An Experimental Studies on GPC at Ambient Curing Temperature

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Abstract— The demand of cement (OPC) is increasing for satisfying the need of development of infrastructure facilities. OPC production releases more quantity of carbon dioxide to the atmosphere, it is harmful to the human health and also pollute environment. Therefore, it is essential to find alternatives to make the concrete environment friendly. In this respect, Davidovits (1988) proposed an alternative binder for the concrete technology and it shows a good results. These binders are produced by an alkaline liquid reacts with the silica (Si) and aluminium (Al) present in the source materials. The technology proposed by the Davidovits is commonly called as Geo-polymers or Geo-polymer technology. This paper presents the study on Mechanical properties of GPC of class f fly ash (FA-50%) & GGBS(50%) based GPC using silica sand as sand replacement at different levels (0%,10%,20%&30%). These properties have been tested for 7, 28&90 days curing at ambient room temperature. From the results, it is concluded that the increased replacement level of Silica Sand from 0% to 20% increased the mechanical properties of GPC mixes.

Key words: Geopolymer Concrete, Silica Sand, Mechanical Properties

I. Introduction

Geopolymer binder which was introduced by Davidovits1978, is an inorganic polymer binder, rich in silica and aluminium. In the process of polymerization of materials, alkaline substances are to be added [1]. The source material for silica and aluminium are Fly ash (FA), which is produced from thermal power plants as a waste and ground granulated blast furnace slag (GGBS), which is produced from AASTRA Chemicals, Chennai. Alkaline substances used for obtaining Polymerization reaction are alkaline grade sodium silicate solution (Na2Sio3) and sodium hydroxide solution (NaOH) as an alkaline activator, were taken as 8M. Geopolymer concrete made with only fly ash as a source material for silica and aluminium has shown poor results [2]. Geopolymer concrete require curing under ambient room temperature itself. Results are already concluded that GGBS and FA blended GPC mixes attained enhanced mechanical properties at ambient room temperature itself [3]. The behaviour of geopolymers were studied the many of researches using various types of source materials like fly ash, GGBS, silica sand etc. The present study deal with the development and the mechanical properties of geopolymer concrete incorporating silica sand as fine aggregate with different replacement levels from 10% to 30% at ambient room temperature curing [4]. To develop a mixture proportioning process to manufacture fly ash (ASTM Class F) and GGBS based geopolymer concrete incorporating silica sand as fine aggregate [5]. To identify and study the effect of prominent parameters that affects the properties of fly ash and GGBS based geopolymer concrete [6].

The present investigation is aimed to study the strength properties of hardened low calcium fly ash-based geopolymer concrete incorporating silica sand as fine aggregate with different replacement levels from 10% to 30% at ambient room temperature curing.

II. Experimental Study

A. Materials

In this respect, FA, GGBS and silica sand were used as binders whose chemical and physical properties are tabulated in Table1. According to ASTM C 618 (2003) [7], class F fly ash produced from Lanco Industry, srikalahasti, A.P and GGBS produced from AASTRA chemicals, Chennai, A.P were used in the manufacturing of GPC.

Particulars	Class F fly ash	GGBS	Silica sand
Chemical composition			
% Silica(Sio2)	65.6	30.61	81.5
% Alumina(Al2O3)	28.0	16.24	0.64
%Iron Oxide(Fe2O3)	3.0	0.584	0.76
% Lime(Cao)	1.0	34.48	0.14
% Magnesium(Mgo)	1.0	6.79	0.99
%Titanium Oxide(TiO)	0.5	-	-
%Sulphur Trioxide(So3)	0.2	1.85	-
Loss on Ignition	0.29	2.1	-
Physical properties			
Specific gravity	2.12	2.94	2.60
Fineness(m2/kg)	360	400	-

Table 1: chemical and physical properties of class F fly ash, GGBS and silica sand

The alkaline liquid used was a combination of sodium silicate solution(Na2O = 13.7%, SiO2 = 29.4% and water = 55.9%) and sodium hydroxide (NaOH) in pellets form with 97% - 98% purity was purchased from local suppliers. The sodium hydroxide (NaOH) solution was prepared with a concentration of 8M. The sodium silicate solution and sodium hydroxide solution were mixed together one day before prior to use. Crushed granite stones of size 20mm and 10mm used as coarse aggregate, river sand used as fine aggregate and silica sand used as replacement of natural sand at different levels 100:0, 90:10, 80:20 and 70:30. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20mm and 10mm were 2.66 and 0.3% respectively. The bulk specific gravity in oven dry condition and water absorption of the fine aggregate were 2.62 and 1% respectively. The bulk specific gravity in oven dry condition and water absorption of silica sand were 2.60 and 0.4% respectively.

