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Study on the compressive strength of fly ash based geo polymer concrete

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Abstract. Introduction of the alternative materials for complete replacement of cement in ordinary concrete will play an important role to control greenhouse gas and its effect. The 100% replacement of binder with fly ash (in integration with potassium hydroxide (koh) and potassium silicate (k_2sio_3) solutions) in concrete gives a significant alternative to conventional cement concrete. This paper focuses on the effect of alkaline solutions koh and k_2sio_3 on strength properties of fly ash based geo polymer concrete (fgpc); compared the strength at different molarities of alkaline activator koh at different curing temperature. Fly ash based geo polymer concrete was produced from low calcium fly ash, triggered by addition of koh and k_2sio_3 solution and by assimilation of superplasticizer for suitable workability. The molarities of potassium hydroxide as 8m, 10m and 12m molarities were used at various curing temperatures such as 60˚c, 70 ˚c and 80˚c. Results showed that for given proportion to get maximum compressive strength the optimum molarity of alkaline solution is 12m and optimum curing temperature is 70 ˚c.

1. Introduction

Concrete is one of the essential materials for the infrastructure development due to its versatile applications and global use of it is second only to water. To fulfil this huge demand of the concrete, the cement production is also increasing day- by- day. Carbon dioxide (CO_2) emissions from the cement producing industries are generating up to 5% of worldwide man-made emissions of it. Hence, to reduce the environmental impact due to cement manufacturing, innovation of the alternative materials has now become the need of the hour. Flyash based Geopolymer Concrete (FGPC) is one of the alternative to the conventional Ordinary Portland Cement (OPC) concrete where the pozzolanic material like fly ash is used as a binder instead of cement[1,2,3,4,5]. Use of the fly ash as a geopolymer binder can save up to 80% of CO_2 emission. The fly ash is composed of fine particles and is a by-product of the coal fired electric and steam producing plants. Fly ash based GPC is ideally used for building and repairing infrastructure. FGPC has high early strength, also their time of setting can be controlled and they remain integral for a very long time. Due to the characteristics the FGPC is used for pre-casting units[7,8,9,10].

2. Objectives

The objectives are to study the effect of alkaline solution of KOH and K_2SiO_3 on the Strength properties of a FGPC, to compare the strength of the FGPC at different molarities of alkaline activator (KOH) and to compare strength of FGPC at different curing temperatures.

3. Research Significance

From the most of the research papers it is found that KOH and K_2SiO_3 alkali were used as an activator by a little number of investigators. No one has provided the optimum molarity and optimum curing temperature for KOH activator to get maximum compressive strength of geopolymer concrete.

4. Experimental Investigation

4.1. Materials

The Coarse aggregate and Fine Aggregate used for the FGPC mixes were satisfied the requirements given in IS: 2386 Part 3. The specific gravity values of fine aggregate and coarse aggregate used is 2.57 and 2.66, respectively. For the concrete mixes, Class F fly ash from Ennore thermal power plant was used. The Combinations of KOH and K_2SiO_3 were used to activate the binder material. The alkaline solutions were made 24 hours prior to use[6]. Three various concentrations of KOH like 8 M, 10M and 12M were used. The workability of FGPC was enhanced with the use of Sulphonated Naphthalene based superplasticizer. The Chemical Composition of Fly ash is given in Table 1.

Table 1. Chemical Composition of Fly ash

Components	Low Calcium Fly Ash (%)
Silicon dioxide	19 - 59
Aluminum oxide	4 - 34
Iron oxide	11 - 41
Calcium oxide	0 - 6
Loss of ignition	0 - 16

The properties of Potassium Silicate and Compositions of Potassium Hydroxide are given in Table 2 and Table 3, respectively.

Table 2. Properties of Potassium Silicate

Physical Properties		Chemical properties	
Specific Gravity	1.385	K_2O % (by mass)	12.79
Baume	40	SiO_2 %	26.98
Viscosity	250 cps	Weight ratio	1:2.1
Twaddle	76	Molar Ratio	1:3.3
pH	12	Total solids	39.8

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Table 3. Composition of Potassium Hydroxide

Compounds	Percentage	Compounds	Percentage
Assay	85 min	Sulphate	0.01 max
Carbonate	2 max	Lead	0.001 max
Chloride	0.005 max	Sodium	1 max

4.2. Mix Design

There are no standardized procedures for the mix design for FGPC. With the help of previous research work, different trials were made. Three trial mixes with different molarities of Potassium Hydroxide such as 8M, 10M, and 12M were used. Also, the ratio of potassium silicate to potassium hydroxide as 1.50 was fixed. The 100 mm cube specimens were cast with trail mixes given in Table 4 and specimens were kept in the oven for 24 hours at varying curing temperatures of 60˚C, 70 ˚C and 80 ˚C. After hot air curing, the specimens were kept in ambient air. The ratio between alkaline solution and Fly ash is given in Table 5.

