Experimental Study on Geopolymer Concrete using Steel Fibres

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***Abstract*— Geopolymer concrete (GPC) are representing the most promising green and eco-friendly alternative to Ordinary Portland cement (OPC). This paper presents results of an experimental program on the mechanical properties of Fibre Reinforced Geopolymer Concrete (FRGPC) such as compressive strength, split tensile strength, flexural strength. FRGPC contains flyash, alkaline liquids, fine aggregate, coarse aggregate and steel fibre. Alkaline liquid to fly ash ratio was fixed as 0.45 with 100% replacement of OPC. For alkaline liquid combination, ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5. Steel fibre was added to the mix in volume fractions of 0.5%, 1.0%, and 1.5% by volume of concrete. Specimens were subjected to 24 hours of Heat curing at 80°C in heat curing chamber. Based on the test results, optimum % were formulated and compared it with conventional Concrete.**

***Keywords*— Geopolymer concrete, flyash, alkaline liquids, steel fibre.**

I. Introduction

Geopolymer is an inorganic polymer. Joseph Davidovits (1978) proposed that an alkaline liquid could be used to react with silicon (Si) and aluminum (Al) as source material of geological origin or with by-product materials such as fly ash and rice husk ash to produce binders[1]. Since the chemical reaction that is taking place in this case is a polymerization process and the precursors are of geological origin, these binders were named as 'Geopolymer'. Geopolymer Concrete is gaining importance world over as the carbon emission and consequent global warming has become the major concern of the entire countries world over. One tone of cement production results in the emission of one tone of carbon dioxide. Many countries are promoting the use of fly ash as building material by granting carbon credit, which will not only reduces the production of cement and emission of carbon dioxide but also promotes the consumption of the waste material fly ash which poses a major problem for disposal world over. In India almost all the states have thermal power plants and abundant availability of fly ash. 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. The alkaline solution sodium hydroxide and sodium silicates are cheap and locally available. This paper is devoted to heat-cured low-calcium fly ash-based geopolymer concrete. Low calcium (ASTM Class F) fly ash is preferred as a source material than high-calcium (ASTM Class C) fly ash[2].

II. MATERIALS USED

A. Fly ash

Low calcium Class F type fly ash obtained from Ennore thermal power station and it was analysed as per IS:3812-1981 having specific gravity of 2.21 were used.

B. Aggregates:

The coarse aggregate is choosen by shape as per IS 2386 (Part I) 1963, surface texture characteritics of aggregate is classified as in IS 383 – 1970[3]. Coarse aggregates comprising of different sizes 20mm, 12mm, 6mm having fineness modulus of 8.04 bulk density of 1578 kg/m^3 and specific gravity of 2.74 were used. The sand is used as fine aggregate and it is collected from nearby area. The sand has been sieved in 4.75 mm sieve having specific gravity of 2.62 and fineness of 3.14 were used.

C. Alkaline solution:

Alkaline solution plays most important role in geopolymerization process. The alkaline liquid used was a combination of sodium silicate and sodium hydroxide solution. The molarity used for mixing of NaOH is 8M. It means 8 part of NaOH pellets is to be added in distilled water. When mixed and stirred gradually an exothermic reaction takes place and extreme amount of heat is evolved. Hence for safety hand gloves are used. The mix solution is left for settling down for 24 hours. The NaOH solution and sodium silicate solution were prepared separately and mixed together at the time of casting.

D. Super plasticizer:

To improve the workability of fresh geopolymer concrete water reducing Sulphonated napthalene polymer based super plasticizer CONPLAST SP 430 was used in all of the geopolymer mixes.

E. Cement:

The cement used for this study is Portland Pozzolanic Cement is conforming to Indian Standard IS 12269 – 1987 of grade 53 having specific gravity of 3.10 were used[4].

F. Steel fibres:

Fig. 1 Hooked end steel fibres

In this work, steel fibre having geometry of cylindrical with hooked ends was used. The length and diameter of fibres are 50mm and 1mm respectively. The aspect ratio (l/d) of the steel fibre is 50. The tensile strength is about 1100 Mpa .

III. Methodology

A. Mix design:

The mix design of geopolymer concrete was adopted from Srinivasan et al. Mix proportions for characteristic strength of 30Mpa (G30) and mix proportion of conventional concrete (M30) are described in Table I[5],[6],[7].

TABLE II Mix proportions of G30 and M30

Ingredients		Gpc	Gpc1	Gpc2	Gpc 3	Cc M30
Fly ash (kg/m^3)		378	378	378	378	-
Cement (kg/m^3)		-	-	-	-	450
Fine aggregate(kg/m^3)		554	554	554	554	687
Coarse aggregate (kg/m^3)	20mm	388	388	388	388	1120
	12mm	543	543	543	543	
	6mm	363	363	363	363	
Sodium hydroxide(kg/m^3)		50	50	50	50	-
Sodium silicate(kg/m^3)		124	124	124	124	-
Super plasticizer(kg/m^3)		7.5	7.5	7.5	7.5	-
water(kg/m^3)		55.4	55.4	55.4	55.4	197
Steel fibre(%)		0%	0.5%	1.0%	1.5%	-

B. Mixing of geopolymer concrete:

The solid constituents of geopolymer concrete mix i.e. fly ash, fine and coarse aggregates were dry mixed in pan mixer for about three minutes. After dry mixing, alkaline solution was added to the dry mix and wet mixing was done for 3-4 minutes. Finally extra water along with superplasticizer was added to achieve workable GPC mix. Steel fibre was added to the wet mix in different proportions such as 0.5%, 1.0%, and 1.5% by the volume of the concrete . Prior to casting, the inner walls of moulds were coated with lubricating oil to prevent adhesion with the concrete specimens. All specimens were cast horizontally in three layers. Each layer was compacted using a tamping rod. The specimens considered in this study consisted of 15 numbers of 150 mm x150 mm size cubes, 15 numbers of 150 mm diameter and 300 mm long cylinders, 15 numbers of 100mm x100mm x500mm size prisms.

