International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

Behaviour of Fiber Reinforced Geopolymer Concrete

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***Abstract*: This paper presents the behavior of geopolymer concrete with small and big fibers. The aluminosilicate materials used for geopolymer concrete are fly ash and GGBS. For this study standard cube, cylinder and beam specimens are casted and tested to investigate compressive, split tensile and flexural strengths. The experimental results shows that incorporation of steel fibers for the geopolymer mixes improve the strength properties. Few models are generated to estimate the strengths with alliance of cube compressive strength.**

***Keywords* : Small fibers, big fibers, geopolymer, compressive, split tensile, flexural strength.**

I. INTRODUCTION

In 1978 Joseph Davidovits (1999) proposed geopolymer concrete as another new material for construction industry. Since then many research works are going on in this arena. Among many studies, few works are presenting to know about this material in view of strength. Davidovits[1] described the Mineral binder family whose chemical symphony is similar to zeolites and coined the word Geopolymer. Hamilton [2] estimated the durability of FRP using accelerated curing condition under 60°C elevated temperature for notched three-point bending test. Hadigheh et al., [3]examined the long term performance of fiber reinforced polymer materials and discussed potential degradation. Shafqat et al.,[4] explored the resistance offered by hybrid FRP composite shell to chloride ingress. Yue Li[5] studied the effect of elevated temperature on mechanical properties of Fibre Reinforced Plastic. Alam & Hussein [6] investigated and concluded that there is a strong relationship between the shear capacity and flexural cracking load of FRP reinforced concrete beams without stirrups. Thangaraj Sathanandam et al.,[7] observed tensile strength improvement in glass fiber-reinforced fly ash based Geopolymer Concrete. Albitar et al.,[8] using fly ash/Granulated Lead Smelter Slag (GLSS)-based Geopolymer Concrete columns and beams tested under concentric and eccentric loading exhibited similar structural behaviour to OPC.

Revised Manuscript Received on November 30, 2019.
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Kim Hung Mo et al.,[9] steel fibre improve the mechanical properties and also enhance the flexural toughness. Kolli et al.[10] confirmed the mechanical behaviour of geopolymer concrete is similar to that of ordinary Portland cement concrete.

II. IMPORTANCE OF THE WORK

It is clear that, no work has been reported with addition of small and big fibers in the available literature; hence investigation is planned to predict the performance of fiber reinforced geopolymer concrete.

III. OBJECTIVES

The present investigation was planned with the following objectives.

1. To evaluate cube and cylinder compressive strengths
2. To evaluate split and flexural strengths
3. To develop models in order to estimate strengths.

To achieve above objectives four mixes are prepared in the present study, the mix-1 is GPC0, it is read as Geopolymer concrete with 0% fiber and 2nd and 3rd mixes are GPCS1 and GPCB1 read as Geoplolymer Concrete mix with 1% small fiber and 1% big fiber respectively. 4th mix is GPCS1B1 read as Geopolymer concrete mix with 1% small fiber and 1% big fiber.

IV. MATERAIALS AND METHODOLOGY

The following materials were used for the experimental work
Source materials: Fly ash and GGBS (Ground Granulated Blast Furnace Slag) were used.
Coarse and fine aggregates: 20mm size course aggregate and natural river sand was used
Activators: Sodium Hydroxide and Sodium Silicate were used
Water: potable water was used.
Small fibres: Fiber with 0.25mm diameter and 13mm length, with an aspect ratio of 52 and brass coated received from Fiber Zone Company, Ahmadabad, Gujarat (State)-380009, are used as small fiber.
Big fibres: Fiber with 0.75mm diameter and 50mm length, with an aspect ratio of 66.67 and crimped are obtained from Fiber Zone Company are used as big fibers.

From the above materials mix design was adopted as per B.Vijaya Rangan [11] and the output of the mix proportion is providing in the Table 1.

For each mix three samples tested and the results has presented in the next section. The material and tested specimens can be viewed in figure 1.

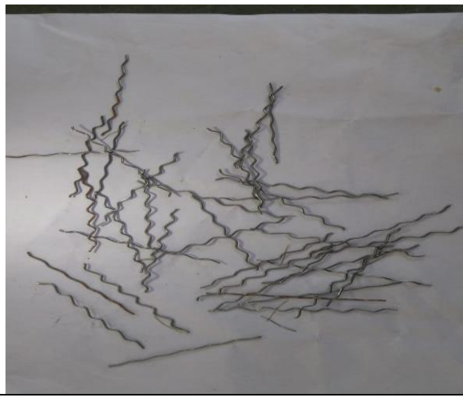
Table 1: Materials required per cubic meter

Fly ash (Kg/m^3)	GGBS (Kg/m^3)	FA (Kg/m^3)	CS (Kg/m^3)	NaOH (Kg/m^3)	Na_2SiO_3 (Kg/m^3)	Extra water (Kg/m^3)	Super plasticizer (Kg/m^3)
206.9	206.9	540.0	1260.0	62.07	124.19	22.0	2.00

