



Behavior of Geo-polymer Concrete at Elevated Curing Temperature

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ABSTRACT

Production of Portland cement is resulting in two major environmental issues that are needed to be considered before it's too late to find out the solution. Firstly, manufacturing of PC is emitting 5% of the global CO₂ into the atmosphere causing global warming. Secondly, manufacture of PC requires limestone and clay that are depleting day by day. To produce 1 ton of PC, 1.6 tons of raw materials are needed to be extracted from the earth. To overcome the above problem a new concrete called Geopolymer is used. Geopolymer is an amorphous aluminosilicate product that exhibits the ideal hardening properties of elements. In the present study the strength development of geo polymer concrete is determined by varying temperature. To prepare geopolymer concrete the material used is Ground Granulated Blast Furnace Slag, sodium hydroxide activator and hydrated sodium silicate binder. The sodium hydroxide is varied in two molarities, 8 and 10 respectively. The sodium silicate had 30% water content in it. The curing was done in the oven with varying temperatures of 60, 80 and 100 degrees. The compressive strength test, split tensile test and flexural strength test showed higher strength at 8 molar and curing temperature being 100 degrees.

Keywords : Geopolymer concrete, NaOH, Hydrated sodium silicate.

I. INTRODUCTION

Geopolymer is a type of amorphous aluminosilicate product that exhibits the ideal properties of rock-forming elements, i.e. hardness, chemical stability and longevity. Geopolymer are used in aggregates to produce geopolymer concretes (GPC) which are ideal for structures and repairing work, since they have very high early strength. The properties of geopolymer include high early strength, low shrinkage, temperature resistance, sulphate resistance. These high-alkali binders do not generate any alkali-aggregate reaction. The geopolymer binder has low CO₂ cementations content. It does not rely on the calcinations of limestone that

generates CO₂. This technology can save up to 80% of CO₂ emission caused by the cement and aggregate industries. Geopolymer binders can be produced from waste materials containing Silicon (Si) and Aluminium (Al) ions. These waste materials can be Fly Ash, ground granulated blast furnace slag, met kaolin or any other waste sources of Si and Al. The other chemicals need to be added are sodium hydroxide, sodium silicate and water. Since geopolymers do not hydrate, they show characteristics of low shrinkage and excellent heat resistance. In 1978, Davidovits introduced the word 'GEOPOLYMER' to explain an innovative cementations material which has ceramic-like properties. With comparing to OPC, the

manufacturer of fly ash-ground granulated blast furnace slag (GGBS) based geo-polymer does not absorbed high levels of energy, as fly ash and slag is already an industrial by-product. This geo-polymer technology has the potential to reduce emissions by 80%. These also exhibit ceramic-like properties with superior resistance to fire at elevated temperatures. Fly ash, is available in huge quantity worldwide due to coal burning operations, is an excellent aluminosilicate material, whereas granulated blast furnace slag is a by-product produced from steel plants. In India, fly ash is currently under-utilized according to data available in the year 2000, 90 million tons per annum were produced but only 20-25% of it was effectively utilized in cementations application. Normally for ore feed containing 60 to 65% iron, slag production varies from about 300 to 540 kg per ton of pig or crude iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as one tone of slag per ton of pig iron produced. Steel slag produces about 20% by mass of the crude steel outcome.

Lately, much research as highlighted the use of fly ash-based geo-polymer in concrete manufacturing. Geo-polymers also shown to have good bond strength to cement concrete; hence it is a good repair material for use in filling work and construction work. Fly ash and slag based geo-polymer/aggregate composites have high performance compared to cement concrete in certain areas such as resistance to sulfate attacks and have lower longer loading failure and expansion and contraction than conventional concrete. Geo-polymers are generally performed better than the conventional concretes in fire, due to their ceramic-like properties. In the present study the mix design of Geo-Polymer Concrete and the effect of varying proportion of activator and temperature on the concrete with respect to strength development of Ground Granulated Blast-furnace Slag based on Geo-Polymer Concrete are carried out. In the present study geopolymer concrete were prepared by varying molarity and temperature and optimum mix are prepared.