B. Mix design

Based on the limited past research on GPC, the mix proportions were selected based on Rangan's method. Geopolymer concrete mix proportions of constituent materials are shown in Table 2.

Materials	Mass(Kg/m^3)			
	100:0	90:10	80:20	70:30

Coarse aggregate	20mm	774	774	774	774
	10mm	516	516	516	516
Fine aggregate		549	494.1	439.2	384.3
silica sand		0	54.9	109.8	164.7
Fly ash(Class F)		204.5	204.5	204.5	204.5
GGBS		204.5	204.5	204.5	204.5
Sodium silicate solution		102	102	102	102
Sodium hydroxide solution		41	41	41	41
Extra water		55	55	55	55
Super plasticizer		2.86	2.86	2.86	2.86

Table 2: GPC mix proportions of constituent materials

C. Experimental setup

Compressive strength test was conducted on the cubical specimens for all the mixes viz., silica sand as replacement at 100:0, 90:10, 80:20 and 70:30 after 7, 28 and 90days of curing as per IS516:1991 [10]. Three cubical specimens of each proportion of size 150mmx150mmx150mm were castes and tested for each age and each mix. The unit weight of hardened concrete (Yc) was determined after 28days of curing prior to compression test.

Splitting Tensile Strength (STS) test was conducted on the specimens for all the mixes after 28 days of curing. Three cylindrical specimens of size 150 mm x 300 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimens occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured.

Modulus Of Elasticity (MOE) test was performed on the specimens for all the mixes after 28 days of curing. Three cylindrical specimens of size 150 mm x 300 mm were cast and tested for each age and each mix. Each specimen was loaded until an average stress of (C+5) kg/cm^2 is reached. Here, C is the one –third of the average equivalent cube compressive strength. The secant modulus is calculated from the slope of the straight line drawn from the origin of axes to the stress-strain curve and this secant modulus is the required modulus of elasticity of the concrete (Ec).

Fig. 1: Set up of a compressive strength test

Fig. 2: Set up of a Split tensile strength test

Fig. 3: Set up of a Modulus of Elasticity test

III. RESULTS AND DISCUSSION

A. Mechanical properties

From Table 3, we can clearly noticed that there is an increase in the compressive strength of cubes from 31.2 MPa of 100:0 S to 31.3 MPa of 90:10 to 32.9 MPa of 80:20 and decreases at 30.5 MPa of 70:30 for 7days and an increase in compressive strength from 42.3 MPa of 100:0 to 44.97 MPa of 90:10 to 48.2 MPa of 80:20 and decreases at 41.6 MPa of 70:30 for 28days and an increase in compressive strength from 45.42 MPa of 100:0 to 45.91 MPa of 90:10 to 56.53 MPa of 80:20 and decreases at 44.66 MPa of 70:30 for 90days. This increase in performance at 80:20 is due to increase in silica content present in silica sand but 70:30 , results were poor because there is no reactivity due to increasing silica sand content at 8M.The performance has also been increased from 28days to 90days. The comparison at different replacement levels has been shown in figure 3.

Mix Type	Compressive strength (MPa)		
	7 days	28 days	90 days
100:0	31.2	42.3	45.42
90:10	31.3	44.97	45.91
80:20	32.9	48.2	56.53
70:30	30.5	41.6	44.66

Table 3: Compressive strength of cubes at 7, 28 and 90days curing

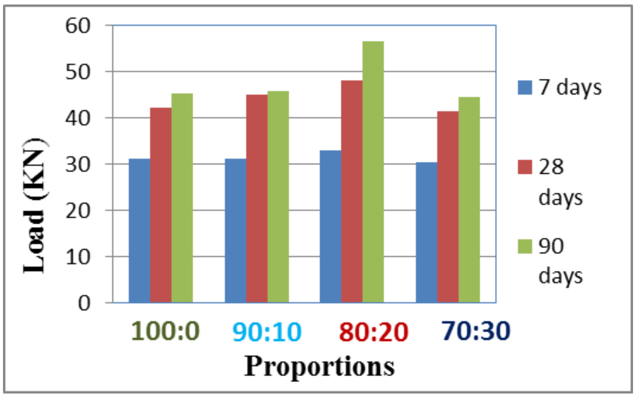

Fig. 3: Comparison of Compressive strength of cubes at 7, 28 and 90days curing

B. Split Tensile Strength

From Table 4, we can clearly noticed that there is an increase in the split tensile strength of cylinders from 3.085 MPa of 100:0 S to 3.20 MPa of 90:10 to 3.52 MPa of 80:20 and decrease at 2.83 MPa of 70:30 for 7 days and an increase in split tensile strength from 4.25 MPa of 100:0 to 4.63 MPa of 90:10 to 4.85 MPa of 80:20 and decrease at 4.21 MPa of 70:30 for 28 days and an increase in split tensile strength from 4.21 MPa of 100:0 to 4.84 MPa of 90:10 to 5.10 MPa of 80:20 and decrease at 4.28 MPa of 70:30 for 90 days. This increase in performance at 80%S+20%SS is due to increase in silica content present in silica sand but 70:30, results were poor because there is no reactivity due to increasing silica sand content at 8M. The performance has also been increased from 28 days to 90 days. The comparison at different replacement levels has been shown in figure 4.

