STUDY ON MECHANICAL PROPERTIES OF POLYPROPYLENE FIBRE REINFORCED GEOPOLYMER CONCRETE

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ABSTRACT

The ordinary Portland cement (OPC), which is widely used material not only consumes significant amount of natural resources and energy but also pollutes the atmosphere by the emission of CO_2, So as to reduce this ill effect, the search for alternative result is geopolymer concrete. The strength study has to be carried out for different binder composition of fly ash and GGBS incorporated 0.25% polypropylene fibres. In this work, low calcium class F fly ash and GGBS was used as the materials. This paper presents the results of an experimental investigation to determine the performance characteristics of geopolymer reinforced concrete. The mechanical properties of the specimen were studied for both Ambient and Heat curing. The strength properties test was carried out after 28 days for Ambient curing and 24 hours for Heat curing showed that the increase of mechanical properties (Compressive, Split tensile and Flexural strength) resulting from added of polypropylene fibre was relatively high. The test results were studied and it is found that 100% GGBS binder composition with 0.25% polypropylene fibres has shown better performance.

Keywords: Geopolymer concrete, Sodium silicate, Sodium hydroxide, GGBS, Fly Ash, Polypropylene fibre.

1. INTRODUCTION

Nowadays, ordinary Portland cement (OPC) concrete is the most popular and widely used building materials, due to its availability of the raw materials over the world its ease for preparing and fabricating in all sorts of conceivable shapes, About 1.5 tonnes of raw materials is needed in the production of every tonne of Portland cement, at the same time about one tonne of carbon dioxide (CO_2) is released into the environment during the production. Currently, the world annual OPC production is about 1.6 billion tonnes or about 7% of the global loading of industrial alumino silicate waste materials such as FA and GGBS. Geopolymer concretes' (GPC) are inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing /supplementing the conventional concretes. GPC have high strength, with good resistance to chloride penetration, acid attack, etc. These are commonly formed by alkali activation of alumino silicate waste materials such as FA and GGBS, and have a very small green house footprint when compared to traditional concretes. The extensive research works carried out by several investigators corroborate the potential of GPC as a prospective construction material. Since for GPC, it does not have any standards loads for mix design. The strength study has to be carried out for different binder composition of fly ash and GGBS in corporate with 0.25% polypropylene fibres.

SCOPE OF THIS WORK

In this project, we are using fly ash and GGBS as a cement replacement material in concrete, in addition with chemicals such as sodium silicate and sodium hydroxide. The mechanical property has to be studied for different mix which are as follows, Compressive strength, Tensile strength, Flexural strength. To enhance the flexural behaviour of the polypropylene fiber's reinforced geopolymer concrete.

2. EXPERIMENTAL INVESTIGATION

Materials used

The material used for to make geopolymer concrete were fine aggregate, coarse aggregate, Fly ash, GGBS, and alkaline solution such as sodium hydroxide solution and sodium silicate solution is binder and water as workability measure.

Fine Aggregate

Natural river sand with fineness modulus is 2.05. Its gradation meets zone II of IS 383 (1970) requirements and its specific gravity is 2.67.

Coarse Aggregate

Crushed granite stone aggregate of size 20 mm sieve and meets graduation requirements of IS 2386 (1968) part III. The specific gravity is 2.54 and fineness modulus is 6.8.

Fly Ash

Class F Fly ash obtained from mettur power plant.

Table 1 Physical properties of fly ash

Properties	Values
Fineness modulus	7.86
Specific gravity	2.10

Table 2 Chemical properties of fly ash

Chemical prop. Min % by mass	IS : 3812- 1981	FLY ASH MTTP
$SiO_2+Al_2O_3+Fe_2O_3$	70	90.5

GGBS

Ground granulated blast furnace slag is a non metallic product consisting essentially of silicates and aluminates of calcium and other bases.

Table 3 Properties of GGBS

Calcium oxide (CaO)	40-52
Silicon dioxide SiO_2	10-19

Polypropylene Fibre

Polypropylene is one of the cheapest & abundantly available polymers.

