Experimental Investigation on Geopolymer Concrete

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Abstract— Flyash based geopolymer concrete is introduced in 1979 by Davidovits to reduce the use of OPC in concrete. Geopolymer is an inorganic alumino-hydroxide polymer synthesized form predominantly silicon and aluminum materials of geological origin and by product materials such as flyash (with low calcium) and GGBS. In this paper an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash and slag as binder with combination NaOH & Na2SiO3 solutions as activators with different molarities 8M, 12M&16M. The specimen is cured at ambient temperature.

Key words: Geopolymer concrete (GPC), Molarity(M), Fly ash(FL), slag or GGBS(SL)

I. INTRODUCTION

The geopolymer technology is proposed by Davidovits and gives considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO2 emission in to the atmosphere, caused by cement and aggregate industries about 80%. In this technology, the source material that is rich in silicon (Si) and Aluminium (Al) is reacted with a highly alkaline solution through the process of geopolymerisation to produce the binding material. The term „geopolymer" describes a family of mineral binders that have a polymeric silicon-oxygen-aluminium framework structure, similar to that found in zeolites, but without the crystal structure. The polymerisation process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Geopolymer concrete is emerging as a new environmentally friendly construction material for sustainable development, using fly ash and slag in place of OPC as the binding agent. This attempt results in two benefits. i.e. reducing CO2 releases from production of OPC and effective utilisation of industrial waste by products such as flyash, slag etc by decreasing the use of OPC.

II. LITERATURE REVIEW

The climate change is not only due to the global warming, but also due to the paradoxical global dimming due to the pollution in the atmosphere. Global dimming is associated with the reduction of the amount of sunlight reaching the earth due to pollution particles in the air, blocking the sunlight. With the effort to reduce the air pollution that has been taken into implementation, the effect of global dimming may be reduced; however it will increase the effect of global warming .The low-calcium (ASTM Class F) fly ash and slag based geopolymer is used as the binder instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-slag based geopolymer paste binds the loose coarse aggregates, fine aggregates and other unreacted materials together to form the geopolymer concrete, with or without the presence of admixtures.

It is well known that alkali activation of aluminosilicates can produce X-ray amorphous aluminosilicates gels or geopolymers with excellent mechanical as well as chemical properties. The structural backbone of these aluminosilicate (geopolymeric) gels has historically been depicted as consisting of a three dimensional frame work of SiO4 and AlO4 tetrahedra interlinked by shared O atoms. The negatively charged and tetrahedrally co - ordinate Al (III) atoms inside the network are charge-balanced by alkali metal cations such as Na, K and Ca . These gels can be used to bind aggregates, such as sand or natural rocks, to produce mortars and concretes. In other words, geopolymers are inorganic binders that function as the better-known Portland cement. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Palomo et al. concluded that the type of alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Xu and Deventer reported that the proportion of alkaline solution to alumino-silicate powder by mass should be approximately 0.33 to allow the geopolymeric reactions to occur. Alkaline solutions formed a thick gel instantaneously upon mixing with the alumino-silicate powder.

There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

III. EXPERIMENTAL INVESTIGATION

A. *Materials*

Flyash used in this experimental work was obtained from National Thermal Power Corporation (NTPC), Visakhapatnam. Flyash is finely grained residue resulting from the combustion of ground or powdered coal. Mean particle size is about 0.1 to 0.2 μm and finer than cement and consist mainly of glassy spherical particles as well as residues of hematite and magnetite. The specific gravity, fineness modulus, specific surface area and density of flyash are 2.82, 1.375, 310 m2/kg and 1.4 kg/m3 respectively. Ground granulated blast furnace slag of fineness modulus 0.16 was used in the work. Locally available river sand having fineness modulus 2.22, specific gravity 2.4 and conforming to grading zone-III as per I.S: 383 - 1970. Coarse aggregate is of angular shaped crushed granite with maximum size 20mm and its fineness modulus and specific gravity are 7.17 and 2.89 respectively. Potable water with pH value 7.15 was used for the geopolymer concrete.

B. Mix Proportion

Specimen Materials kg/m^3	GPC 8M	GPC 12M	GPC 16M
Coarse aggregate	1293	1295	1295
Fine aggregate	554	555	555
Fly ash	240	184	184
GGBFS	128	184	184
NaOH solution	53	53	53
Molarity NaOH	8M	12M	16M
Na_2SiO_3 solution	131	131	131
Temperature C	Ambient	Ambient	Ambient
Curing period days	7,14	7,14	7,14
Liquid/binder	0.50	0.50	0.50
Age of specimens	7,14	7,14	7,14
Extra water	18.4 (5%)	18.4 (5%)	18.4 (5%)
Super plasticizer	7.36 (2%)	7.36 (2%)	7.36 (2%)

Table.1 Mix Proportion

Materials / Binder content	Coarse aggregate kg/m^3	Fine aggregate kg/m^3	Fly ash kg/m^3	GGBFS kg/m^3	NaOH solution kg/m^3	Na2SiO3 solution kg/m^3	Curing & testing period in days	L/B ratio	EW&SP % of binder
65FA: 35SL	1293	554	240	128	53(8M)	131	3,14	0.5	5%&2%
65FA: 35SL	1293	554	240	128	53(12M)	131	3,14	0.5	5%&2%
65FA: 35SL	1293	554	240	128	53(16M)	131	3,14	0.5	5%&2%

Table 2: Mix Proportion

C. Mixing, Curing, and Testing

Geo-polymer concrete specimens were prepared using the same method as for OPC concrete. Coarse and fine aggregates are mixed with the binder component of pre-determined proportion. Then the activator solution of specified fluid binder ratio is added and mixed to get a homogeneous and uniform mix. This concrete is filled into 150 mm cubes and compacted manually. It is interesting to note that the specimens could be de-moulded within about 2 hours of drying in ambient conditions after casting. The demoulded specimens were left in room temperature until tested without any special curing regime. The specimens were tested as per IS 516:1959 and strengths were calculated for 7& 14days and the results were tabled.