Mix Type	Split Tensile Strength (MPa)		
	7 days	28 days	90 days
100:0	3.085	4.25	4.21
90:10	3.20	4.63	4.84
80:20	3.52	4.85	5.10
70:30	2.83	4.21	4.28

Table 4: Split tensile strength of cylinders at 7 days, 28 days and 90 days of curing

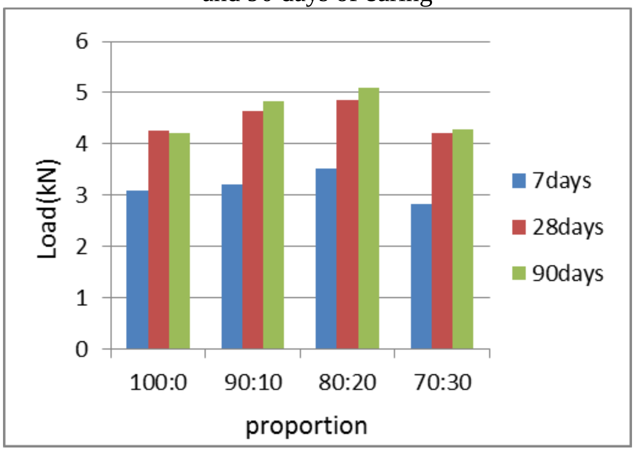

Fig. 4: Comparison of Split Tensile Strength of cylinders at 7, 28 and 90 days curing

C. Modulus of elasticity

From Table 5, we can clearly noticed that there is an increase in the modulus of elasticity of cylinders from 27.34 MPa of 100:0 to 27.85 MPa of 90:10 to 28.79 MPa of 80:20 and decrease at 27.48 MPa of 70:30 for 7 days and an increase in modulus of elasticity from 32.62 MPa of 100:0 to 33.35 MPa of 90:10 to 34.98 MPa of 80:20 and decrease at 32.55 MPa for 28 days and an increase in modulus of elasticity from 33.85 MPa of 100:0 to 33.95 MPa of 90:10 to 37.79 MPa of 80:20 and decrease at 33.56 MPa of 70:30 for 28 days. This increase in performance at 80%S+20%SS is due to increase in silica content present in silica sand but 70:30, results were poor because there is no reactivity due to increasing silica sand content at 8M. The performance has also been increased from 28 days to 90 days. The comparison at different replacement levels has been shown in fig 5

Mix Type	Modulus of Elasticity(GPa)		
	7 days	28 days	90 days
100:0	27.34	32.62	33.85
90:10	27.85	33.35	33.95
80:20	28.79	34.98	37.79
70:30	27.48	32.55	33.56

Table 5: Modulus of Elasticity of cylinders at 7 days, 28 days and 90 days

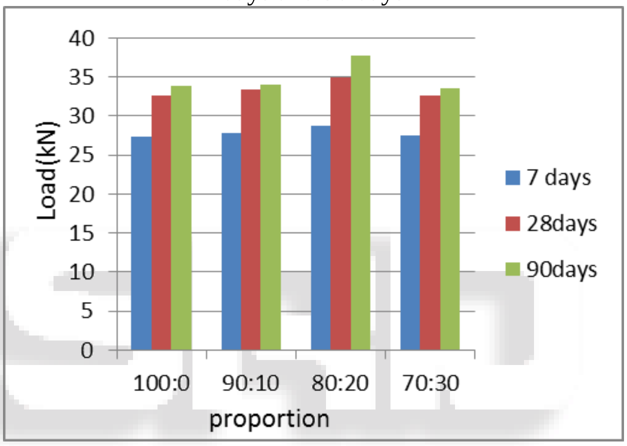

Fig. 5: Comparison of Modulus of Elasticity of cylinders at 7, 28 and 90 days

IV. CONCLUSIONS

1) Compressive strength of cubes increases from 48.2 MPa for 28 days to 56.53 MPa for 90 days for 80:20 proportion.
2) Split tensile strength of cylinders increases from 4.85 MPa for 28 days to 5.10 MPa for 90 days for 80:20 proportion.
3) Modulus of Elasticity increases from 34.98 GPa for 28 days to 37.79 GPa for 90 days for 80:20 proportion.
4) The performance of geopolymer concrete cubes and cylinders gives better results at 80:20 replacement level as natural sand at 8M.

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