# An Experimental Study on Effect of Different Fibres on Strength Properties of Ggbs Blended Concrete

**R.Sai Teja[1], R.Aneesh[2]**
[1, 2] Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] Lenora College of Engineering

***Abstract***- *The Fibre Reinforced Concrete (FRC) is a composite material essentially consisting of concrete reinforced by random placement of short discontinuous and discrete fine fibers of specific geometry. It is now well established that the addition of short, discontinuous fibers plays an important role in the improvement of the mechanical properties of concrete. In the FRC, the fibers help to transfer load to the internal micro cracks. In the recent past, many developments have been made in the fiber reinforced concrete. Also it has been recognized that addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve the properties and can cause a change in the failure mode under compressive deformation from brittle to pseudo-ductile, thereby imparting a degree of toughness to concrete. 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.*

*Hence, this project is aimed at decreasing the hazardous problem by safe reuse of GGBS and Steel fibre and Basalt fibre. In this paper an experimental work is carried out to study the behaviour of steel fibre reinforced concrete with GGBS replacement of cement by various percentages as 0, 10, 20 and 30% on compressive, flexural and split tensile strength with plain M20 grade concrete. Concrete specimens casted are cubes, cylinders and beams. Water curing is adopted for all the testing specimens. After completion of curing process the concrete specimens are tested 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.*

***Keywords***- Steel fibre, Basalt fibre, GGBS, Compressive strength test, Split tensile strength test and Flexural strength test.

## I. INTRODUCTION

### GENERAL

Concrete is one of the most versatile building materials. Concrete is composite material which consists of cement, coarse aggregate, fine aggregate and water in required proportions. Concrete is a material which used for the purpose of construction in now a days. Due to its composite nature concrete is weak in tension but strong in compression. Basic Principle involved in the increase in strength of concrete is heat of Hydration. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high-rise building. The advantages of using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. The disadvantages of using concrete include poor tensile strength, low strain of fracture and formwork requirement. The major disadvantage is that concrete develops micro cracks during curing. It is the rapid propagation of these micro cracks under applied stress that is responsible for the low tensile strength of the material. Plain cement concrete is weak in tension because it contains numerous micro cracks. These micro cracks propagate in the concrete matrix when it is subjected to load. Consequently, plain concrete members cannot sustain tensile stresses developed due to the applied forces without the addition of reinforcing elements that are able to withstand tensile stresses. The propagation of micro cracks and macro cracks, however, still cannot be arrested or slowed by the sole use of discrete reinforcement such as steel and composite rebars. It is believed that the mixing of randomly spaced discontinuous small fibers helps in arresting the propagation of the micro cracks and macro cracks. Hence fibres are added to concrete to overcome these disadvantages.

### GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is a recyclable material created when the molten slag from melted iron ore is quenched rapidly and then ground into a powder. This material has cementatious properties and has been used as a replacement for cement for over 100 years. This project investigates these GGBS characteristics and has several objectives.

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace." In the production of iron, blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. Air cooled slag has a rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with portland cements as well as asphalt mixtures. GGBS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate.

**Table-1:** Chemical Properties of Cement & GGBS

| Chemical Composition | Cement | GGBS |
|---|---|---|
| CaO | 63.20 | 35.27 |
| SiO2 | 21.06 | 34.72 |
| Al2O3 | 5.72 | 19.11 |
| MgO | 1.90 | 8.46 |
| Fe2O3 | 4.38 | 0.5 |
| SO3 | 2.04 | 0.18 |
| Na2O | 0.25 | 0.16 |
| K2O | 0.87 | 0.58 |
| Cl | 0.01 | 0.01 |
| TiO2 | 0.40 | 0.65 |
| P2O5 | 0.09 | 0.01 |
| Mn2O3 | 0.07 | 0.14 (MnO) |
| Glass Content | -- | 95 |

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.

### A. FIBRE REINFORCED CONCRETE

Fibre reinforced concrete is a concrete mix that contains short discrete fibres that are uniformly distributed and randomly oriented. As a result of these different formulations, four categories of fibre reinforcing have been created. These include Basalt fibres, glass fibres, synthetic fibres and natural fibres. Within these different fibres that character of Fibre Reinforced Concrete changes with varying concrete's, fibre materials, geometries, distribution, orientation and densities. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed Volume Fraction (VF). VF typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material.

