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An Experimental Study on Flexural Behaviour of Fiber Reinforced Geopolymer Concrete Slabs

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***Abstract*- This paper deals with experimental investigation to understand the structural performance as a flexural member of Geo polymer concrete. A comparative analysis has been carried out for normal conventional concrete to that of the Steel fiber reinforced geopolymer concrete under ambient curing in relation to compressive, split tensile, flexural strengths. For the experimental work, 70% flyash and 30% GGBS as a replacement of cement and a combination of sodium silicate solution (with water content 55.9%) and sodium hydroxide flakes (with 98% purity) were used. The Alkaline solution was prepared by mixing flakes in the sodium silicate solution together one day prior to use. The ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5 and the molarity of NaoH was kept as 8. Steel fiber of 1.5% of total volume of geopolymer concrete is the optimum dosage with an aspect ratio 71. As the fiber content increases compressive, split tensile and flexural strengths are proportionally increases. It is also found that with addition of fibers the load deflection is reduced by 30%.**

Keywords: Fiber reinforced concrete, Steel fiber, Alkaline solution, Flexural Strength, Slab.

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural ability and strength. Its total consumption is around twenty billions tones, which is equivalent to two tones for every living human being. In India, most of the construction activities are made with concrete, as it is easily available and the moulding can be done even by unskilled labour. Thus, concrete is becoming a very important material for every human.

GEOPOLYMER is an alternative cementitious material which has ceramic-like properties. As oppose to OPC, the manufacturer of fly ash-slag (GGBS) based geo-polymer does not consume high levels of energy, as fly ash and slag are already an industrial by-product. 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.

The motivation for using fly ash and slag as the main raw material is driven by various factors:

- It is cheap and available in bulk quantities.
- It is currently under utilized accept for its use as an additive in OPC.
- It requires less water (or solution) for activation.
- Fly ash and GGBS based geo polymer also provides superior performance and gives better resistance to aggressive environmental condition compared to normal concrete.

The compressive strength of geopolymer concrete increases with the optimum NaOH molarity, binder/alkaline activator ratio, Na2SiO3/NaOH ratio used, and curing process handled. Fibers are mainly used to prevent the prolongation of cracks. The steel fiber used in this work is hook ended type HK0750 having aspect ratios 71. The addition of fiber content reduces the deflection.

II. MATERIALS AND MIX SPECIFICATIONS

A. Flyash : The chemical and physical composition of the fly ash was determined as per IS: 3812-2003.

Sl No	Description	Values	Requirement as per IS:3812:2003
1	Specific gravity	2.2	--------
2	Fineness (Blain's air permeability- m^2 /kg)	522	320
3	Residue on 45 micron sieve, percent (max)	24.4	34

Table 1: Physical properties (Class F)

Sl No	Description (Requirement as per IS:3812:2003)	Values
1	Silicon dioxide (SiO_2)percent by mass,(min)	61.9
2	Aluminium oxide (Al_2O_3), percent by mass	26.06
3	Iron oxide (Fe_2O_3), percent by mass	6.21
4	Magnesium oxide (MgO), percent by mass,(Max)	0.79
5	Calcium oxide (CaO), percent by mass	3.05

Table 2: Chemical properties (Class F)

B. GGBS

Sl no	Description	Values
1	Specific gravity	2.62
2	Fineness by Blaine's air permeability(m2/kg)	321
3	Wet sieve analysis % retained on(45 μ)	2.90

Table 3: Physical properties

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Sl no	Description	Values
1	Silicon dioxide(SiO2)	33.78
2	Aluminum oxide(Al2O3)	17.08
3	CaO (Calcium oxide)	39.87
4	MgO (Magnesium oxide)	7.10

Table 4: Chemical properties

C. *Alkaline solution*: A combination of sodium silicate solution and sodium hydroxide solution were used to initiate the aluminium and the silica in the binder (fly ash & GGBS). The sodium hydroxide is in the form of flakes with 98% purity. Sodium hydroxide solution was prepared by dissolving flakes in the water. For the experimental work the concentration of sodium hydroxide solution used was 8 molars. In order to yield this concentration, one liter of the water contained 8X40=320 grams of flakes, Commercially available sodium silicate was used for this experimental work with water content 55.9% .The ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5. The alkaline solution was prepared by mixing both sodium silicate solution and sodium hydroxide solution together at least one day prior to use.

D. *Steel Fibers:* The steel fiber used is the hook ended type HK0750 having aspect ratios 71. The dosage of fibers was fixed as 1.5% of the total volume of the geopolymer concrete. The length of dividing fiber is 50mm and the diameter of fiber is 0.7.