Table 4. Mix Proportion of Fly ash based Geo polymer Concrete

Mix sample	Fly Ash (kg/m^3)	CA (kg/m^3)	FA (kg/m^3)	KOH		K_2SiO_3 (kg/m^3)	SP (kg/m^3)	Curing Temp (˚C)
				(kg/m^3)	M			
S1	400	1158	686	48	8	72	6	60
S2	400	1158	686	60	10	90	6	70
S3	400	1158	686	72	12	108	6	80

Table 5 Ratios of Alkaline solution to Fly ash

Trials	Alkaline solution/ Fly ash
S1	0.30
S2	0.38
S3	0.45

5. Results and Discussions

All the cubes were tested to find compressive strength by using the Compression Testing Machine (CTM). The rate of loading was 2.5kN/s during the test. The Compressive strength of concrete cubes were tested at 7 and 21 days. The results of the findings of the current work is absolutely matching with the earlier investigators. At the temperature of 70˚C for the period of two hours, the specimens were showing higher compressive strength for the molarity of 12M of alkaline solution of KOH. The optimum usage of superplasticizer was 1.5% by weight of binder. The failure pattern of the cubes is shown in Figure 1.

Figure 1. Testing and Failure Pattern of specimen

Table 6. Results of the Compressive strength

Molarity	Curing Temp °C	Curing Days		Avg. Compressive strength (MPa)	
8	60	7	21	16.9	26.76
	70	7	21	24.5	38.79
	80	7	21	21.4	33.88
10	60	7	21	18.9	29.93
	70	7	21	31.8	50.35
	80	7	21	26.5	41.96
12	60	7	21	20.3	37.14
	70	7	21	38.5	57.75
	80	7	21	29.8	47.18

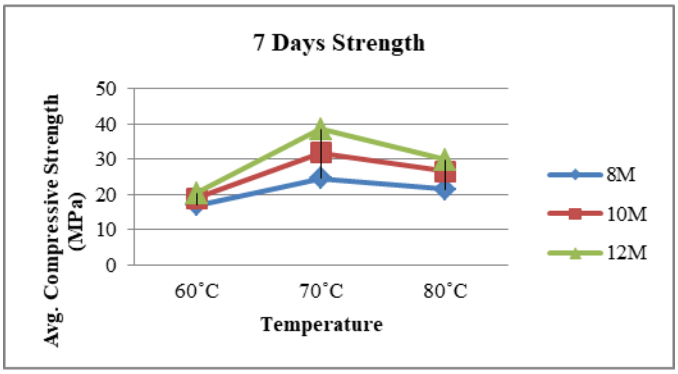

Figure 2. Compressive Strength at the age of 7 days curing

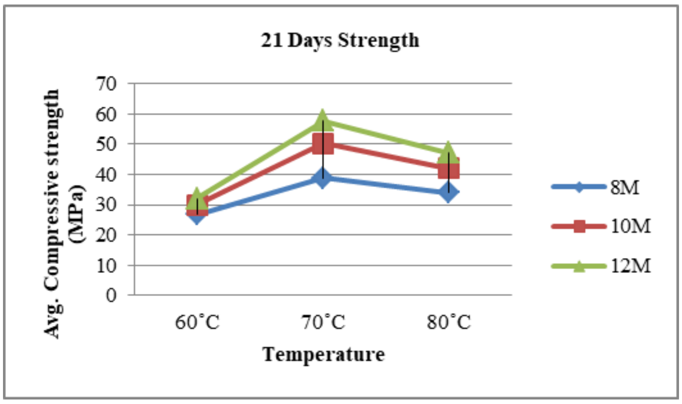

Figure 3. Compressive Strength at the age of 21 days curing

6. Conclusions

Based on the experimental research the following conclusion are drawn:

1. The maximum compressive strength of FGPC is attained for the optimum molarity of 12M of alkaline solution of KOH.
2. The optimum temperature required to get the maximum compressive strength is 70˚C.
3. The optimum superplasticizer content is 1.5% by weight of binder to get required workability and for maximum compressive strength.

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