Increase in the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. Unidirectional fibres uniformly distributed throughout the volume are the most efficient in uniaxial tension. While flexural strength may depend on the unidirectional alignment of the fibres dispersed for away from the neutral plane, flexural shear strength may call for a random orientation. A proper shape and higher aspect ratio are also needed to develop an adequate bond between the concrete and the fibre so that the fracture of the fibres may be fully utilized.

### B. 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
- 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 Basalt 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 basalt FRC.

## II. REVIEW OF LITERATURE

The term fiber reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine or fine and coarse aggregates and discontinuous discrete fibers . Inherently concrete is brittle under tensile loading. Mechanical properties of concrete can be improved by reinforcement with randomly oriented short discrete fibers, which prevent and control initiation, propagation, or coalescence of cracks. FRC can continue to sustain considerable loads even at deflections exceeding fracture deflections of plain concrete. The character and performance of FRC changes depending on matrix properties as well as the fiber material, fiber concentration, fiber geometry, fiber orientation, and fiber distribution.

FRC can be regarded as a composite material with two phases in which concrete represents the matrix phase and the fiber constitutes the inclusion phase. Volume fraction of fiber inclusion is the most commonly used parameter attributed to the properties of FRC. Fiber count, fiber specific surface area, and fiber spacing are other parameters, which may also be used for this purpose. Another convenient numerical parameter describing a fiber is its aspect ratio, defined as the fiber length divided by its equivalent diameter. It is possible to make several classifications among fiber types. Fibers can be divided into two groups; those with elastic modulo lower than the cement matrix, such as cellulose, nylon, and polypropylene and those with higher elastic module such as asbestos, glass, steel, and carbon. Another classification can be made according to the origin of the fiber material such as metallic, polymeric, or natural.

The early theoretical studies, initiated by Romuald, Batson, and Mandel, in the1950’s and 1960’s focused mainly on the characteristics of steel fiber reinforced concrete (SFRC). Only straight steel fibers were used in the beginning. Though remarkable improvements in toughness and ductility were obtained, problems immixing and workability were encountered. These problems were overcome with the advent of deformed steel fibers and high range water reducers. Today steel is the most commonly used fiber type for concrete reinforcement, with the exception of asbestos fibers. Though modest improvements in strength can be obtained, the primary purpose of steel fiber inclusion to concrete is to increase toughness and ductility. Steel fibers are used for crack control, to replace secondary reinforcement, which is also used for this purpose.

**Kurein (1981)** studied on the dyeing behavior of banana fibre. During this study 4 different classes of dyes were used on un mercerized, mercerized cotton fibre and banana fibre. Their dye-uptake, wash-fastness and lightfastness were determined. The dyes selected were direct dye, vat dye,reactive dye, and azo dye. The following conclusions have been drawn Correlating the dye uptake and the fastness properties it may be concluded that the fastness properties may not necessary depend upon the amount of dye present on the fibre. It may be said that this property depends more on the structure of the fibre and the manner in which the dye is present on the fibre. It has been noted that the light fastness of banana fibre is inferior to cotton. This may be attributed to the impurities present in the banana fibre in the form of lignin and the other insoluble matter.bThe published research works on flexural ductility of steel fiber reinforced concrete beam have been studied by many researches D.Y. Gao discussed the influence of steel fiber factor on flexural ductility of beam and concluded that ductility indexes increase with increasing of fiber factor.

**Charles H.Henage (1976)** developed an analytical method based on ultimate strength approach, which has taken into account of bond stress, fibres stress and volume fraction of fibres. After his investigations, he concluded that the incorporation of steel fibres significantly increases the ultimate flexural strength, reduces crack widths and first crack occurred at higher loads.

**Jute Technological Research Laboratories, (JTR Lab) Calcutta**, carried outan experiment work, (1974) on rope making with banana plant fibre. It wasconcluded that banana fibre can replace certain percentage of Mesta, acellulosic fibre in the composition of agricultural ropes. The Mesta or alliedfibers thus saved could be more profitably be used for packaging textiles andother materials fibre yarn makes the cloth brighter, impart better dyeingproperties and can also be bleached. This additional outlet for the products ofbanana plantations would benefit the farmer, but a prerequisite for economicuse of banana fibre will be a steady bulk supply, initially at a somewhat lowerprice than that of the existing comparable fibers.