II. LITERATURE REVIEW

The main aim of the research was to find the desired mix. Based on the following literature we take up further study. R Prasanna Venkatesh, et al [1] carried-out study on Strength and durability properties of geopolymer concrete made with Ground Granulated Blast Furnace Slag and Black Rice Husk Ash. The Geopolymer concrete was prepared with GGBS as the primary binder instead of cement and BRHA was replaced with GGBS at various proportions such as 10%, 20% and 30%. Addition of BRHA in Geopolymer concrete beyond 10% reduce the strength development be the strengths are well above the target for up to 20% replacement. Sama T Aly et al [2] carry out study on Properties of Ceramic Waste Powder-Based Geopolymer Concrete. CWP's to produce geopolymer concrete is studied, and its strength and durability properties were tested. The 7 and 28 days 'curing results of the compressive strength, pores percentage, initial rate of water absorption, and bulk electrical resistivity showed the possibility of producing CWP-based geopolymer concrete. Vishalakshi Talakokula et al [3] conducted a study on Effect of Delay Time and Duration of Steam Curing on Compressive Strength and Microstructure of Geopolymer Concrete. From the Paper the results of an effect of delay time and duration of steam curing on the compressive strength and microstructure development of FA based geopolymer concrete specimens prepared by thermal activation of FA with sodium hydroxide and sodium silicate solution. Activating the FA with NaOH and NaSiO₃ solution slightly increased the compressive strength of the GPC, but greatly decreased the microstructure of the GPC. Hayan Du et al [4] carried out a study on, Effects of characteristics of fly ash on the properties of geopolymer. The properties of class F fly ashes produced were investigated in the present study. The source material used in the geopolymer concrete was activated with sodium hydroxide and sodium silicate solution. The results revealed that the geopolymer produced with wet bottom boiler fly ash (CZ-FA) hardened quickly and had higher early-age strength

and lower shrinkage than the geopolymer produced with dry bottom boiler fly ash (SX- FA). The compressive strength of the two geopolymers made from CZ-FA and SX-FA was 45 MPa and 15 MPa respectively when cured at 60 °C and delayed for 14 d. C Banupriya et al [5] carried out a study on Experimental Investigations on Geopolymer Concrete using GGBS. A high volume GGBS based geopolymer concrete (mix proportion of 65, 70, 75 and 80% FA) used for bricks and high-volume ground granulated blast furnace slag based geopolymer concrete (mix proportion of 65, 70, 75 and 80% GGBS) used for paver blocks gave a rise in strength of concrete in ambient curing conditions.

III. MATERIALS AND METHODS

A. Physical characteristics of the Materials

The preparation of geopolymer concrete consisting of Ground granulated blast furnace slag (GGBS) and alkaline liquid. The physical properties of the above materials are given in Table.1 and Table.2 The fine aggregate and the coarse aggregate is procured from the local vendor and the properties of the aggregates are given in Table.3 and Table.4 respectively. Normal tap water was used to make the NaOH solution of 8 and 10 Molarity. All the materials are tested as per Indian standards.

TABLE I. PHYSICAL & CHEMICAL PROPERTIES OF THE GGBS

SI no	Properties	IS Code	Limits	Result
1	Specific Gravity	IS 2720 part 3-1980	2.7 – 2.8	2.65
2	Bulk Density (kg/cm ³)	IS 2386 part 3 - 1963	1668	1400

Table II. CHEMICAL PROPERTIES OF GGBS

SI no	Chemical Component	Result
1	SiO ₂	33.43%
2	Al ₂ O ₃	18.16%
3	CaO	37.37%

TABLE III. PHYSICAL PROPERTIES OF FINE AGGREGATE

SI no	Properties	Limits	Results
1	Specific gravity	2.65	2.64
2	Zone	-	Zone II
3	Fineness modulus	2-4	2.5

TABLE IV. PHYSICAL PROPERTIES OF COURSE AGGREGATE

SI no	Properties	Limits	Results
1	Specific gravity	2.5 – 3	2.55
2	Water absorption	1 – 2 %	2%
3	Bulk density (gm/cc)	-	1.55

B. Mix Proportion

Geopolymer Concrete mixture design process is new and generally based on performance. The mix proportion for the geopolymer mix are tabulated below in Tabular V

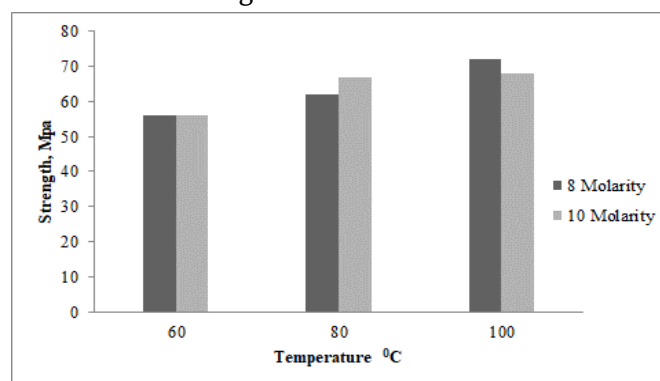
TABLE V. QUANTITY OF MATERIALS

SI no	Material	Quantity
1	Sodium Hydroxide	80Kg
2	Sodium Silicate	200Kg
3	GGBS	425Kg
4	Coarse Aggregate	946.6Kg
5	Fine Aggregate	745.6Kg
6	Water	120Lts