Table 4 Properties of polypropylene fibre

Specification	Values
Aspect Ratio	38
Specific gravity Kg/m^3	8

Sodium Hydroxide

Generally the sodium hydroxides (NaOH) are available in solid state in the forms of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. In this investigation 94 to 96% purity NaOH is used. If NaOH is not used, the mixture was too viscous to cast and the slump was zero. The slump increased with increasing NaOH content from 5% to 12.5%.

Sodium silicate

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form.

3. MIX PROPORTION AND MIX DETAILS

Mix design of Geopolymer concrete

The mix design in the case of geopolymer concrete is inverse to that of conventional concrete. In the case of conventional concrete the material proportion can be found out for the required strength using the code. But in the case of geopolymer concrete there is no design method or codal provisions. Here only by means of trial mixes the concrete is being produced. By testing that concrete produced by trial mixes we will get some strength. The mass of combined aggregates may be taken to between 75% to 80% mass of the geopolymer concrete. The alkaline liquid to binder ratio of mix id S1, S2, S3 is 0.45 and S4, S5 is 0.55. The ratio of Sodium hydroxide to sodium silicate ratio is 1:2.5 (Rangan, 2005). Extra water was added to the mix by 10% of binders to achieve workable concrete. Mix proportion of geopolymer concrete is given in table 5.

Table 5 Mix Proportions of Geopolymer Concrete

MIX id	BINDER (b)	(b)		SAND	C.A	WATER	SODIUM HYDROXIDE	SODIUM SILICATE
		F.A (kg/m^3)	GGBS (kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)
S1	100% F.A,0% GGBS	482.6	0	589.9	987.5	44.2	62.05	155.12
S2	75% F.A,25% GGBS	361.95	120.65	589.9	987.5	44.2	62.05	155.12
S3	50% F.A,50% GGBS	241.3	241.3	589.9	987.5	44.2	62.05	155.12
S4	25% F.A,75% GGBS	120.65	361.95	589.9	987.5	44.2	75.84	155.12
S5	0%F.A, 100%GGBS	0	482.6	589.9	987.5	44.2	75.84	155.12

Preparation of GPCC

The solid should be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in different molar. For instance, NaOH solution with a concentration of 16 molar consist of 16*40= 640grams of NaOH solids per liter of water, were 40 is the molecular weight of NaOH. Note that the mass of water is the major component in both the alkaline- solution. The mass of NaOH solids was measured as 444 grams per Kg of NaOH solution with a concentration of 16 molar. Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react that is polymerization take place. It liberate large amount of heat so it is recommended to leave it for about 20 minutes thus the alkaline liquid is ready as binding agent.

Casting, Curing and testing

Compressive strength studies were studied on cube mould of size 150 mm × 150 mm × 150 mm while cylindrical moulds of size 150 mm diameter and 300 mm long were used for the determination of split tensile strength. The flexural strength studies were carried out in prisms of size 100 mm × 100 mm × 500 mm. In this experimental study totally 90 numbers of concrete specimen were casted with polypropylene fibres in each mixtures. The specimen considered in this study consisted of 30 numbers of 150 mm cubes, 30 numbers of 150 mm diameter and 300 mm long cylinders and 30 numbers of 100 mm × 100 mm × 500 mm size prisms. Before casting machine oil was smeared on the inner surface of the cast iron mould. The Geopolymer specimen were cast and placed inside a jute canvas or tarpaulin. The room heater was kept inside the canvas at 60^0C and a temperature indicator was also placed outside the set up. The canvas should be so tight such that the heat can't come out of the heat curing set up. The specimens were cured for 24 hrs. When the room temperature was less than 30^0C the hardening did not occur at least for 24 hours. Also the handling time is a more appropriate parameter (rather than setting time used in the case of OPC Concrete) for fly ash based geopolymer concrete. The Geopolymer concrete specimens were cast and cured at room temperature for 28 days. In ambient curing five specimen of various mix proportions casted using sand are kept in the laboratory for a period of 28 days in the atmospheric temperature. Since sodium silicate contains 55.9% of water by its mass, so the usual curing procedure is not necessary. It emits water content due to alkaline liquid during the curing period. The laboratory temperature varied between 25°C and 35°C during those days of curing. The minimum value of geopolymer concrete (16 molar concentration) to be 400 mm and a maximum of 550 mm for fresh geopolymer concrete (Rangan, 2005). Tests for compressive and split tensile strengths were conducted using a 2000 KN digital compression testing machine and the test for flexural strength was conducted using a 100 KN flexural testing machine. Test set up for measuring cube and cylinder are shown in Figure 1, Figure 2, and Figure 3 shows the test set up for measuring the prisms. These tests were conducted as per the relevant Indian Standard specification (IS 516-1959, IS 5816-1970).