## III. MATERIALS USED

### 3.1 MATERIALS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Fine aggregate
4. Water
5. GGBS
6. Steel fibre
7. Basalt fibre

### 3.2 CEMENT

Cement is a commonly used binding material in the construction. The cement is obtained by burning a mixture of calcareous (calcium) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. It was first produced by a mason Joseph Aspdin in England in 1924. He patented it as portland cement.

**Table No-1** Physical Properties of Cement

| Sl. No. | Properties | Values |
|---|---|---|
| 1 | Specific Gravity | 3.14 |
| 2. | Standard consistency | 33% |
| 3. | Initial setting time in min. | 30 |
| 4. | Final setting time in min | 490 |

### 3.3 COARSE AGGREGATE

Since approximately three-quarters of the volume of concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate limit the strength of concrete but the aggregate properties greatly affect the durability and structural performance of concrete.

Aggregate was originally viewed as an inert, inexpensive material dispersed throughout the cement paste so as to produce large volume of concrete. In fact, aggregate is not truly inert because it's physical, thermal and sometimes, chemical properties influence the performance of concrete. For example, by improving its volume stability and durability over that of the cement paste. From the economic view point, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state. Material which retained on 4.75 mm size classified as a coarse aggregate. For most works, 20 mm aggregate is suitable. The locally available aggregate having nominal size of 20mm was used.

**Table-3** Properties of Coarse Aggregate

| Sl. No. | Properties | Values |
|---|---|---|
| 1 | Specific Gravity | 2.77 |
| 2. | Fineness modulus | 2.59 |
| 3. | Water absorption | 0.4% |

### 3.4 FINE AGGREGATES:

Fine aggregate is a material such as sand, crushed stones or crushed gravel passing through 4.75 mm size. Locally available sand is used as fine aggregate in the concrete mix.

**Table-2** Properties of Fine Aggregate

| Sl. No. | Properties | Values |
|---|---|---|
| 1 | Specific Gravity | 2.53 |
| 2. | Fineness modulus | 2.97 |
| 3. | Water absorption | 10% |
| 4. | Zone | II |

### 3.5 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. 1: Steel Fibre

### 3.6 Basalt Fiber

The fibers used were chopped basalt fibers which are uniformly and randomly distributed in the concrete matrix. For the experimental work length 12mm and the fiber diameter 13µ basalt chopped fiber were used. Chopped basalt fibers are shown in figure.

Fig. 2 Basalt Fibre

**Table-3 Properties of basalt fibre**

| Capability | Basalt fiber |
|---|---|
| Tensile strength, M Pa | 3000~4840 |
| Tensile strength, M Pa | 79.3~93.1 |
| Elastic modulus, G Pa | 3.1~6 |
| Elongation at break, % | 2.65-2.8 |
| Specific gravity | 6~21 |
| Diameter of filament, mμ | -260~+500 |
| Temperature of application, °C | 1450 |
| Price, Rs./kg | 150 |

## IV. METHODOLOGY

In the present work, proportioning for concrete mix of M20 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 Basalt fibre. The adopted mixes proportioned by weight batching method are summarized Table 4.

Mix proportion for M20 grade concrete

| *Normal Mix* | *Control Mix Concrete* |
|---|---|
| *Cement(kg/m3)* | *394.9* |
| *Water (kg/m3)* | *196.84* |
| *Fine aggregate (kg/m3)* | *685.45* |
| *Coarse aggregate (kg/m3)* | *1115.29* |

### 4.1 LABORATORY EXPERIMENTATION

In the present experimental investigation GGBS has been used as partial replacement of cement in concrete mixes. On replacing cement with different weight percentage of GGBS the compressive strength, Flexural strength and tensile strength is studied at different ages of concrete cured in water and further studied effect of fibers on GGBS blended concrete. The details of laboratory experimentation are as follows.

### 4.2 LIST OF TESTS CONDUCTED

The following tests were conducted as per IS codes of practice.

