IJARIIT
INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 4)
Available online at: www.ijariit.com

Some studies on concrete prepare by using fiber reinforcement and GGBS as a partial replacement of cement

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ABSTRACT

In our work experimental investigation is carried out to study the different strength characteristics of concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) and an addition of steel fiber. In this investigation of M30 grade of concrete, cement is replaced with GGBS ground granulated blast furnace slag (10%, 20% and 30%) by weight and addition of steel fibers with different aspect ratio of 79 & 55 in different percentage (0.5%, 1% and 1.5%) to the weight of concrete. Economical and technical analysis has been done on GGBS and steel fiber concrete. workability of concrete and Strength of concrete was determined by performing compression test (150mm x 150mm x 150mm) size cube, split tensile test (150 mm diameter and 300 mm length cylinders) and flexural strength (100 mm x 100mm x 500mm) size beam. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of conventional concrete.

Keywords— *Ground granulated blast furnace slag (GGBS), Steel fibre, Compressive strength, Split tensile strength, Flexural strength*

1. INTRODUCTION

The cement production process is a more energy consuming process, which results in the emission of carbon dioxide and other greenhouse gases, these gases adversely effect on the environment. The production cost of cement is increases and natural resources giving the raw material for its manufacturing are decreasing. The Fly ash (FA), GGBS, Rice Husk Ash (RHA), and Silica Fume (SF) are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. The ground granulated blast furnace slag (GGBS) is a waste product from the iron manufacturing industry, which may be used as partial replacement of cement in concrete because it has more cementitious properties. Concrete is the most widely used structural material around the world, because of its higher compressive strength, low cost and can be easily manufactured with the locally available materials, but concrete weak in tensile strength. So, to increase tensile strength and resistance to cracks fibres are added, such type of concrete is known as fibre reinforced concrete. Fibre reinforced concrete increases the toughness and durability of concrete. Fibre reinforced concrete (FRC) is concrete containing fibrous material which increases its structural bonding. It contains short discrete fibres that are uniformly distributed and randomly oriented. GGBS is a waste product in 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 the formation of granular particles generally not larger than 5 mm in diameter. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS (ground granulated blast furnace slag). Grinding of the granulated slag is carried out in a rotating ball mill.

2. EXPERIMENTAL PROGRAMME

The experimental program is designed to check the effect of GGBS and steel fiber on different properties on the M30 grade of concrete i.e. workability, compressive strength, split tensile strength and flexural strength of concrete and comparing results with conventional concrete. The program consists of casting and testing of total 17 cubes, 17 beams, and 17 cylinders specimens. The specimen of a standard cube of 150mm x 150mm x 150mm, a standard beam of 100mm x 100mm x 500mm and standard cylinder of 150 mm diameter and 300 mm height were casted with and without Steel fiber and GGBS. Compressive testing machine (CTM) is used to test the specimens.

3. MATERIAL USED

In this experimental work, various materials are used like….

1. Cement
2. Fine aggregate

3. Coarse aggregate
4. Water
5. Steel fibers
6. GGBS

3.1 Cement

Ordinary Portland cement of 53 grade is used in this experimental work and its properties were tested as per Indian standards IS 4031. Ordinary Portland cement conforming to IS 12269:198711 with specific gravity 3.15 is used Table 3.1 shows the properties of OPC.

Fig. 1: Cement used

3.2 Fine aggregate

The sand used for this experimental work was locally procured and passing through 4.75mm sieve with specific gravity 2.80. It should have fineness modulus 2.50-3.50 and silt contents should not be more than 4%. It is also noteworthy that the material's gradation was determined by sieving analysis in the laboratory. The physical properties of fine aggregate were noted to predict the overall impact on the concrete mix.

Fig. 2: Fine Aggregate

3.3 Coarse aggregate

The crushed aggregate of maximum size 20mm & minimum 10mm is used in the present study. Its specific gravity is 2.85. Locally available coarse aggregate is used. It should be hard, strong, dense, durable and clean. It must be free from a vein, adherent coatings and injurious amount of disintegrated pieces, alkalis, vegetable matters and other deleterious substances.

Fig. 3: Coarse Aggregate

3.4 Water

Freshwater free from any organic matter and potable water was used. Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Water which is suitable for drinking is satisfactory for use in concrete. Water should be free from acids, oils, alkalis, vegetables or other organic impurities.

3.5 GGBS

Blast furnace slag is a by-product of pig iron manufacture. The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). Using GGBS for cement replacement gives more water tightness, chemical resistance and low heat of hydration. The fineness modulus of GGBS using Blaine' fineness is 320m²/kg and other properties of GGBS. GGBS material was procured from Bhutda Corporation, Bhopal.

