Experimental Study on Strength Properties of Concrete Using Fibres & GGBS as Partial Replacement of Cement

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Abstract

The use of fibre reinforcement concrete provides the ductility and toughness required for higher strength. The single type of fibre with reinforcement in concrete improves the mechanical properties at certain level. In concrete the different type of pozzolanic materials are normally used to improve the properties. GGBS can be used as partial replacement of cement for better performance and it helps in producing high strength concrete because of the total participation in hardening process. Fibres are generally used to resist cracking and to assist in strengthening of concrete. Adding a steel and sisal fibres to concrete at low volume dosage rates provides benefits not available in conventional concrete. The use of GGBS, steel and sisal fibre improves the shear strength, torsional structural strength, impact strength and enhanced fatigue and crack resistance. This study focuses on the compression, split tensile and flexural strength properties of M20 grade concrete. The fibre reinforced concrete contains different percentage of GGBS used as partial replacement for cement in addition to steel and sisal fibre. The GGBS is added to the concrete with the percentage of 0%, 10%, 20% and 30% by the weight of cement and 0%, 0.5%, 1% and 1.5% of steel and sisal fibre is used. Concrete specimens casted are cubes, cylinders and beams. After completion of curing process the concrete specimens are tested at 28 days and the final test results are recorded, analyzed and discussed. The strength achieved due to the addition of GGBS and fibres is compared with the nominal concrete and also the strength achieved by GGBS with the addition of steel fibres is compared with the sisal FRC.
Keywords: GGBS, M-sand, Steel fibre, Sisal fibre, Compressive strength test, Split tensile strength test and Flexural strength test

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I. Introduction

A. General

Concrete is one of the man-made construction material which is universally, abundantly utilized in construction. Basically concrete contains ingredients like water, aggregate, cement & other pozzolanic material. Cement binds all the ingredients thus giving a hard homogeneous concrete. Large scale production of cement is causing environmental problem on one hand and diminution of natural resources on the other hand. This threat to ecology has led researchers to use industrial byproducts as supplementary cementitious materials in concrete. Various supplementary materials like GGBS, fly ash, and husk ash are used based on their pozzolanic properties. GGBS is one of the most important cementitious supplementary material which can become a better substitute and also it is a mineral admixture which needs to be explored. GGBS improves the mechanical properties of concrete and it also reduces the cement content in concrete and even GGBS can be used independently as a substitute to concrete. GGBS is used widely in concrete production and fibres are also added to this matrix. GGBS is higher level material which can withstand corrosion and chemical effects.

B. Ground Granulated Blast Furnace Slag (GGBS)

GGBS is waste product generated during the manufacture of iron by blast furnace method. The molten slag is lighter and floats on the top of the molten iron. The process of granulating the slag involves cooling the molten slag through high pressure water jets. This rapid cooling of slag results in formation of granular particles generally not larger than 5mm in diameter. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volume of water. The quenching, optimizes the cementitious properties and produces granules similar to a coarse sand. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS (ground granulated blast furnace slag). The addition of GGBS improves the mechanical properties of concrete and it also reduces the cement content in concrete. GGBS is a pozzolanic material used as partial replacement of cement for better performance. The major 4 factors which influence the hydraulic property slag are glass content, fineness, mineralogical composition and chemical composition. GGBS is used to replace cement content typically ranging from 20 to 50 percent. The advantages of using GGBS are

- GGBS in concrete increases the strength and durability of the concrete structures.

- It reduces voids in concrete, hence reducing permeability.
- GGBS gives a workable mix and it possesses compaction characteristics.
- The structure made of GGBS has sulphate attack resistance properties.
- The heat of hydration is less compared to nominal mix hydration.
- GGBS makes the concrete more chemically stable.