- Specific gravity
- Fineness
- Normal Consistency
- Water absorption test
- Sieve Analysis
- Slump test
- Compressive strength test
- Split tensile strength test
- Flexural strength test.

## V. RESULTS AND DISCUSSIONS

The result of the experimental investigation on GGBS Blended fibre reinforced concrete where GGBS has been used as partial replacement of cement in concrete mixes. On replacing cement with different percentage of GGBS the workability, compressive strength is studied after cubes cured in normal water and further discrete reinforcement is provided and different tests are conducted and the test results are given below.

**Table 5.1: Variation of slump for different percentages of GGBS**

| GGBS(%) | SLUMP(mm) |
|---|---|
| 0 | 78 |
| 10 | 80 |
| 20 | 82 |
| 30 | 90 |

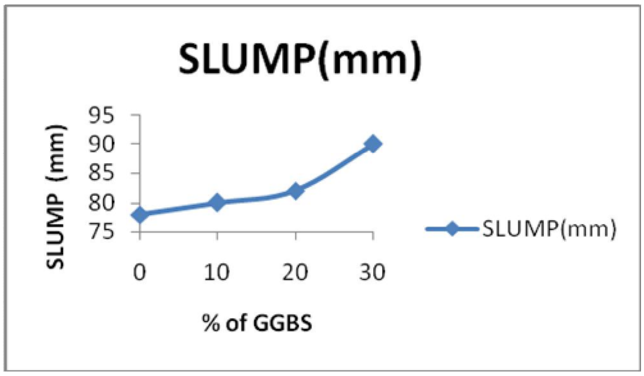


**Fig 5.1** Variation of SLUMP with % Replacement of GGBS

**Table 5.2: Variation of Compressive strength for different percentages of GGBS**

| GGBS (%) | 7 Days | 14 Days | 28 Days |
|---|---|---|---|
| 0 | 21.28 | 28 | 32.81 |
| 10 | 22.11 | 29.1 | 34.02 |
| 20 | 23.6 | 31.17 | 36.42 |
| 30 | 18.54 | 24.4 | 28.81 |

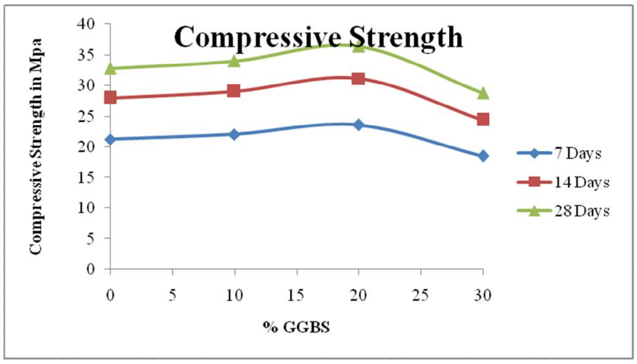


**Fig 5.2** Variation of Compressive strength with % Replacement of GGBS

**Table 5.3: Variation of Flexural strength for different percentages of GGBS**

| GGBS(%) | 7 Days | 14 Days | 28 Days |
|---|---|---|---|
| 0 | 2.9 | 4.27 | 6.13 |
| 10 | 3.18 | 4.68 | 6.33 |
| 20 | 3.31 | 4.84 | 6.6 |
| 30 | 3.09 | 4.44 | 6.01 |

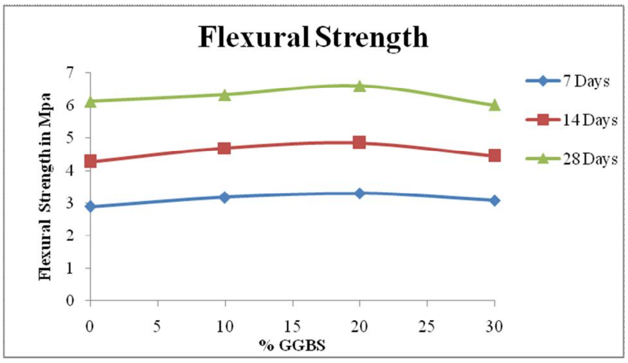


**Fig 5.3** Variation of Flexural strength with % Replacement of GGBS

**Table 5.4: Variation of split tensile strength for different percentages of GGBS**

| GGBS (%) | 7 DAYS | 14 DAYS | 28 DAYS |
|---|---|---|---|
| 0 | 1.39 | 1.85 | 2.5 |
| 10 | 1.51 | 1.93 | 2.55 |
| 20 | 1.64 | 2.13 | 2.98 |
| 30 | 1.43 | 1.77 | 2.34 |