Fig. 4: GGBS

3.6 Steel fibre

Steel fiber having low carbon and hook end type was used. The steel fiber which is used in concrete is of density 7900 kg/m^3. The steel fibers can be of any shape like a crimped wire, hooked or a flat and are described as a parameter called aspect ratio. Steel fiber properties such as, crack resistance and increase in toughness are dependent on the mechanical properties of the fiber, bonding properties of the fiber and matrix, as well as the quantity and distribution within the matrix of the fibers. Steel fibers can be defined as discrete, short length of steel having ratio of its length to diameter (i.e. aspect ratio) in the range of 30 to150. The addition of steel fibers reduces the workability of the concrete. The steel fibers have dimensions of 0.45 x 25 mm, aspect ratio of 45, and a density of 7.85 g/cm^3. Collect from Arvind Industries Pvt. Ltd. Bhopal.

Table 1: Properties of steel fiber used in concrete

Fibre type	L_f, mm	D_f, mm	Aspect ratio	F_{uf}
RC 80/ 30 BP	30	0.38	79	2300
ZP 305	30	0.55	55	1300

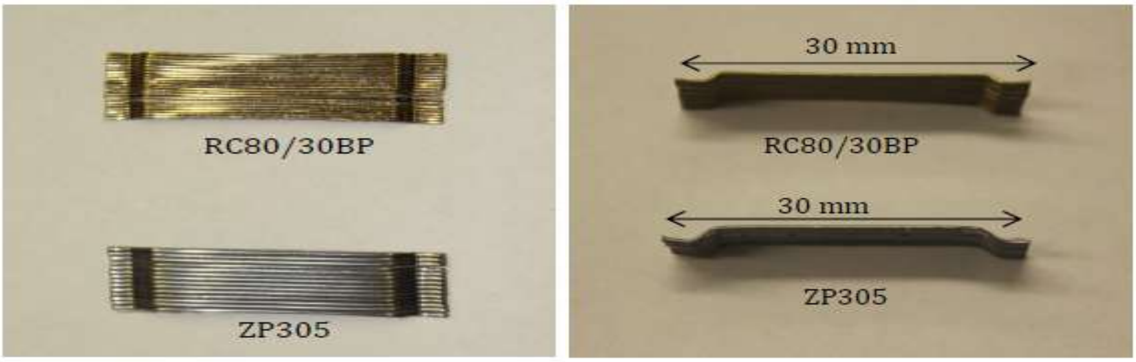

Fig. 5: Hook end steel fibers

4. TEST CONDUCTED

Tests were carried out for finding the compressive, flexural and split tensile strength. A standard test procedure is followed for each test and performance of concrete mix is studied.

4.1 Workability test

The slump test takes a look at which is a field take a look at is most effective an approximate measure of consistency defining stages of consistency for most practical works. This test is performed through filling fresh concrete inside the mold and measure the settlement i.e., slump.

Fig. 6: Workability test conducted in the lab

4.2 Compressive strength test

For compressive strength test, cube specimens of dimensions 150 mm x 150 mm x150 mm were cast for M30 grade of concrete. The compressive strength test was carried out conforming to IS 516-1959 to obtain compressive strength for an M30 grade of concretes. The compressive strength of concrete with ordinary Portland cement and ground granulated blast furnace slag concrete at the age of 7days, 21 days and 28days are conducted.

Fig. 7: Compressive strength test conducted in the lab

4.3 Flexural strength test

Flexural strength test was conducted on beam specimens under two-point loading as per I.S.516-1959. The average ultimate flexural tensile stress was determined from the failure flexural loads. For flexural strength test beam specimens of dimension 100mm x100mm x 500 mm were cast. The Flexural strength test was found for 28 days.

Fig. 3.10: Specimen loading for the flexural strength test

4.4 Split tensile strength test

The splitting tensile strength test was performed according to with IS 5816:1999 test method. The load shall be applied without shock and increased constantly at a nominal rate in the range 1.2 N/ (mm/min) to 2.4 N/ (mm/min). Maintain as far as possible, until failure. On manually controlled machines as failure is approached the loading rate will lower; at this degree, the controls will be operated to maintain as far as feasible the specified loading rate. The most load applied shall then be recorded.