IV. RESULT AND DISCUSSION

A. Compressive strength

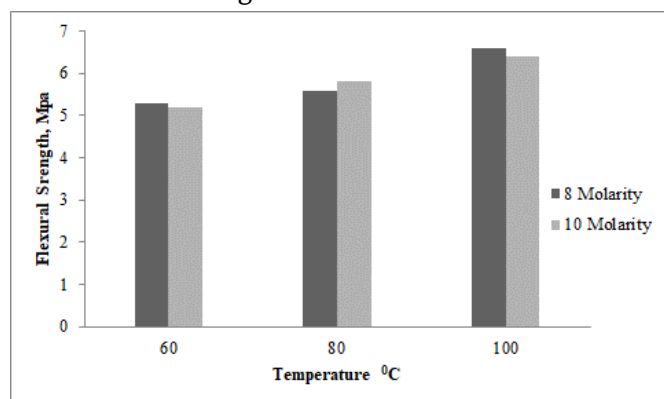
The one-day cube compressive strength of oven – dry geopolymer cubes at varying temperature are showed in the Fig. 1. It is evident from the above table of comparison of compressive strength of the geo- polymer concrete, the strength of the concrete is maximum at 8 molarity of the sodium hydroxide solution, cured at the elevated temperature of 100°C when compared to the ambient temperature (60°C) strength, or even the 10 molarity of sodium hydroxide solution cure at 100°C. When compared to the strength of 10 molar cured at 100°C, 8 molar mix is 7.5% more strength.



B. Flexural strength

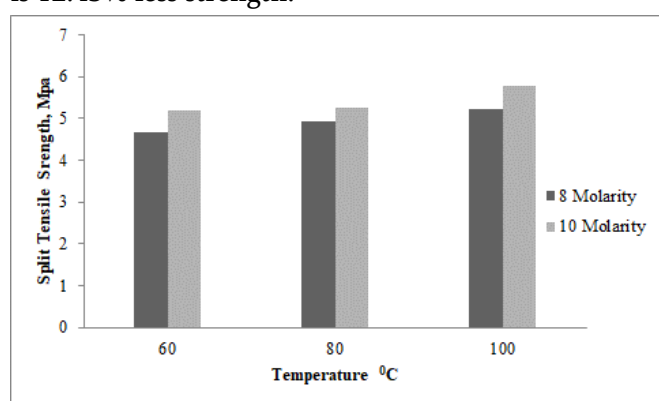
The one-day flexural strength of oven – dry geopolymer beam at varying temperature is showed in the Fig.2. It is evident from the above table of comparison of flexural strength of the geo-polymer concrete, the flexural strength of the concrete is maximum at 8 molarity of the sodium hydroxide solution, cured at elevated temperature of 100°C

when compared to the ambient temperature (60°C) strength, or even the 10 molarity of sodium hydroxide solution cure at 100°C. When compared to the strength of 10 molar cured at 100°C, 8 molar mix is 4.8% more strength.



C. Split Tensile strength test

The one-day Split tensile strength test of oven – dry geopolymers cylinder at varying temperature is shown in Fig.3. It is evident from the above table of comparison of split tensile strength of the geo- polymer concrete, the strength of the concrete is maximum at 10 molarity of the sodium hydroxide solution, cured at the elevated temperature of 100°C when compared to the ambient temperature (60°C) strength, or even the 8 molarity of sodium hydroxide solution cure at 100°C. When compared to the strength of 10 molar cured at 100°C, the 8 molar mix is 12.43% less strength.



V. CONCLUSION

The elevated temperatures certainly raised the compression, flexural and split tensile strength of the geo-polymer concrete by an average 0.625%, 0.275% and 0.212% respectively per degree Celsius. The

main aim of our experiment being the study on strength development of the geo-polymer concrete can be positively concluded saying that increasing the temperature from ambient curing temperature (60°C) to elevated temperatures, such as, 80°C and 100°C leads to elevate the strength of the concrete. Evident from the results a 8 molar mix gives higher strength compared to 10 molar mix. The compressive strength increased by 12.5% when cured at 80° and by 28.6% when cured at 100° compared to 60° curing. The flexural strength increased by 5.5% when cured at 80° and by 22.2% when cured at 100° compared to 60° curing. The split tensile strength increased by 4.24% when cured at 80° and by 9.13% when cured at 100° compared to 60° curing. The GPC becomes slightly brittle with the increase in the temperature.

VI. REFERENCES

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