Figure 1. Compressive strength Test

Figure 2. Split tensile strength Test

Figure 3. Flexural strength Test

4.RESULTS AND DISCUSSION

In this study hardened properties of geopolymer concrete were investigated by using polypropylene fibre Reinforced concrete at different binder composition of concrete, In the present study, such properties of geopolymer concrete were investigated based strength studies.

Compressive Strength Test Results

Totally there were 30 cubes casted to determine the compressive strength of GPC, Where 15 cubes were casted for ambient curing and the remaining 15 were casted for heat curing.

Table 6 Compressive Strength for different mix proportions of geopolymer concrete

MIX Ratio	COMPRESSSIVE STRENGTH IN Mpa	
	Ambient Curing	Heat Curing
S1	17.5	18.2
S2	21.7	23.1
S3	28.4	30
S4	30	31.7
S5	32	35.1

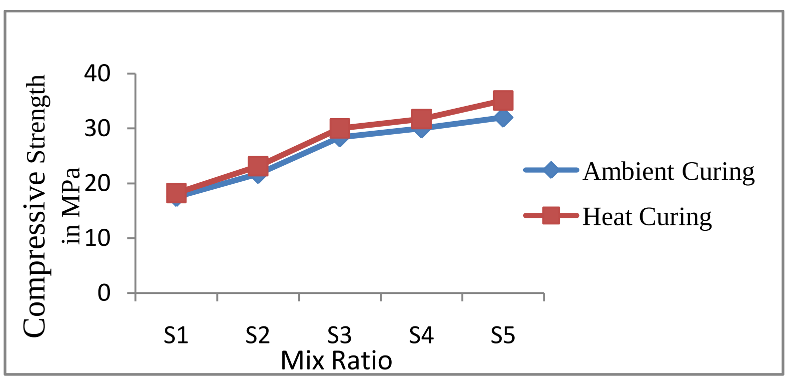

Figure 4, Compressive Strength for geopolymer concrete

From the Figure 4. It can be observed that the compressive strength of geopolymer concrete increases when heat curing is adopted.

Split Tensile Strength Result

Tests were carried out conforming to IS 5816 (1976) to obtain the splitting tensile strength for various concrete structures. Totally there were 30 cylinders casted to determine the tensile strength of GPC, Where 15 cylinder were casted for ambient curing and the remaining 15 were casted for heat curing.

Table 7 Split Tensile strength for different ages of geopolymer concrete

MIX Ratio	SPLIT TENSILE STRENGTH IN Mpa	
	Ambient Curing	Heat Curing
S1	2.87	2.9
S2	2.9	3
S3	3.67	3.74
S4	4.1	4.24
S5	4.38	4.7

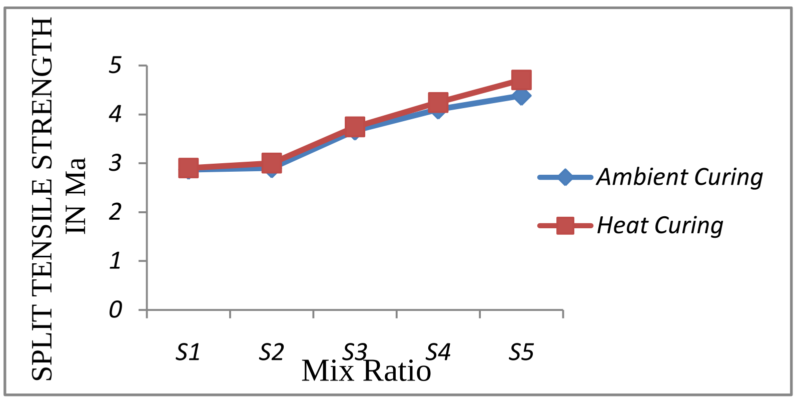

Figure 5, Split Tensile strength of geopolymer concrete

From the Figure 5, it can be observed that the split tensile strength of geopolymer concrete increases when heat curing is adopted.