Fig. 11: Specimen loading for the split tensile strength test

5. RESULTS AND DISCUSSIONS

5.1 Workability test

Slump cone test was executed to determine the degree of workability of GGBS and steel fiber concrete. It was observed that as a percentage of fiber increases workability reduces. The reduction in workability is due to more water required to lubricate more amount of fiber. As the amount of fiber increases less space is available for movement of fiber. Results are highlighted in the fig. below:

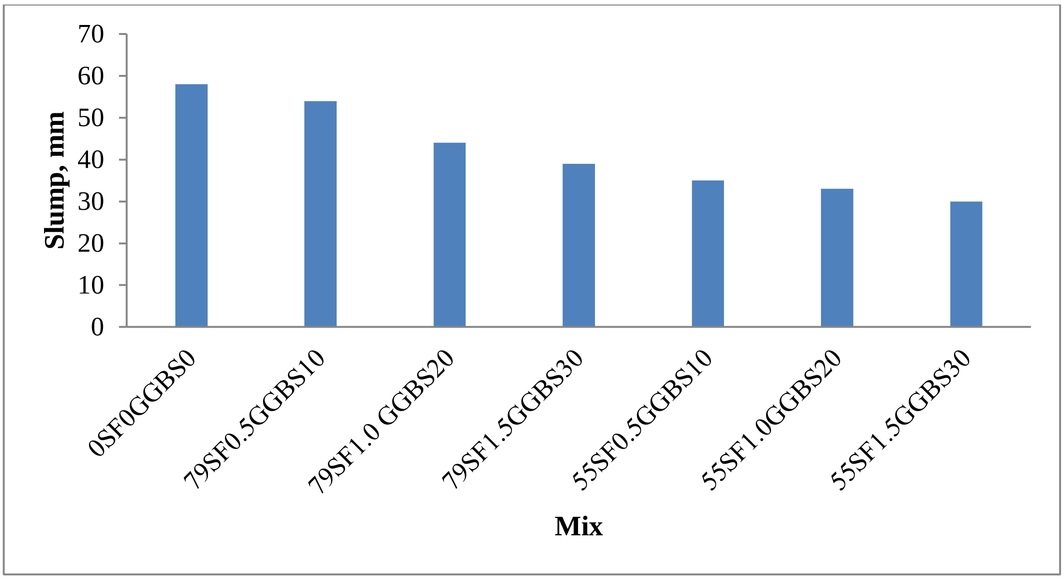

Fig. 12: Slump Test Result

5.2 Compressive strength test

Compressive strength test usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste.

For 7 days of curing

Fig. 4.2 showed the result of the compressive strength of concrete with fibers using an M30 grade of concrete. It clearly demonstrates that the compressive strength increases with increasing fiber volume fraction and aspect ratio. The incorporation of steel fiber into matrix serves to increase the ultimate compressive strength by the resultant arresting growth of cracks based on the bond of steel fiber and cement paste. The maximum value of compressive strength recorded at 10 % GGBS and 1.5 % fiber with aspect ratio 79 is 23.79 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % GGBS and 1.5 % fiber with aspect ratio 79.

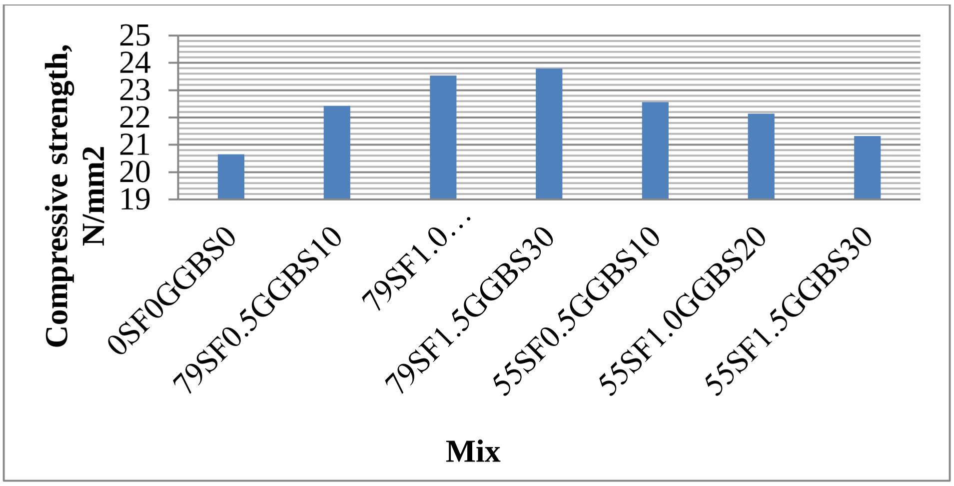

Fig. 13: Compressive Strength of M30 grade concrete at 7 days curing

For 21 days of curing

Fig. 4.2 showed the result of the compressive strength of concrete with fibers using an M30 grade of concrete. It clearly demonstrates that the compressive strength increases with increasing fiber volume fraction and aspect ratio. The incorporation of steel fiber into matrix serves to increase the ultimate compressive strength by the resultant arresting growth of cracks based on the bond of steel fiber and cement paste. The maximum value of compressive strength recorded at 10 % GGBS and 1.5 % fiber with aspect ratio 79 is 27.64 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % GGBS and 1.5 % fiber with aspect ratio 79.