C. Curing of geopolymer concrete:

Setting time of geopolymer concrete depend on many factors such as composition of alkaline solution and ratio of alkaline liquid to fly ash by mass. As the curing temperature increases, setting time of concrete decreases. During curing process, geopolymer concrete experiences polymerization process. Due to the increase of temperature, polymerization process becomes more rapid. The curing time may varied from 4 hours to 96 hours (4 days). The rate of increase in strength was rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heat curing time need not been more than 24 hours in practical applications After casting, specimens were placed inside the heat curing chamber and cured at 80°C for 24 hours. After curing, the specimens were removed from the chamber and left to air-dry at room temperature for another 24 hours before demoulding. The test specimens were then left in the laboratory ambient conditions until the day of testing.

IV. RESULTS

A. Compressive strength:

The average compressive strength of geopolymer concrete with and without fibres for heat curing of 24 hours at 80°C and conventional concrete was shown in Table IIIIV. Compressive strength of GPC and CC specimens were compared by plotting graphs as shown in Figure 2. The increase in compressive strength was about 8.2% and 25.9% for GPC1 and GPC2 respectively with respect to GPC mix and decrease in compressive strength was about 18.1% GPC3 respectively with respect to GPC2 mix.

TABLE VVI Compressive strength of CC and GPC mix

Mix ID	Average compressive strength(N/mm^2)	Increase in compressive strength(%)
CC	38.1	-
GPC	31.6	0
GPC 1	34.2	8.2
GPC 2	39.8	25.9
GPC 3	37.3	18.1

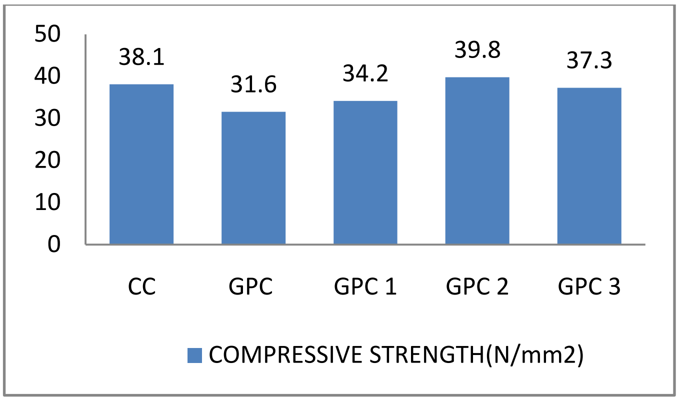

Fig. 2 Compressive strength chart(N/mm^2)

B. Split tensile strength:

The average split tensile strength of geopolymer concrete with and without fibres for heat curing of 24 hours at 80°C was shown in Table VIIVIIIIX. Split tensile strength of GPC and CC specimens were compared by plotting graphs as shown in Figure 3. The increase in split tensile strength was about 26.9% and 57.4% for GPC1 and GPC2 respectively with respect to GPC mix and decrease in split tensile strength was about 44.2% for GPC3 respectively with respect to GPC2 mix.

TABLE XXIXII Tensile strength of CC and GPC mix

Mix ID	Average tensile strength (N/mm^2)	Increase in tensile strength(%)
CC	4.34	-
GPC	2.89	0
GPC 1	3.67	26.9
GPC 2	4.55	57.4
GPC 3	4.17	44.2

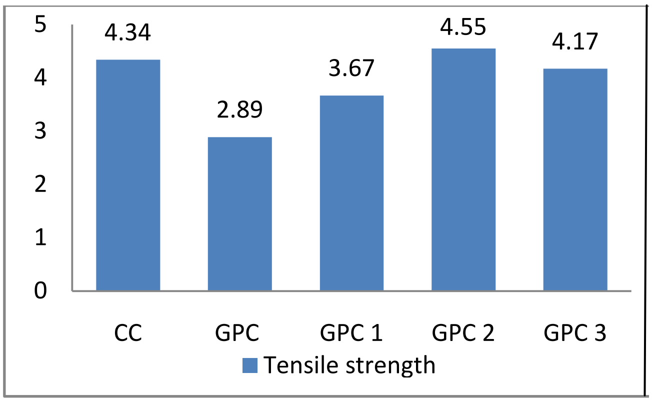

Fig. 3 Split tensile strength chart(N/mm^2)

V. CONCLUSION AND FUTURE WORK

1. Compressive strength of 1% steel fiber geopolymer concrete has found to be 5% increase in strength, when compared to that of conventional concrete.
2. Split tensile strength of 1% steel fiber geopolymer concrete has found to be 5% increase in strength, when compared to that of conventional concrete.
3. Hence 1% concentration of steel fibers is found to be the optimum dosage for his project work.
4. For the future work, the continuation of project research with 15 numbers of prisms to find flexural strength of steel fibre geopolymer concrete prism and compared with conventional concrete prism.

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