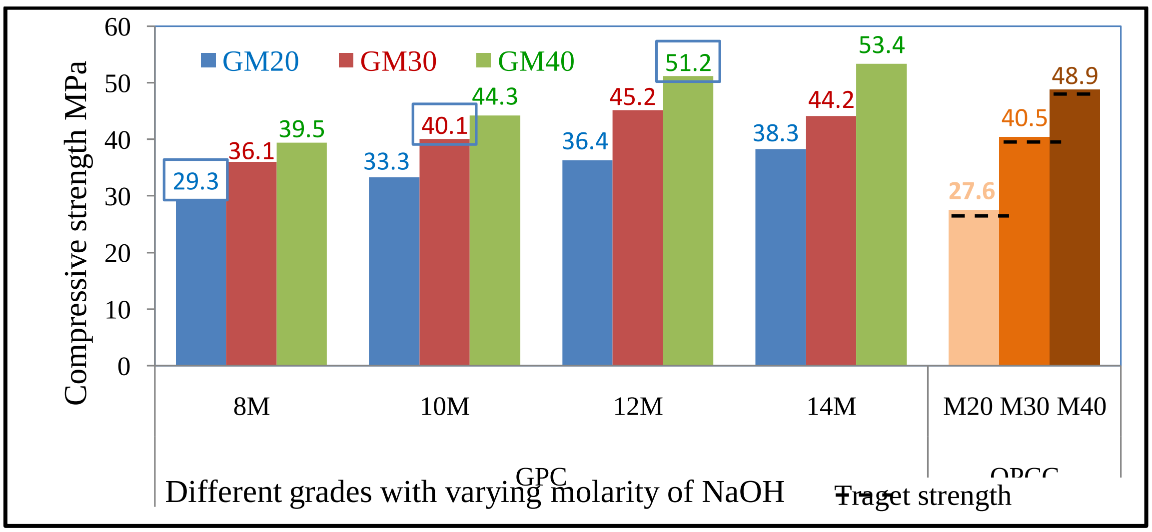

Fig.4 Comparison of compressive strength in hot curing

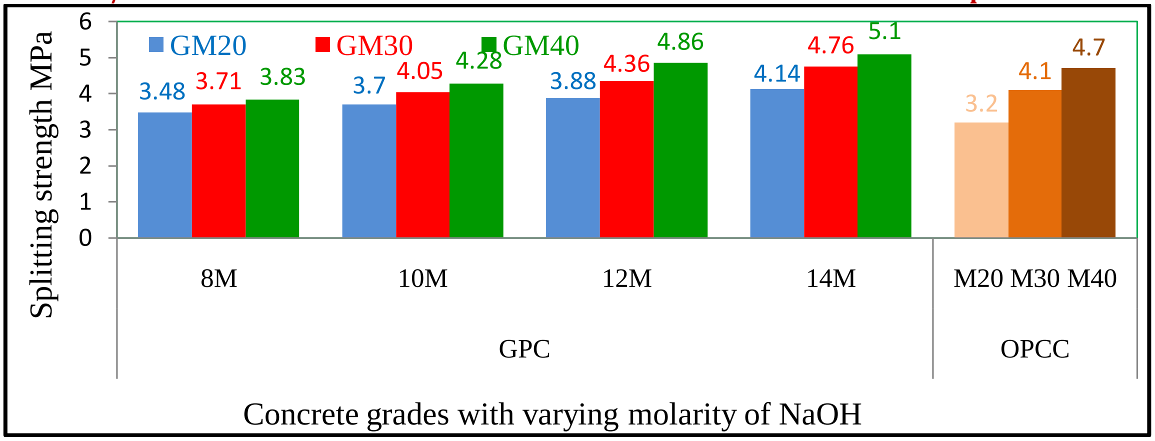

Fig.5 Comparison of Splitting tensile strengthin hot curing

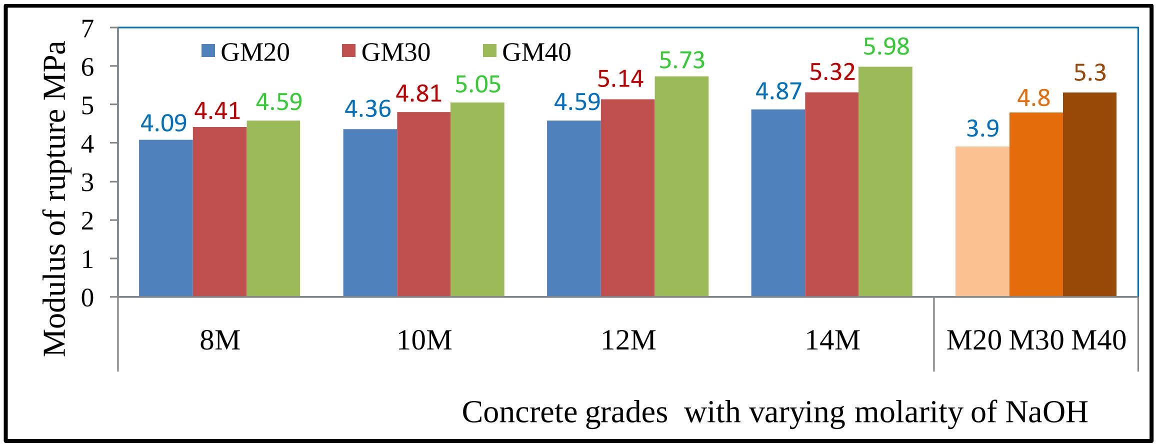

Fig.6 Comparison of flexural strengthin hot curing

V. CONCLUSIONS

- The slump values of GPC are always less compared to similar grades of OPCC for all the three grades. The variation of slump values with respect to the variation of molarity of NaOH is not significant for GPC.
- The compressive strength increases for increase in the molarity of NaOH irrespective of the grades of GPC.
- The expected grade strength of GPC is reached for specimic molarities of NaOH like 8M for GM20, 10M for GM30 and 12M for GM40 respectively. The high concentration of NaOH like 14M are not required.
- The same trend like compressive strength is also observed for splitting tensile strength as well as modulus of rupture of GPC

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