Flexural strength test result

Totally there were 30 prisms casted to determine the flexural strength of GPC, Where 15 prism were casted for ambient curing and the remaining 15 were casted for heat curing.

Table 8 Flexural Strength for different mix proportions of geopolymer concrete

MIX Ratio	FLEXURAL STRENGTH IN Mpa	
	Ambient Curing	Heat Curing
S1	1.26	1.6
S2	2.28	2.6
S3	2.94	3.5
S4	3.45	4.74
S5	3.9	5.5

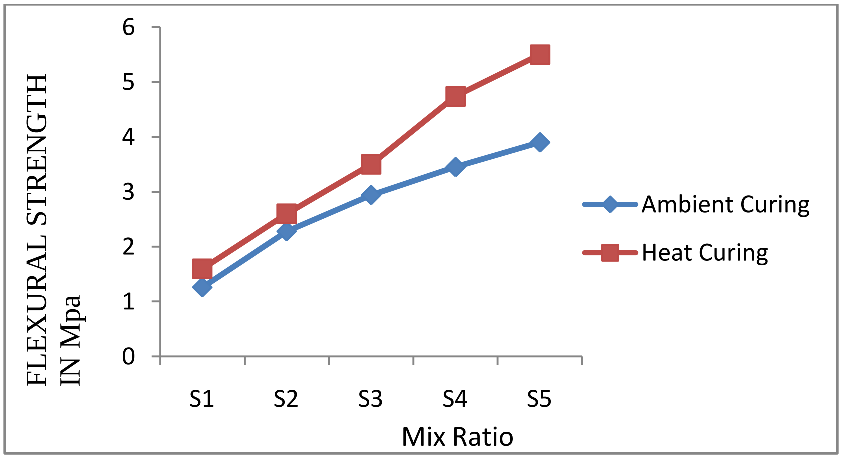

Figure 6, Flexural strength of geopolymer concrete

From the Figure 6, it can be observed that the flexural strength of geopolymer concrete increases when heat curing is adopted.

Percentage Increase of Compressive Strength Values for Heat curing from Ambient curing

It can be observed that the compressive strength of geopolymer concrete increases enormously with increase in percentage of slag (GGBS) to fly ash. The percentage increase of compressive strength in varying significantly in heat curing when compared to ambient curing.

Table 9 Percentage increases of compressive strength values for heat curing from ambient curing

Mix Ratio	Compressive strength in Mpa
S1	4
S2	6.45
S3	5.63
S4	5.36
S5	9.68

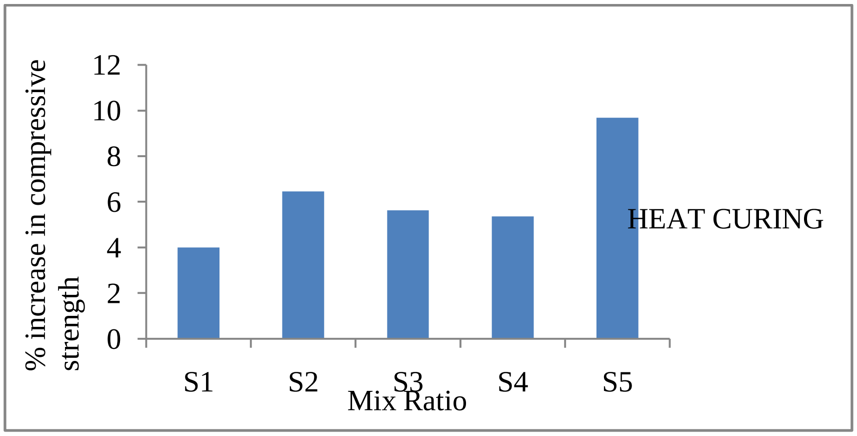

Fig 7. % increase in Compressive strength test

Percentage Increase of Split Tensile Strength Values for Heat curing from Ambient curing

It can be observed that the split tensile strength of geopolymer concrete increases enormously with increase in percentage of slag (GGBS) to fly ash. The percentage increase of compressive strength in varying significantly in heat curing when compared to ambient curing.