C. *Fibre Reinforced Concrete (FRC)*

Fibre is a natural or manufactured substance, which is used to enhance the flexure strengthening of reinforced concrete members. In this composite material, short discontinues or discrete fibres are randomly distributed throughout the total mass of concrete. The performance of this composite material is far superior to that of nominal concrete. Now a days the fibre reinforced concretes are used in airport and highway pavements, explosive resistance structures, earthquake resistant, mines, tunnels, overlays, hydraulic structures etc. Various experimental investigations are conducted on the development of fibre reinforced concrete with addition of fibres namely steel, glass, synthetic and carbon fibres, thus the strength, ductility, toughness are increased and cracks are avoided. The main advantage of using fibre reinforced concrete is to reduce the small cracks, permeability and also to improve the impact resistance. The fibres when added to concrete enhances the total strength of concrete. The combination of cement, fine and coarse aggregate and water with discrete, discontinuous, uniformly distributed fibres is called FRC. Concrete members reinforced with long reinforcing bars possess the required tensile strength but they lack in ductility. Even shear stresses are also found in critical locations in a plane concrete member. Using of steel as a reinforcement increases the strength of the concrete but development of micro cracks cannot be arrested. The fibres when added to this normal concrete increases the total strength toughness and tensile strength in particular.

II. OBJECTIVES

- The main objective of this study is to increase the concrete strength by using GGBS and low cost fibres.
- To study the workability of concrete mixes
- Plain concrete called as Conventional Concrete (CC).
- Fibre reinforced concrete with different percentage of GGBS.
- To evaluate the mechanical properties such as compression strength, Split tensile strength, Flexure strength for M20 grades of FRC with 10%, 20% and 30% of GGBS as partial replacement of cement in addition to 0%, 0.5%, 1% and 1.5% of hook end steel and sisal fibre individually is found out and compared.
- The strength achievement of GGBS and the addition of fibres is compared with the nominal concrete and also the strength achieved by GGBS with the addition of Steel FRC are compared with the Sisal FRC.

III. MATERIAL PROPERTIES

A. *Cement*

The Cement used in this experimental work is BIRLA SUPER 53 grade ordinary Portland cement. All properties of OPC were evaluated referring IS: 12269:1987. The cement utilized for casting was fresh and as per standards.

B. *Fine Aggregate*

Now a day's natural sand is not freely available for the construction purpose due to the scarcity of natural sand, M-Sand is used as a substitute for natural sand. Good quality of M-sand as per the IS 383-1970 code conforming to ZONE I and passing through 4.75 mm sieve was used.

C. *Coarse Aggregate*

Locally available aggregate passing through 20mm and retained on 4.75 mm sieve is used in this experimental investigation. The coarse aggregate conforming to IS: 383-1970 was used.

D. *GGBS*

GGBS (Fig 1) used in this work was obtained from NANDI CEMENTS Pvt.Ltd Bengaluru.

Fig 1: GGBS

E. Fibres

1) Steel Fibre

The steel fibre provides the ductility, toughness, impact resistance, compression, tensile, flexural strength required for higher strength concrete. The hook end steel fibre (Fig 2) were made available from Jeemull Jaichandlall(m) Pvt.Ltd, Tamilnadu and used in study has the following properties:
Dimension: 60mm X 0.75mm
Fibre shape: Hook end
Tensile strength: 1100 and 1700 Mpa
Aspect ratio: 80mm

Fig. 2: Hooked End Steel Fibre

2) Sisal Fibers

Sisal fibre (Botanical name: Agave sisal and Fig 3) is used as natural fibres in reinforcing concrete. It is traditionally used for rope, twine manufacturing and many other traditional applications. Sisal fibre used in this study has the following properties:
Dimension: 32mm X 0.4mm
Fibre color: Creamy white
Aspect ratio: 80mm

Fig. 3: Sisal Fibre

F. Water

The Potable water was used for the blending and curing of the concrete and the pH value of water was below 6. The water used was free from any acid, oils and salt or sugar materials.

IV. EXPERIMENTAL WORK

A. Mix Design

In the present work, proportioning for concrete mix of M_{20} grade was carried out according to IS: 10262-2009 recommendations. GGBS is added to the cement with the percentage of 0%, 10%, 20% & 30% as a partial replacement in addition to 0%, 0.5%, 1%, 1.5% of steel and sisal fibre. The adopted mixes proportioned by weight batching method are summarized Table 1.