E. *Design Parameters*: The details of ingredients for the experimental work are as follows:

Sl no.	Design parameters	Values	Quantity (kg/m^3)
1	The wet density of geopolymer concrete	2400	2400
2	Fly ash	70%	286
3	GGBS	30%	122
4	Steel fiber	1.5%	36
5	Molarity	8M	-
6	Coarse and fine agg	77%	554+1294= 1848
7	Ratio of Sodium silicate to Sodium Hydroxide solution	2.5:1	-
8	Sodium silicate	-	103
9	NaOH(30kgwater+11kg NaOH)	-	41

Table 5: Design parameters

III. EXPERIMENTAL PROGRAM AND RESULTS

A. Tests on Geopolymer Concrete Cubes And Cylinders:

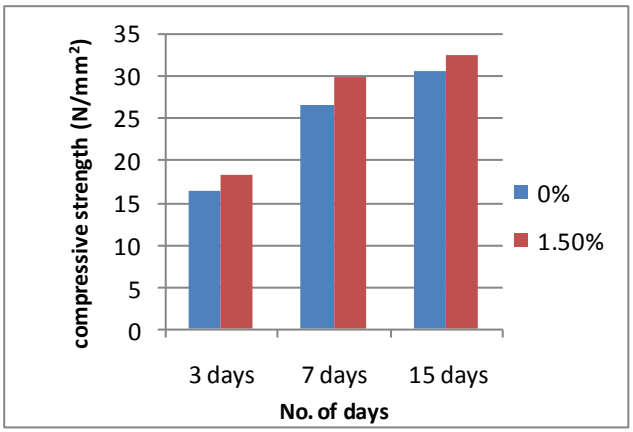
The basic test as per the Indian standard code IS: 516-1959 (reaffirmed 1999) was conducted for concrete mix with and without the addition of fibers on 2000kN capacity UTM to study the behavior of the concrete. The specimens used for this test are 150X150X150 mm cubes and 150 mm dia, 300 mm length cylinders for compressive strength test and split tensile strength test respectively.

- *Compressive Strength Test:*

Figure 1: Test set up for compression

Sl. No	Fiber added(%)	Days of curing	Load at failure(KN)	Compressive strength(Mpa)
1	0	3	367	16.31
2	1.5	3	410.85	18.26
3	0	7	596.4	26.51
4	1.5	7	670.5	29.8
5	0	15	687.6	30.56
6	1.5	15	726.75	32.3

Table 6: Compressive strength test for steel fiber reinforced geo polymer concrete



Graph 1: Compressive strength v/s Days

From the above table it is clear that the compressive strength of concrete at 3 days, 7 days and 28 days is increasing with the fiber content when compared to that of conventional concrete and also observed that 15% gain is seen in the compressive strength on adding fiber content.

- *Split Tensile Strength Test:*

Sl. No	Type of specimen	Load P(kN)	Split tensile strength$f_{ct}=2P/\pi ld$ (N/mm^2)
1	Without Fiber	205	2.89
2	Steel Fiber	220	3.11

Table 7: Split tensile strength test for steel fiber reinforced geo polymer concrete

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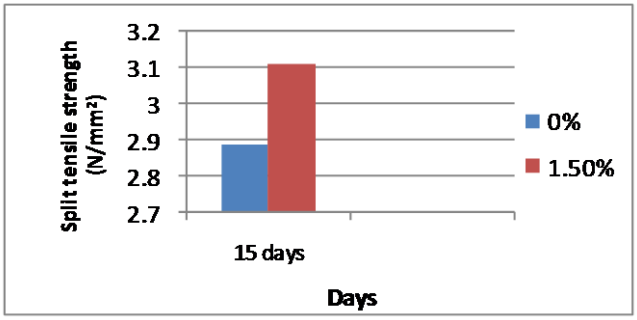

Graph 2: Split tensile strength v/s days

From the above graph it is observed that split tensile strength of concrete with fiber content is more when it is compared with that of conventional concrete at 15 days. It is found that 1.5% addition of steel fibers in the weight of concrete is the optimum dosage. Also 15% increase in the tensile strength of fiber reinforced geopolymer concrete is seen at this optimum dosage.

B. Tests on Geopolymer Concrete Slabs

- *Flexural Test:*

This paper discuss with the casting of reinforced geopolymer concrete slab specimens with detailed test program. In order achieve the required tensile reinforcement HYSD bars having yield strength 500 N/mm^2 were used for the production of reinforced geopolymer concrete slabs with fiber (steel fiber) and without fiber. Totally three reinforced geopolymer concrete slabs were casted and tested, among that one was conventional geopolymer concrete slab(S1), and the other two were steel fiber reinforced geopolymer concrete slab(S2, S3). The behaviour of load deflection characteristics are presented in this paper.

Slab Details:

The dimensions of a member was selected based on the, practical limitations, such as size of the loading frame and its capacity, capacity of the hydraulic jack used for loading the slabs. Accordingly, dimensions of the slab are as follows
Overall Length = 1000mm, Overall Breadth =1000mm, Overall Depth = 60mm

Geometry and reinforcement arrangement:

All three slabs were 1000mm x 1000mm x 60mm. The clear cover to reinforcement was 10mm on all faces. The geometry and reinforcement arrangement of slabs were presented in table.