D. Fresh GPC

The fresh Geopolymer concrete can be handled up to 80 min with slump up to 200mm.

IV. Test Results and Discussions

In this section, strength development of ambient cured geo-polymer concrete is discussed with reference to the factors considered at the selected levels. Experimental results are presented in the form of few representative graphs facilitating the discussions.

Age of specimen in days	8M GPC specimen (Nmm^2)	12M GPC specimen (N/mm^2)	16M GPC specimen (N/mm^2)
7	40	42	44
14	47	49	52

Table.3 Variation of Compressive Strength with Ages and Molarities

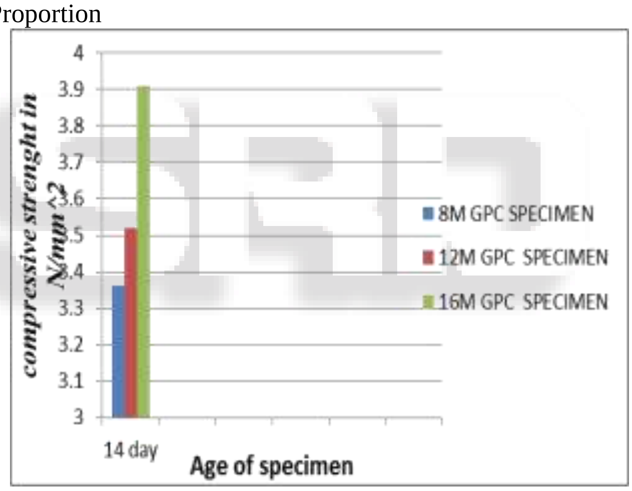

Fig. 1: Variation of Compressive Strength with Ages and Molarities.

Age of specimen in days	8M GPC specimen (N/mm^2)	12M GPC specimen (N/mm^2)	16M GPC specimen (N/mm^2)
14	2.8	2.9	3.1

Table 4: Spilt Tensile strength at 14 day

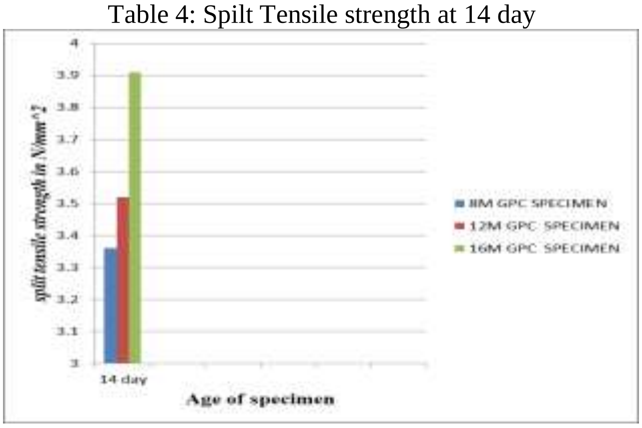

Fig. 2: Split Tensile strength at 14 day

Age of specimen in days	8M GPC specimen (N/mm^2)	12M GPC specimen (N/mm^2)	16M GPC specimen (N/mm^2)
14	3.36	3.52	3.91

Table 5: Flexure strength at 14 day

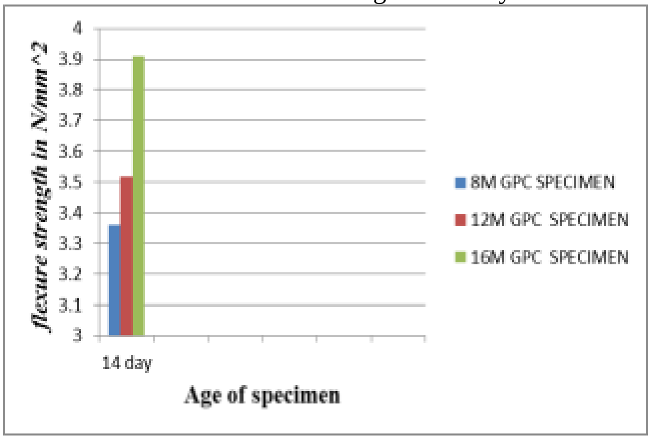

Fig. 3: Flexure strength at 14 day.

V. CONCLUSIONS

1) As the molarity increases compressive strength increases.
2) Early strength development
3) As the molarity increases split tensile strength and flexure strength also increases
4) Split tensile strength of geopolymer concrete increases marginally as compressive strength increases.
5) The relationship between compressive strength and tensile strength is similar to conventional concrete.
6) Highest tensile strength i.e., 3.10 N/mm2 was observed for 16M.
7) Lowest tensile strength i.e., 2.80 N/mm2 was observed for 8M.
8) Highest flexure strength i.e., 3.91N/mm2 was observed for 16M.
9) Lowest flexure strength i.e., 3.36 N/mm2 was observed for 8M.

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