Table – 1
Mix proportion for M_{20} grade concrete

Normal Mix	*Control Mix Concrete*
Cement(kg/m^3)	*394.3*
Water (kg/m^3)	*197.16*
Fine aggregate (kg/m^3)	*686.15*
Coarse aggregate (kg/m^3)	*1114.63*

B. Slump Test

The concrete slump test is the measure of the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and there by the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions. Slump test results obtained are graphically show in Fig 4.

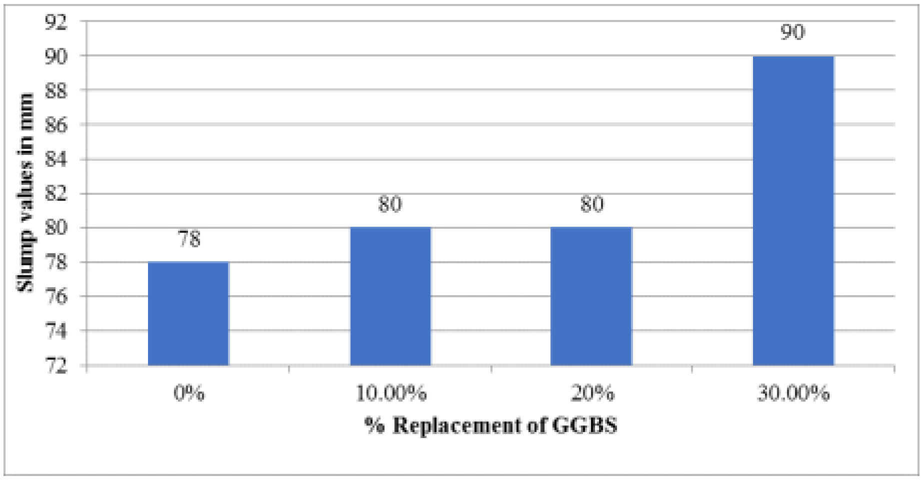

Fig. 4: Graph Showing Slump Values

C. *Compressive Strength*

In this experimental investigation totally 39 cubes of 150 mm x 150 mm x 150 mm size were casted and after curing period of 28 days, the cubes were tested in compressive testing apparatus. The cube test was conducted as per IS 516: 1959. The test result are tabulated in Table 2 and shown graphically in Fig 5, Fig 6 and Fig 7.
Compressive strength = P/A N/mm^2

Table – 2
Compression Strength Result for 28 Days

Descriptions			*Steel FRC*	*Sisal FRC*
sample	*% of GGBS added*	*% of Fibre added*	*Compression Strength in N/mm^2*	*Compression Strength in N/mm^2*
A-10% GGBS	*10*	*0*	*34.00*	*34.00*
		0.5	*36.68*	*30.98*
		1	*42.18*	*33.49*
		1.5	*34.66*	*27.75*
B-20% GBBS	*20*	*0*	*32.25*	*32.25*
		0.5	*42.42*	*28.96*
		1	*45.36*	*34.76*
		1.5	*36.04*	*27.02*
C-30% GGBS	*30*	*0*	*28.61*	*28.61*
		0.5	*39.77*	*27.16*
		1	*31.89*	*31.69*
		1.5	*30.13*	*28.04*
Nominal	*0*	*0*	*32.61*	