Slab	Slab Dimension	Reinforcement	
		Main Reinforcement	Distribution Reinforcement
S1	1000X1000X60	8Φ @ 100 c/c	8 Φ @ 100mm c/c
S2, S3	1000X1000X60	8Φ @ 90 c/c	8 Φ @ 90 mm c/c

Table 8:Slab details

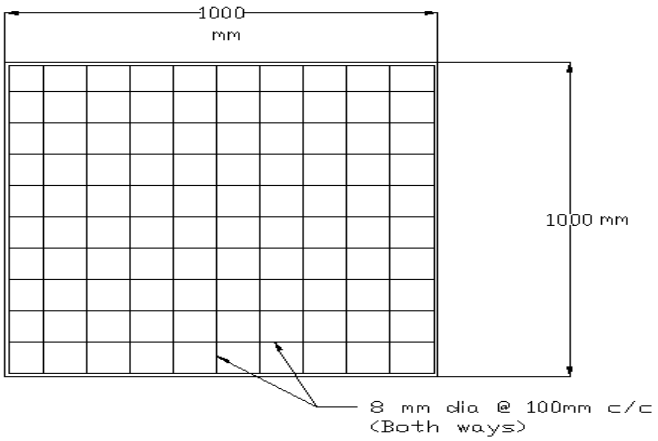

Figure 2: Slab Reinforcement

Test Setup And Instrumentation:

All the slabs are simply supported and tested in 500 kN capacity loading frame for uniformly distributed load, one dial gauge of least count 0.001 mm was placed on the center of tension face of the slab to measure the deflection along the length.

Before placing the slab specimens on the loading frame, all the specimens were white washed in order to facilitate marking of cracks. After white wash the slab specimens were placed on the loading frame with all the arrangement load is applied in an interval of 2kN using hydraulic jack at the same time deflection is noted down with the help of digital dial gauges, and also Demec gauge reading is also noted. Crack load and ultimate load is recorded also the cracking patterns are marked to study the crack patterns of the specimens. The loading is continued until the failure of slab specimens.

Experimental Results:

The test set up was done for the first specimen (control slab S1), Digital dial gauges was fixed at the bottom centre of slab. Initial adjustments were done before the experiment. The first signs of distress in control slab specimens was hairline cracks at the flexure zone. Additional cracks emerged and the existing cracks widened and propagated towards the edges of slab as the load was increased. The first crack was observed at 48 kN. The load – deflection graphs is plotted for the specimen.

The other two slabs were tested with steel fiber (S2,S3) which showed the first crack at 50 KN.

As the load increases slab starts to deflect at the center in the direction of load and cracks are developed along the tension face of the slab specimens, eventually all the slab specimens failed in a typical flexure mode.

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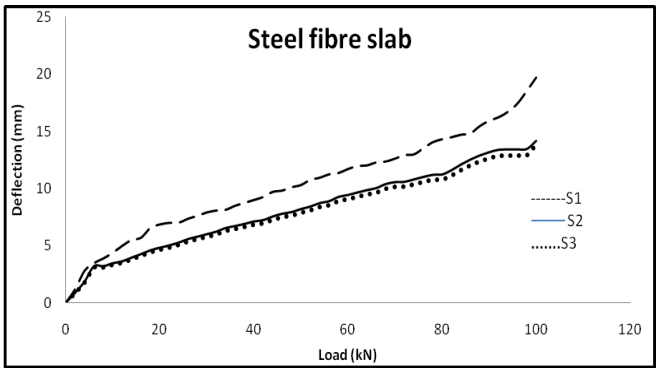

Graph 3: Load-deflection curve for GPC slab and Steel fiber reinforced slab

From the above graph 3, it could be seen that the deflection of slab reduces with the addition of fibers when compared to the slab without fiber. From the results it is observed that the first crack occurs in the slab at almost the same load for all specimens considered. But in steel fiber reinforced slabs (steel) the prolongation of the crack is restricted due to the presence of fibers thus the second and third cracks appear later compare to the slab without fiber.

CONCLUSION

1. It was noticed that 70% fly ash and 30% GGBS combination works similar to OPC from the experiments.
2. The mix design was done by assuming the density of GPC as same as RCC that is 2400kg/m^3 the total mass of the aggregate was taken as 77% of the entire concrete mix by mass.
   - Mass of GPC source material was taken as 408 kg and total mass of alkaline liquid was($NaOH+Na_2Sio_3$)=144 kg
   - Molarity of NaOH was considered as 8M and ratio of chemical solution was fixed as 2.5 throughout the work.
3. If the proper quality control is exercised, then the cost of production of cubic meter GPC concrete can be reduced to that of ordinary Portland cement concrete.
4. The deflection of slab reduces with the addition of fibers to it when compared to the slab without fiber.
5. The first crack occurs in the slab at almost the same load for specimens with or without fiber.
6. In steel fiber reinforced slabs the prolongation of the crack is restricted due to the presence of fibers thus the second and third cracks appear later compare to the slab without fiber.

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