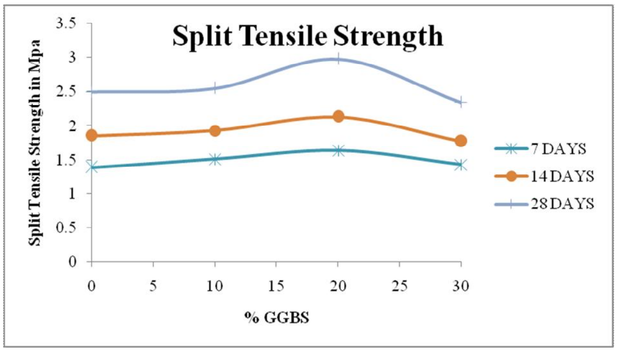


**Fig 5.4** Variation of Split tensile strength with % Replacement of GGBS

It can be inferred from the graphs, that there is a gradual increase in properties like Compressive strength, Split tensile strength, and Flexural strength with percentage replacement of GGBS. From the above results the 20% replacement of Cement with GGBS can be considered as optimum.

For the optimum percentage of GGBS, percentage addition of Steel fiber and Basalt Fibre from 0 to 1.5% with an increment of 0.5% and compared the properties with two fibres and the results are given below.

**Table 5.5: Variation of compressive strength for different percentages of steel and basalt fibre for 28 Days**

| % Addition of fibre | STEEL FIBRE | BASALT FIBRE |
|---|---|---|
| 0% | 36.25 | 31.44 |
| 0.50% | 42.42 | 34.18 |
| 1.00% | 45.36 | 34.97 |
| 1.50% | 36.04 | 32.53 |

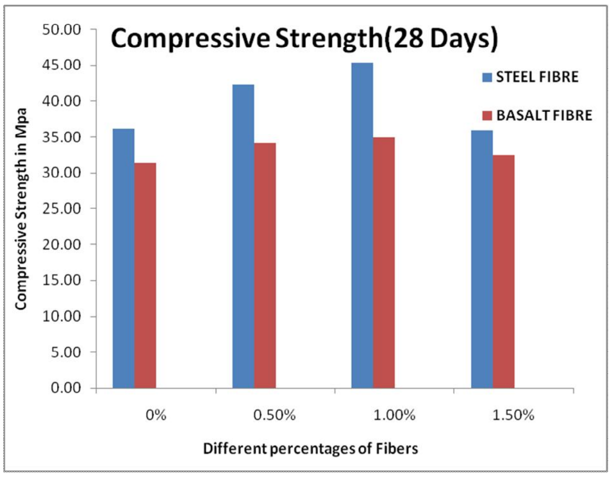


**Fig 5.5** Comparison of Compressive strength of Steel and Basalt FRC with respect to 20% of GGBS and fibres at 28 days

**Table 5.6: Variation of Flexural strength for different percentages of steel and basalt fibre for 28 Days**

| % Addition of fibre | STEEL FIBRE | BASALT FIBRE |
|---|---|---|
| 0% | 6.6 | 5.7 |
| 0.50% | 6.96 | 6.11 |
| 1.00% | 7.28 | 6.23 |
| 1.50% | 6.81 | 5.93 |

