Experimental Investigation on Geopolymer Concrete Using Steel Fibers

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Abstract- *With the increase in the constructional activities throughout the globe, the demand for the construction materials is being hiked as the days pass by. The excessive use of the natural resources has also lead to their depletion, giving rise to the crisis for natural materials and escalating their cost accordingly. In these scenarios geopolymer is one of the best available alternatives for the conservation of the natural resources. The Geopolymer mainly comprises of waste by-products from the different industries such as thermal power plants, steel plants and so on. The geopolymer also helps reduce the emissions of carbon dioxide from the cement industries by cutting down the cement requirement. In this study efforts have been undertaken to incorporate the geopolymer materials into the concrete and study the variation in the strength parameters. The geopolymer used for the present investigation is ground granulated blast furnace slag (GGBS), which is used as the 100% replacement for the binder material. Along with the geoploymer mix, hooked end steel fibres have been integrated in different percentages i.e. 0.5%, 1.0% and 1.5% to the mix and to bind all the materials, sodium silicate and sodium hydroxide are used as activators. The cube, cylinder and beam specimens were cast and the ambient curing technology 26±30C is adopted for the specimens. The marginal increase in compressive strength whereas a significant increase in tensile strength and flexural strength is observed.*

Keywords- Geopolymer, GGBS, Sodium silicate and Sodium hydroxide activator, ambient curing technology.

I. INTRODUCTION

The past century of expeditious industrialization has introduced significant and noteworthy improvements in the construction industry [1]. Cement is one of the most widely used materials in the construction industry and has grown to a popular heights, but the production of cement requires natural resources which are depleting day by day. Approximately 1 tonne of carbon dioxide (CO_2) is released in the manufacture of every 1 tonne of cement [2]. The CO_2 that is released in the production of the cement, contributes a significant portion of the greenhouse gasses which is a primary cause in the global warming [3, 4]. By keeping the sustainability as a pivotal criterion of the study the GGBS has been used as a replacement for the cement [8]. Ground granulated blast furnace slag (GGBS) is the waste by-product generated form the iron industries [5, 4 & 6]. The GGBS mainly comprises of CaO, SiO_2, Al_2O_3 and MgO [6]. By using the GGBS as a replacement for the cement, about 48% of the emission rate in the greenhouse gasses can be reduced [7]. The GGBS mix doesn't require water for the purpose of curing owing to the absence of the hydration reaction thus helping in conserving the precious water resource. The ambient curing technology has been adopted for the present study which requires no additional water for curing. Various types of fibres are available in the market i.e. organic fibres, glass fibres, polypropylene fibres, steel fibres, carbon fibres and so on. For the present study steel fibres with hooked ends have been used, Steel fibres are found to improve the durability aspect of the structure by hindering the crack formation due to the plastic and drying shrinkage phenomenon and also decreases the permeability of the concrete. The addition of the steel fibres has a significant effect on the improvement of split tensile strength and flexural strength whereas it has no remarkable increment in the compressive strength [9].

II. OBJECTIVES

- To investigate the tensile strength, compressive strength and flexural strength characteristics of the geopolymer concrete.
- To determine the effectiveness of the GGBS as a replacement for cement.
- To sustain the depleting natural resources by using the GGBS waste.
- To determine the influence of the fibers on the tensile and flexural strength parameters.

III. MATERIALS USED

For the preparation of mixes , the local industries materials are procured, the GGBFS (in accordance to IS

12089- 1987 [22]) was procured from Jindal Iron and Steel Plant, Bellary. The chemical composition and physical properties of GGBFS are shown in Table I The alkaline activators are sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) flakes together call as alkaline activators. The liquid sodium silicate [Na_2O=14.7%, SiO_2=32.35%, H_2O=52.95% by mass] having density of 1570kg/m3 and NaOH flakes (96% purity) with a density of 2110 kg/m3 was impart by a N.R. Chemicals laboratory. for the preparation of alkali solution Potable tap water was used which is available in institution. The coarse aggregates used were crushed granite aggregates with a maximum size of 20mm.The manufactured sand was used ofs meeting the requirements of IS: 383-1970[23] was used as fine aggregates, properties of aggregate are listed in table II.

