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Experimental Study on Strength Development of Geopolymer Concrete at Elevated Temperature

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Abstract* — Production of Portland cement (PC) 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 Co_2 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 is used called Geopolymer. Geopolymer is a type of amorphous alumino-silicate product that exhibits the ideal properties of rock-forming 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, split tensile and flexural strength showed higher strength at 8 molars and curing temperature being 100 degrees.

***Keywords*— Geopolymer concrete, NaOH, Hydrated sodium silicate.**

I. INTRODUCTION

A new concrete is geopolymer has been prepared which does not require cement. Geopolymer is a type of amorphous alumino-silicate product that exhibits the ideal properties of rock-forming elements, i.e. hardness, chemical stability and longevity. Geopolymer binders are used together with aggregates to produce geopolymer concretes (GPC) which are ideal for building and repairing infrastructures, since they have very high early strength. The properties of geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. These high-alkali binders do not generate any alkali-aggregate reaction. The geopolymer binder is a low CO_2 cementations material. It does not relay on the calcinations of limestone that generates CO_2. This technology can save up to 80% of CO_2 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 describe an alternative cementitious material which has ceramic-like properties. As oppose to OPC, the manufacturer of fly ash-ground granulated blast furnace slag (GGBS) based geo-polymer does not consume high levels of energy, as fly ash and slag are already an industrial by-product. This geo-polymer technology has the potential to reduce emissions by 80%. Because high temperature calcining is not required. These also exhibit ceramic-like properties with superior resistance to fire at elevated temperatures. Fly ash, which is available abundantly worldwide from coal burning operations, is an excellent alumino-silicate source material, whereas granulated blast furnace slag is a by-product produced from steel plants. In India, fly ash is currently under- utilized according to figures in the year 2000, 90 million tons per annum were produced but only 20-25% of it was effectively utilized in cementitious application. Typically for ore feed containing 60 to 65% iron, slag production ranges 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 output is approximately 20% by mass of the crude steel output.

Lately, much research as highlighted the potential use of fly ash-based geo-polymer in concrete production. Geo-polymers have also been shown to have good bond strength to cement concrete; hence it is a good repair material with superior abrasion resistance. Fly ash and slag based geo-polymer/aggregate composites have superior performance compared to cement concrete in certain areas such as resistance to sulfate attacks and have lower creep and shrinkage than conventional concrete. Geo-polymers are generally believed to perform 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 optimum 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% retards the strength development yet the strengths are well above the target for up to 20% replacement levels. Sama T Aly et al [2] carry out study on Properties of Ceramic Waste Powder-Based Geopolymer Concrete. CWP's ability to produce geopolymer concrete is studied, and its compressive strength and durability characteristics were tested. The 7- and 28-days' 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. This paper reports the results of an experimental study on the 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 two types of fly ash geopolymers made from class F fly ashes produced in wet bottom and dry bottom boilers 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 Properties 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

Sl no	Properties	IS Code	Results	Limits
1	Specific Gravity	IS 2720 part 3- 1980	2.62	2.7 – 2.8
2	Bulk Density (kg/cm^3)	IS 2386 part 3 - 1963	1300	1668

TABLE II
CHEMICAL PROPERTIES OF GGBS

Sl no	Chemical Component	Result
1	SiO_2	32.43%
2	AL_2O_3	18.16%
3	CaO	38.37%

TABLE III
PHYSICAL PROPERTIES OF FINE AGGREGATE

Sl no	Properties	Limits	Results
1	Specific gravity	2.65	2.64
2	Zone	-	Zone II
3	Fineness modulus	2-4	2.6

TABLE IV
PHYSICAL PROPERTIES OF COARS AGGREGATE

Sl no	Properties	Limits	Results
1	Specific gravity	2.5 – 3	2.506
2	Water absorption	1 – 2 %	2%
3	Bulk density (gm/cc)	-	1.55

B. MIX PROPORTION

The mix proportion for the geopolymer mix are tabulated below in Tabular V

TABLE V
QUANTITY OF MATERIALS

Sl no	Material	Quantity
1	Sodium Hydroxide	80Kg
2	Sodium Silicate	200Kg
3	GGBS	424Kg
4	Coarse Aggregate	947.6Kg
5	Fine Aggregate	744.6Kg
6	Water	120Lts

IV. RESULT AND DISCUSSION

1. Compressive strength

The one-day compressive strength of oven – dry geopolymer cubes at varying temperature are showed in the Table.VI

TABLE VI

Sl no	Molarity	Temperature ^{0}C	Strength (Mpa)
1	8	60	57
2		80	63
3		100	72
4	10	60	56
5		80	67
6		100	67

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.

2. Flexural strength

The one-day flexural strength of oven – dry geopolymer beam at varying temperature are showed in the Table.VII

TABLE VII

Sl no	Molarity	Temperature ^{0}C	Flexural Strength (Mpa)
1	8	60	5.4
2		80	5.7
3		100	6.6
4	10	60	5.1
5		80	5.7
6		100	6.3

It is evident from the above table of comparison of flexural 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 4.8% more strength.

2. Split Tensile strength test

The one-day Split tensile strength test of oven – dry geopolymer cylinder at varying temperature are showed in the Table.VIII

TABLE VII

Sl no	Molarity	Temperature ^{0}C	Strength (Mpa)
1	8	60	4.71
2		80	4.91
3		100	5.14
4	10	60	5.09
5		80	5.35
6		100	5.87

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 100C, the 8 molar mix is 12.43% less strength.

V. CONCLUSIONS

The elevated temperatures certainly raised the compressive, flexural and split tensile strength of the geo-polymer concrete by an average of 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 increase in 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.

REFERENCES

[1] R Prasanna Venkatesh, et al "Strength and durability properties of geopolymer concrete made with Ground Granulated Blast Furnace Slag and Black Rice Husk Ash", 2015, pp 741-747.
[2] Sama T Aly, "Properties of Ceramic Waste Powder – Based Geopolymer Concrete", ICPC. 2018, pp 1-5.
[3] Vishalakshi Talakokula, et al, "Effect of Delay Time and Duration of Steam Curing on Compressive Strength and Microstructure of Geopolymer Concrete". International Journal of Engineering Science Invention, Vol 2, 2015, pp 24-31.
[4] Hayan Du, et al "Effects of characteristics of fly ash on the properties of geopolymer", Res. J. Eng Sci. 2013.
[5] IS 10262: 2009 Guidelines for Concrete mix proportioning.
[6] IS 516: 1959 Methods of test for Strength of Concrete
[7] IS: 456-2000, Code of Practice for Plain and Reinforced Cement Concrete.
[8] IS: 516-1959, Indian standards, Methods of Tests for Strength of Concrete.
[9] IS: 5816-1999, Indian standards, Split tensile strength test on concrete.