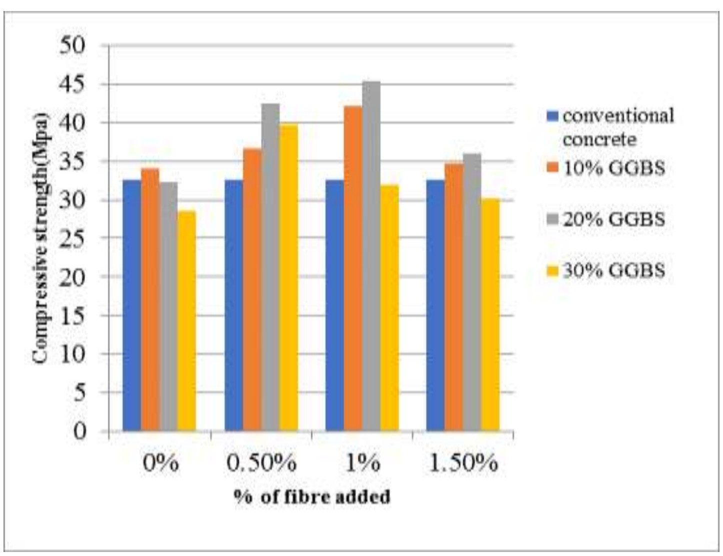

Fig. 5: Variation of Compression strength of Steel FRC with respect to % of GGBS and fibres at 28 days

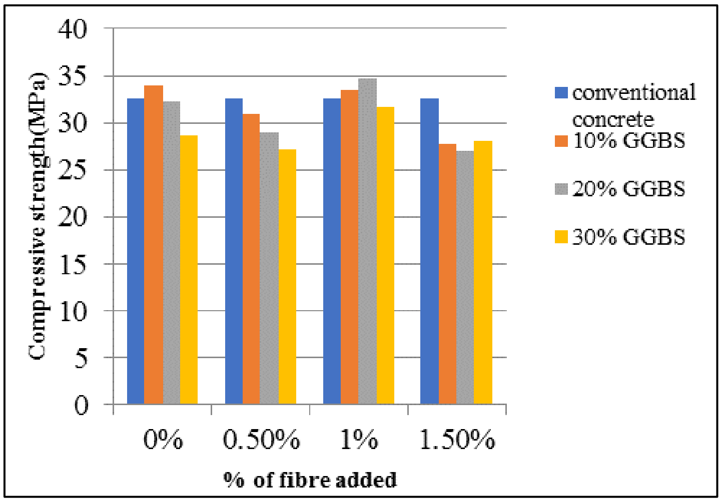

Fig. 6: Variation of Compression strength of Sisal FRC with respect to % of GGBS and fibres at 28 days

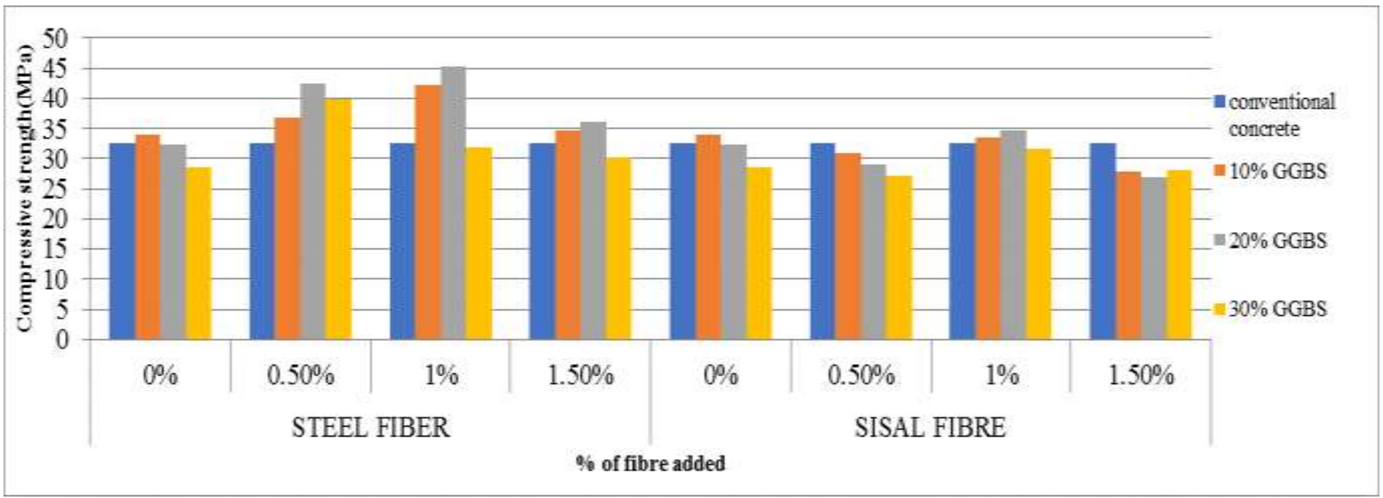

Fig. 7: Comparison of Compression strength of Steel and Sisal FRC with respect to % of GGBS and fibres at 28 days