Table I: Physical Properties and Chemical Composition of GGBS

Constituents	Percentages %
CaO	34.77
Al_2O_3	16.7
Fe_2O_3	1.2
SiO_2	32.52
MgO	9.65
Na_2O	0.16
K_2O	0.07
SO_3	0.88
Insoluble Residue	4.03
Loss of Ignition	0.04
Specific gravity	2.9

Table II: Physical Properties of Aggregates Used

S. No	Test	Crushed granite aggregate	Fine aggregate	Method test reference
1	Specific gravity	2.59	2.63	IS 2386 (P-III)-1963
2	Bulk density • Loose	1361 kg/m³	1560 kg/m³	
	• Compact	1445 kg/m³	1640 kg/m³	
3	Aggregate crushing value	17.34%	-	IS 2386 (P III & IV)-1963
4	Aggregate impact value	16%	-	
5	Water absorption	0.45%	0.63%	

IV. METHODOLOGY

The specimens with different proportions of fibre dosages i.e. 0%, 0.5%, 1.0% and 1.5% were prepared a constant activator modulus. The dosage of the sodium oxide (Na_2O) was fixed for all the mixes used in the work. The activator modulus of 1.25 has been adopted for the present investigation based on the observation [4]. The compressive strength test, split tensile strength and flexural strength were conducted on the specimens as per I.S. codal specifications.

Fig 1: Casted Specimens

Table III: Concrete Mix Proportion

Mix Id	Water binder Ratio	Fiber dosage in %	Binder (GGBS) in Kg/m³	Fine aggregate in Kg/m³	Coarse aggregate in Kg/m³	Na_2SiO_3 in Kg/m³	NaOH in Kg/m³	Added water Kg/m³
GPC 0	0.41	0	421	630	1116.7	65	9.4	150
GPC 1	0.41	0.5	421	630	1116.7	65	94	150
GPC 2	0.41	1.0	421	630	1116.7	65	9.4	150
GPC 3	0.41	1.5	421	630	1116.7	65	9.4	150

V. RESULTS AND DISCUSSIONS

A. Compressive Strength

Compressive strength: The test results obtained for the compressive strength test is as shown in fig 2. From fig 2 it can be clearly observed that there is a marginal strength gain over a curing period of 28 days. For the 0% dosage of the fibre, the compressive strength was found to marginally increase from 41.99 MPa and 55.59 MPa for 7 days and 28 days respectively similarly for 0.5% dosage of the fibre, 48.34 MPa and 57.88 MPa for 7 days and 28 days and for 1.0% dosage of the fibre, 50.36 MPa and 58.91 MPa for 7 days and 28 days [4, 10]. This trend in the strength gain continues till the fibre dosage of 1.0% and any further addition of the fibre to the mix is found to reduce the compressive strength [4].

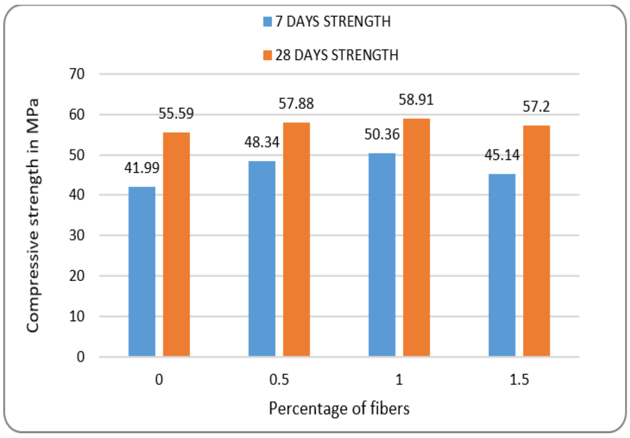

Fig 2: Variation of Compressive Strength in Geopolymer Concrete with Different Dosage of Fibres.