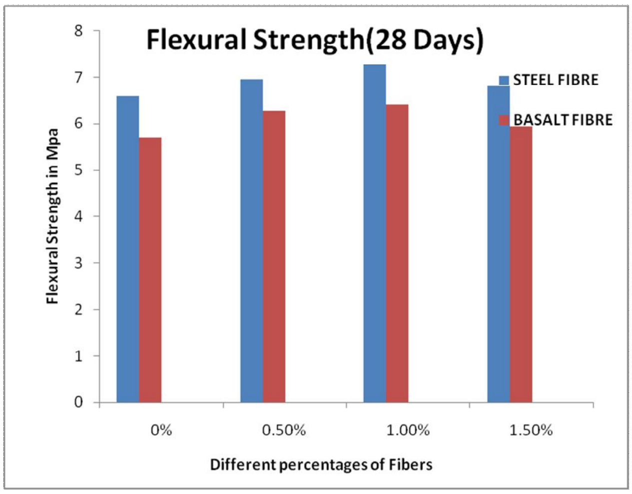


**Fig 5.6** Comparison of Flexural strength of Steel and Basalt FRC with respect to 20% of GGBS and fibres at 28 days.

**Table 5.7: Variation of Split tensile strength for different percentages of steel and basalt fibre for 28 Days**

| % Addition of fibre | STEEL FIBRE | BASALT FIBRE |
|---|---|---|
| 0% | 2.55 | 2.43 |
| 0.50% | 3.04 | 2.97 |
| 1.00% | 3.59 | 3.24 |
| 1.50% | 4.13 | 2.68 |

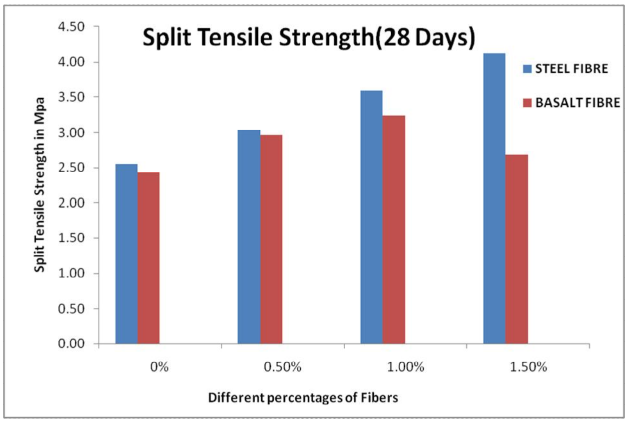


**Fig 5.7** Comparison of Split Tensile strength of Steel and Basalt FRC with respect to 20% of GGBS and fibres at 28 days.

It can be inferred from the graphs, that there is a gradual increase in Properties of concrete with percentage replacement of GGBS and percentage addition of Steel and Basalt Fibres.

From the results it is concluded that 1.0% addition of steel fibre shows maximum compressive strength, flexural and Split Tensile strength when compared to Basalt Fibre.

## VI. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- From the laboratory studies, it is observed that the Replacement of cement by GGBS is found to increase in the strength of concrete.
- After performing workability test observed that, when increasing percentage of GGBS in concrete leads to the increase in workability of the concrete.
- While testing, nominal concrete specimen's shows a typical cracking pattern, but the Steel FRC and Basalt 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 is more (up to 11%) when compared with nominal concrete strength and 20% GGBS in concrete and 1 % steel fibre.
- By the addition of 1.0% steel fibre and 20% GGBS the overall strength enhances particularly the split tensile and flexure strength of steel FRC is more up to 40% tensile strength and up to 10.3% flexure strength. when compared with nominal concrete strength and various percentage GGBS in concrete and steel fibre.
- By the addition of 1% basalt fibre and 20% GGBS the overall strength enhances the compressive strength up to 11.22% particularly the split tensile and flexure strength of Basalt FRC is up to 33.33% tensile strength and up to 7.54% flexure strength when compared with nominal concrete strength and 20%GGBS in concrete and basalt fibre.
- For the same grade of concrete and fibre percentage, the compression, split tensile, and flexure strength at 28 days of Steel FRC is greater than that of Basalt FRC, the magnitude depends on the fibre percentage.
- Steel FRC achieves higher compression, split tensile and flexure strength when compared to Basalt fibre reinforced concrete.
- It is evident that the addition of GGBS to the virgin Marine Clay showed an improvement in Mechanical Properties to some extent and on further blending it with

fibre reinforcing inclusions the strength mobilization was more pronounced**.**

- Finally it can be summarized that the materials GGBS and Fibre inclusions had shown promising influence on the Mechanical Properties of concrete, thereby giving a two-fold advantage in improving problematic Marine Clay and also solving a problem of waste disposal.

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