D. Flexural Strength

In this experimental investigation totally 39 beams of 500 mm x 100 mm x 100 mm size were casted and after curing period of 28 days, the beams were tested in universal flexural testing machine. The beam test was conducted as per IS 516: 1959. The test result tabulated are in Table 3 and shown graphically in Fig 8, Fig 9 and Fig 10.

Flexural Strength = pl/bd^2, N/mm^2

Table – 3
Flexural Strength Result for 28 Days

Descriptions			*Steel FRC*	*Sisal FRC*
Sample	*% of GGBS added*	*% of Fibre added*	*Flexural Strength in N/mm^2*	*Flexural Strength in N/mm^2*
A-10% GGBS	*10*	*0*	*6.33*	*6.33*
		0.5	*6.53*	*6.20*
		1	*6.86*	*6.40*
		1.5	*6.75*	*6.26*
B-20% GBBS	*20*	*0*	*6.60*	*6.60*
		0.5	*6.66*	*6.46*
		1	*5.80*	*6.73*
		1.5	*7.00*	*6.53*
C-30% GGBS	*30*	*0*	*6.00*	*6.00*
		0.5	*6.40*	*6.26*
		1	*6.53*	*6.53*
		1.5	*6.80*	*6.46*
Nominal	*0*	*0*	*6.13*	

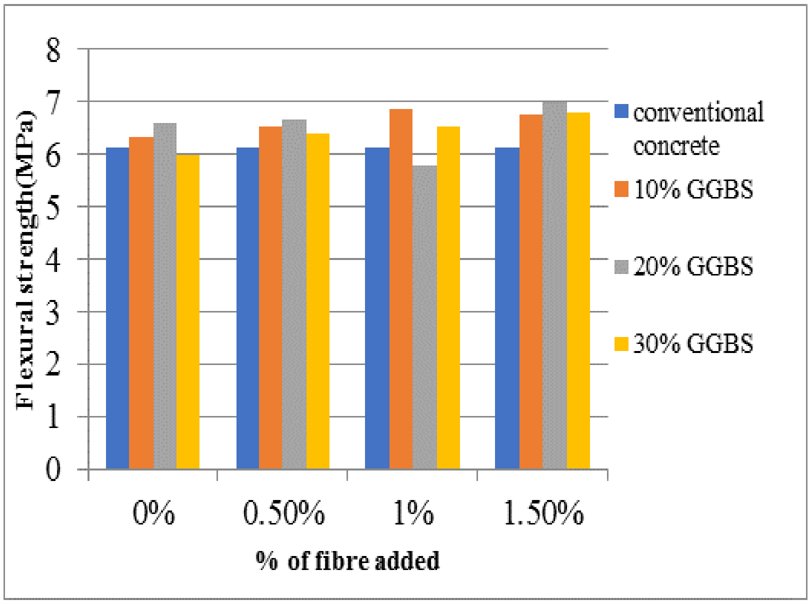

Fig. 8: Variation of Flexural strength of Steel FRC with to % of GGBS and fibres at 28 days