B. Tensile strength

The results obtained from the split tensile strength test indicate that the split tensile strength of the specimens with fibre dosage, increases as shown in fig. 3 for the fibre dosages of 0.5%, 1.0% and 1.5% the split tensile strengths are 3.92 MPa, 3.95 MPa and 4.07 MPa respectively on 28th day. The addition of the fibres mitigates the crack formation, when loads are applied through the deception of the stresses throughout the specimen by the virtue of bond stress. This phenomenon continues either till failure of the fibre or till the pull-out of the fibres due to de-bonding [11].

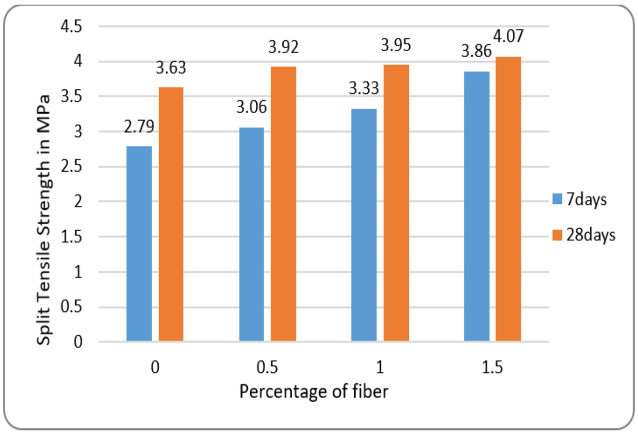

Fig 3: Variation of Compressive strength in Geopolymer concrete with different dosage of fibre.

C. Flexural strength

The results of the flexural strength test, reveal the increase in the flexural strength as the percentage of the fibre dosage in the mix is increased as shown by the fig. 4 for the fibre dosages of 0.5%, 1.0% and 1.5% the flexural strengths are 4.25 MPa, 4.93 MPa and 5.06 MPa respectively on 28th day. The flexural strength is found to increase as the compressive strength increases [4, 10].

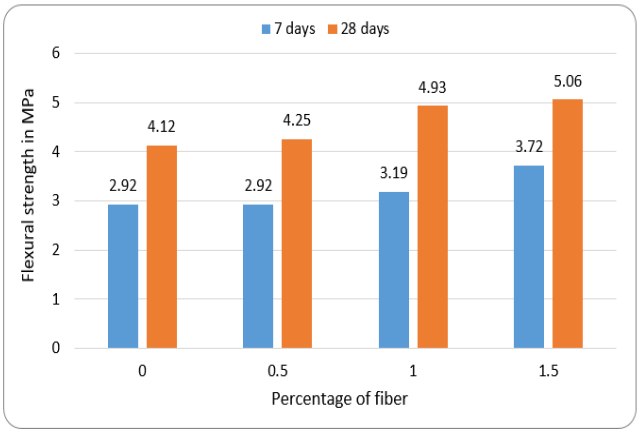

Fig 4: Variation of Compressive Strength in Geopolymer Concrete with Different Dosage of Fibres.

VI. CONCLUSION

- The strength of the specimen under compression is found to increase by 6.5% over the curing period of 28 days when compared with the specimen with 0% fibre dosage.
- The maximum compressive strength is achieved at the fibre dosage of 1.0%.
- The increase in the percentage of the fibre dosage reduces the strength.

- The split tensile strength is found to increase by 12% over the curing period of 28 days when compared with the specimens with 0% fibre dosage.
- The flexural strength of the specimen increases by 22% over the curing period of 28 days when compared with the specimens with 0% fibers dosage.
- Early gain in strength was observed in GPC mixes.

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