Table 10 Percentage increases of compressive strength values for heat curing from ambient curing

Mix Ratio	Split Tensile strength in Mpa
S1	1.04
S2	3.44
S3	1.90
S4	3.41
S5	7.3

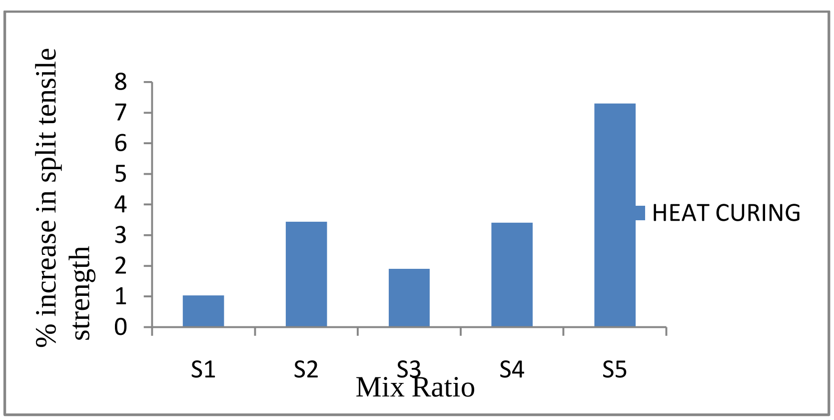

Fig 8. % increase in split tensile strength

Percentage Increase of Flexural Strength Values for Heat curing from Ambient curing

It can be observed that the flexural strength of geopolymer concrete increases enormously with increase in percentage of slag (GGBS) to fly ash. The percentage increase of compressive strength in varying significantly in heat curing when compared to ambient curing.

Table 11 Percentage increase of compressive strength values for heat curing from ambient curing

MIX Ratio	Flexural strength in Mpa
S1	26.9
S2	14
S3	19
S4	37.39
S5	41

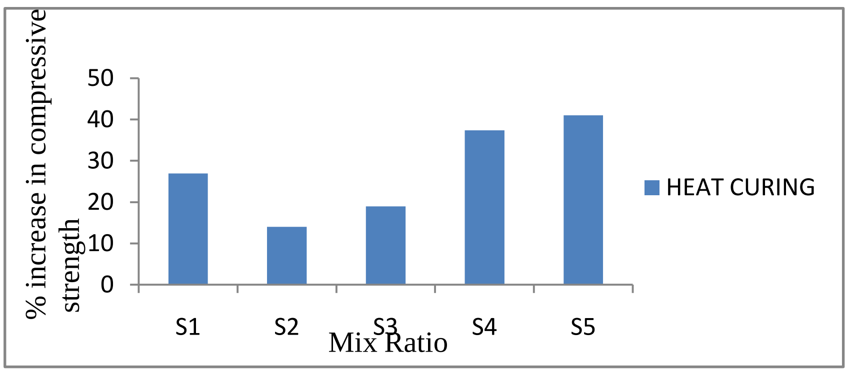

Fig 9. % increase in Flexural strength test

5. CONCLUSION

- In geopolymer material, Fly ash and GGBS is used as the source material, instead of the Portland cement, to make concrete.
- There is no mix design procedure for geopolymer concrete.
- The higher concentration of GGBS (slag) results in higher compressive, split tensile and flexural strength of geopolymer concrete.
- There is no necessity of exposing geopolymer concrete to higher temperature in 0% F.A and 100 % GGBS attained high strength in Mix S5.
- The percentage increases were studied and it is found that the GPC has shown good improvement in flexural strength.

6. REFERENCES

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