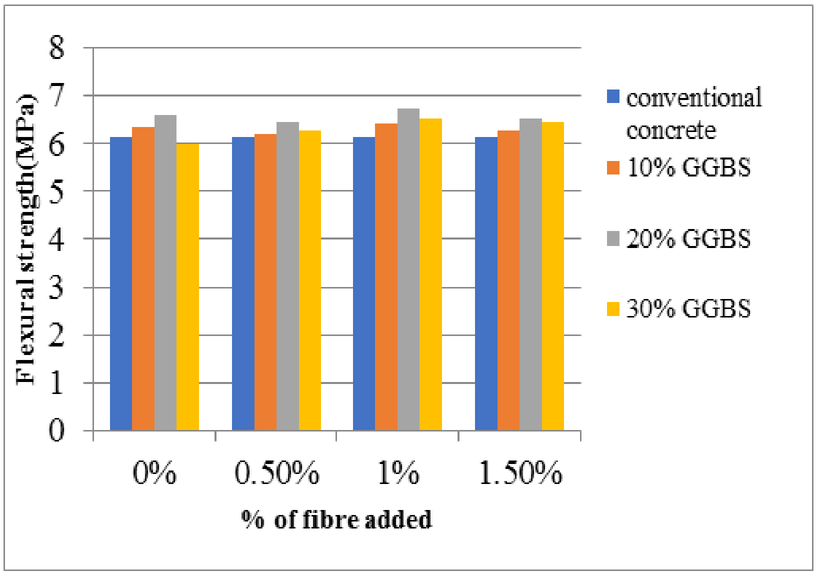

Fig. 9: Variation of Flexural strength of Sisal FRC with respect to % of GGBS and fibres at 28 days

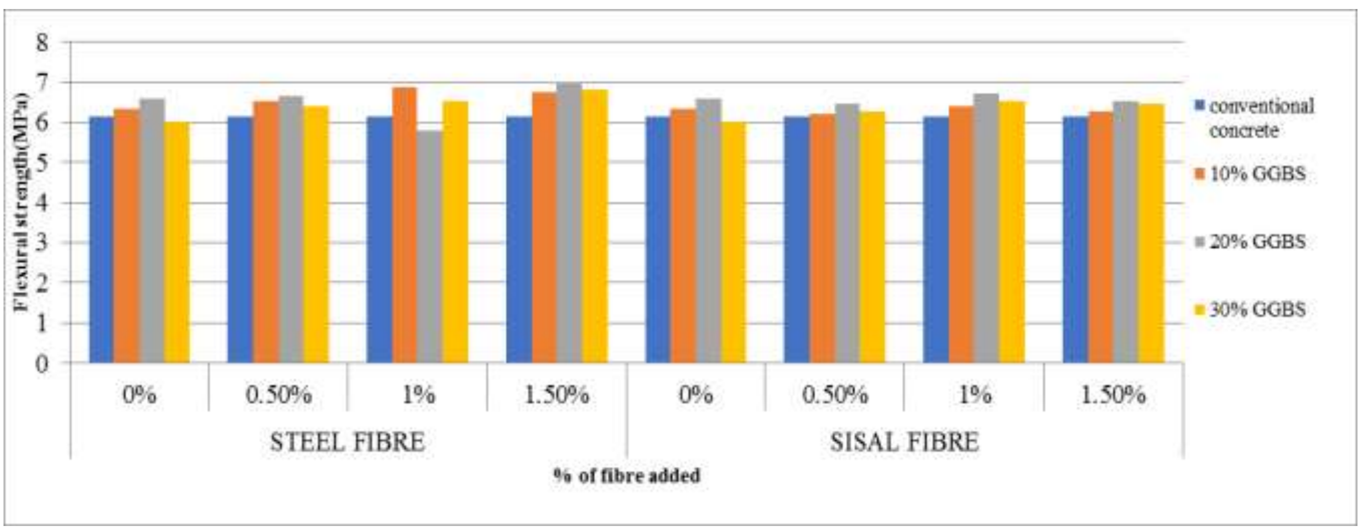

Fig. 10: Comparison of Flexure strength of Steel and Sisal FRC with respect to % of GGBS and fibres at 28 days

E. Split Tensile Strength

In this experimental investigation totally 39 cylinders of 150 mm diameter 300 mm length size were casted and after curing period of 28 days, the cylinders were tested under universal tensile testing machine. The split test was conducted as per IS 516: 1959. The test result tabulated are in Table 4 and shown graphically in Fig 11, Fig 12 and Fig 13.