Coarse and fine aggregate

Activitaors and water mixing

Small fibres



Big fibres

Dry mix with small fibers

Dry mix with big fibers

	
Mix ing of geopolymer concrete	Casted specimens
	
Tested Cube Specimens	Cylinder under compression
	
Split tensile test	Beam test

V.STRENGTH RESULTS

A. Cube and cylinder compressive strengths

Compressive strength results are presented in Table 2. From this table it is noticed that, the provision of steel fibers for the geopolymer mixes increased the cube compressive strengths. The mixes with small and big fibers show 10.7% and 20.0% compressive strength increment than the mix without fibers. The mix with addition of both small and big fibers enhanced the strength by 31.1% when compared with the mix without fibers.

The cylinder compressive strength was presented in the Table 2. Similar to cube compression for small and big fibres show strength increments by 14.6% and 17.0% when compared with geopolymer mix without fibers, for the mix with addition of both fibers, the strength enhancement was about 34.2%.

In the above discussion it is observed that, the provision of fibers improve the strengths of geopolymer concrete, but the degree of increment depends upon the type and dosage of fibers to the geopolymer matrix.

B. Split and flexural strengths

All four mixes are tested for split and flexural strengths and the results are furnished in Table 2. From this table it is witnessed, lower strength for the geopolymer mix without fibers.

For the mixes with small and big fibers the split and flexural strengths are increased by 17.1% and 7.2% and 35.5 and 22.9% respectively. This indicates as the addition of fibers to the geopolymer mixes strengths are increasing, this type of trend also noticed in the above section for compressive strengths also. The mix with addition of 1% small and 1% big fibers showed 53.7% and 44.0% increment of strength for split tensile and flexural strengths respectively.

Fibers in geopolymer concrete acts as strength enhancers, by creating proper bonding between the matrix and fibers. The small fibers have less stability than the big or length fibers. In our work 13mm and 30mm length fibers are used, 30mm length fibers possessed good bond and dimensional stability than the small fibers. When the mix with provision of small and length fibers the energy absorption of the tested materials is more rather than the individual mixed specimens, this excited in the form of strength of the mix. As per the rule of mixers, the mix with fibers shows higher strength values and it is evident herein.

Table 2: Strength results

Sl. No	Mix	Cube Comp Stress (MPa)	Cylinder Comp Stress (MPa)	Split Tensile Stress (MPa)	Flexural Strength (MPa)
1	GPC0	33.40	28.70	4.50	5.97
2	GPCS1	37.00	32.90	5.27	6.40
3	GPCB1	40.10	33.60	6.10	7.34
4	GPCS1B1	43.80	38.54	6.92	8.60

C.Regression models

Number IS456-2000 code provides relation for mechanical strengths with cube compressive strength; accordingly this investigation proposed a relation for cylinder compressive, split tensile and flexural strengths with cube compressive strength.

Relation between cylinder and cube compressive strength: With the available test results, following relation is proposed to find the cylinder compressive strength with a correlation coefficient of 0.9509.

$$fcy = 0.88fc - 0.80$$

Relation between spilt Tensile and cube compressive strength: The following equation is proposed to estimate split tensile strength with use of cube compressive strength with 0.9975correlation coefficient.

$$fsp = 2.91\sqrt{fc} - 12.41$$

Relation between flexural and cube compressive strengths: Using experimental results, proposed an equation to predict flexural strength with a correlation coefficient of 0.9489

$$ft = 3.17\sqrt{fc} - 12.62$$

Performances of all the above proposed equations are shown in Table 3. The cylindrical compressive, split tensile and flexural strengths deviate by about 3, 2 and 4% with the experimental results. This indicates that, proposed equations show good concurrence with the experimental results.

Table 3: Performance of Models

Sl.No	Mix	Cylindrical compressive strength			Split tensile strength			Flexural strength		
		Exp	RM	Exp/RM	Exp	RM	Exp/RM	Exp	RM	Exp/RM
1	GPC0	28.70	28.59	1.00	4.50	4.40	1.02	5.97	5.70	1.04
2	GPCS1	32.90	31.76	1.03	5.27	5.29	0.99	6.40	6.66	0.96
3	GPCB1	33.60	34.49	0.97	6.10	6.01	1.01	7.34	7.45	0.98
4	GPCS1B1	38.54	37.74	1.02	6.92	6.84	1.01	8.60	8.35	1.02

VI. CONCLUSION

1. The incorporation of fiber to the geopolymer mixes yield superior split tensile, compressive and flexural strengths.
2. GPCB1 mix show more strength than GPCS1 mix but both GPCS1 and GPCB1 mixes exhibit more strength vales than GPC0 mix.
4. Among all mixes, GPCS1B1 mix exhibit top performance.
5. The furnished models show good consistency with the test results.

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