Split Tensile strength = $2P / \pi DL$, N/mm^2

Table - 4
Split Tensile Strength Result for 28 Days

Descriptions			*Steel FRC*	*Sisal FRC*
Sample	*% of GGBS added*	*% of Fibre added*	*Split tensile Strength in N/mm^2*	*Split tensile Strength in N/mm^2*
A-10% GGBS	*10*	*0*	*2.98*	*2.98*
		0.5	*2.96*	*2.56*
		1	*3.21*	*3.03*
		1.5	*3.80*	*2.47*
B-20% GBBS	*20*	*0*	*2.55*	*2.55*
		0.5	*3.04*	*2.59*
		1	*3.59*	*3.17*
		1.5	*4.13*	*2.61*
C-30% GGBS	*30*	*0*	*2.34*	*2.34*
		0.5	*3.11*	*2.13*
		1	*3.48*	*2.87*
		1.5	*3.29*	*2.68*
Nominal	*0*	*0*	*2.50*	

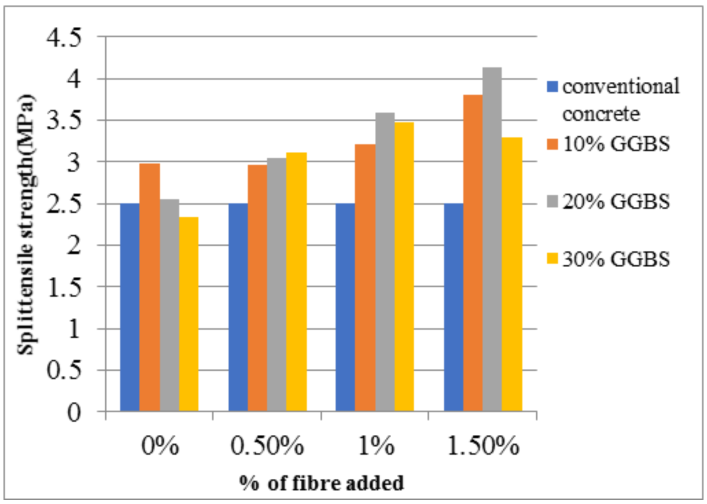

Fig. 11: Variation of Split tensile strength of Steel FRC with respect to % of GGBS and fibres at 28 days

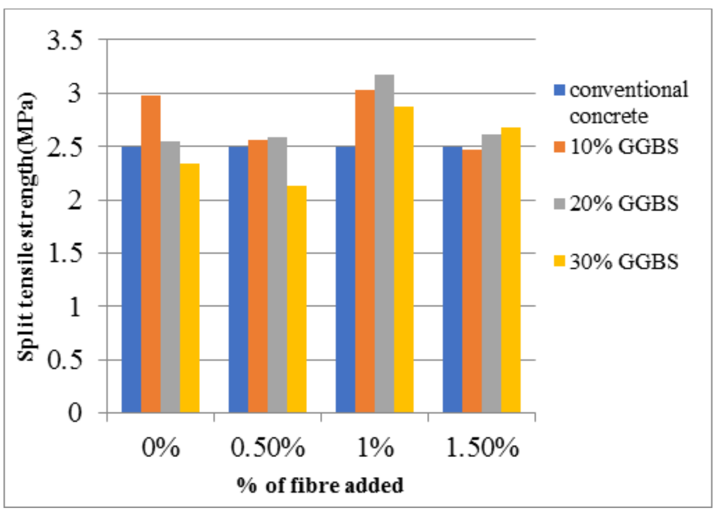

Fig. 12: Variation of Split tensile strength of Sisal FRC with respect to % of GGBS and fibres at 28 days

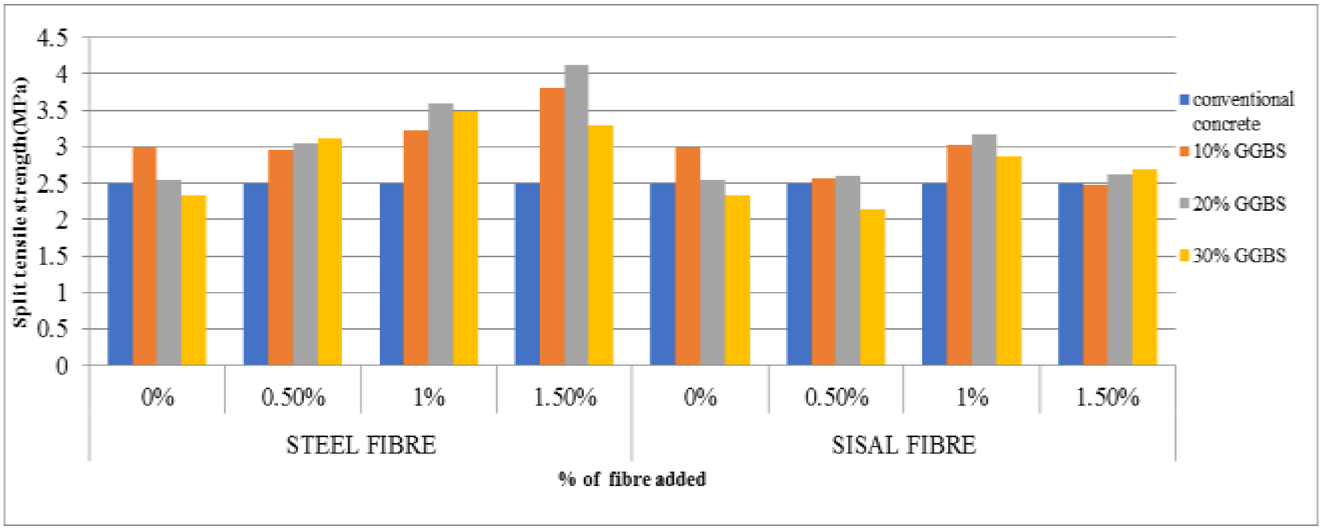

Fig. 13: Comparison of Split tensile strength of Steel and Sisal FRC with respect to % of GGBS and fibres at 28 days

V. CONCLUSION

On the basis of present experimental study, the following conclusions are drawn:

- Replacement of cement by GGBS is found to increase in the strength of concrete.
- While testing, nominal concrete specimen's shows a typical cracking pattern, but the Steel FRC and Sisal FRC specimens show reduced crack. This shows the ductile behavior due to the presence of fibres.
- The steel fibre makes the concrete stronger in tension and compression.
- By the addition of 1% steel fibre and 20% GGBS the compressive strength of steel FRC (Fig 5) is more (up to 39%) when compared with nominal concrete strength and various parentage GGBS in concrete and steel fibre.
- By the addition of 1% sisal fibre and 20% GGBS the compressive strength of sisal FRC (Fig 6) is more (up to 7%) when compared with nominal concrete strength and various percentage GGBS in concrete and sisal fibre.
- By the addition of 1.5% steel fibre and 20% GGBS the overall strength enhances particularly the split tensile and flexure strength of steel FRC is more (Fig 11: up to 65% tensile strength) and (Fig 8: up to 15% flexure strength) when compared with nominal concrete strength and various percentage GGBS in concrete and steel fibre.
- By the addition of 1% sisal fibre and 20% GGBS the overall strength enhances particularly the split tensile and flexure strength of sisal FRC is more (Fig 12: up to 27% tensile strength) and (Fig 9: up to 10% flexure strength) when compared with nominal concrete strength and various percentage GGBS in concrete and sisal fibre.
- For the same grade of concrete and fibre percentage, the compression (Fig 7: up to 30%), split tensile(Fig 13: up to 58%) and flexure strength (Fig 10: up to 8%) at 28 days of Steel FRC is greater than that of Sisal FRC, the magnitude depends on the fibre percentage.
- Steel FRC achieves higher compression, split tensile and flexure strength when compared to Sisal fibre reinforced concrete.

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