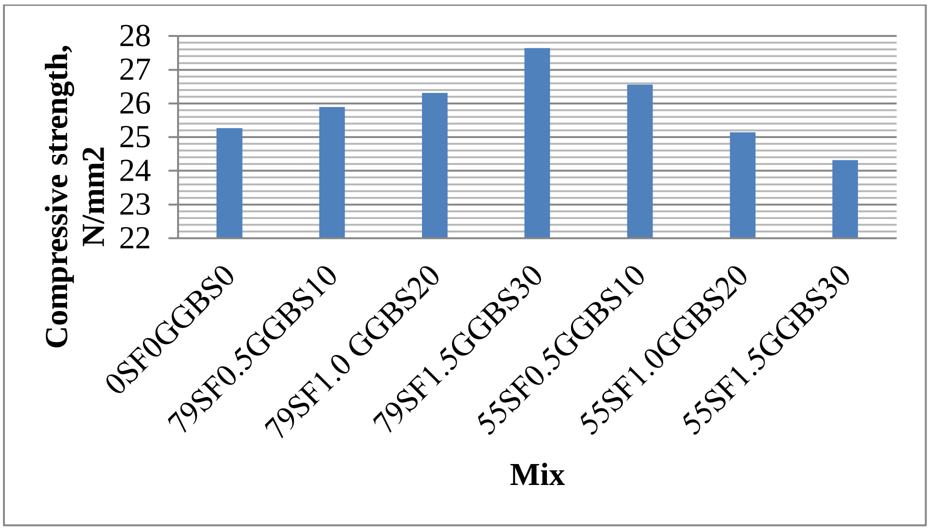

Fig. 14: Compressive Strength of M30 grade concrete at 21 days curing

For 28 days of curing

Fig. 4.2 showed the result of the compressive strength of concrete with fibers using an M30 grade of concrete. It clearly demonstrates that the compressive strength increases with increasing fiber volume fraction and aspect ratio. The incorporation of steel fiber into matrix serves to increase the ultimate compressive strength by the resultant arresting growth of cracks based on the bond of steel fiber and cement paste. The maximum value of compressive strength recorded at 10 % GGBS and 1.5 % fiber with aspect ratio 79 is 27.64 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % GGBS and 1.5 % fiber with aspect ratio 79.

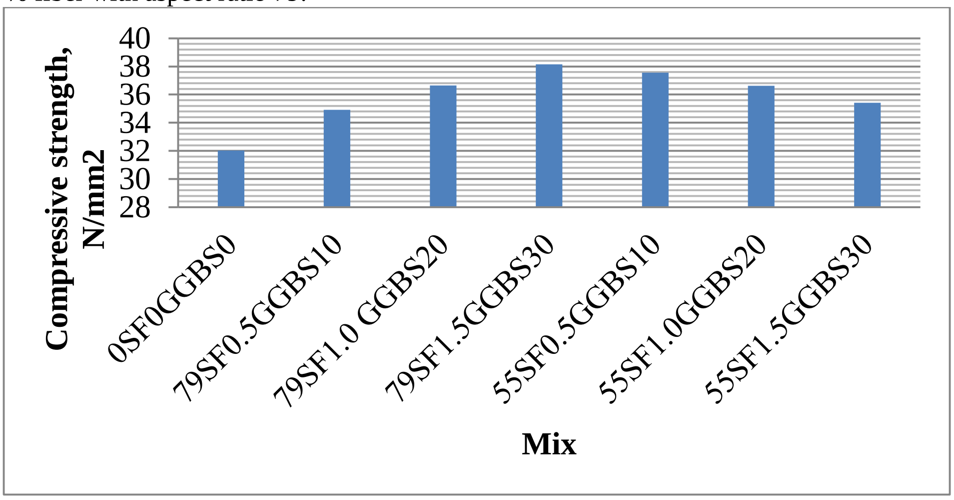

Fig. 15: Compressive Strength of M30 grade concrete at 28 days curing

5.3 Flexural strength test

For each of the different dosages, 17 beams with the dimensions 100 mm × 100 mm × 500 mm were prepared. A temping rod was used for compaction of concrete in prisms. All beams were demoulded after one day and immersed in the curing tank for a period of 28 days to assure sufficient curing. After 28 days of curing, each beam was tested. The result shows that the beam gave good performance at 10 % GGBS and 1.5 % fiber with aspect ratio 79 which is more than the maximum value of flexural strength at 10 % GGBS and 1.5 % fiber with aspect ratio 79 is 8.23 N/mm^2. Further addition of GGBS shows that flexural strength gradually increases. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % GGBS and 1.5 % fiber with aspect ratio 79.

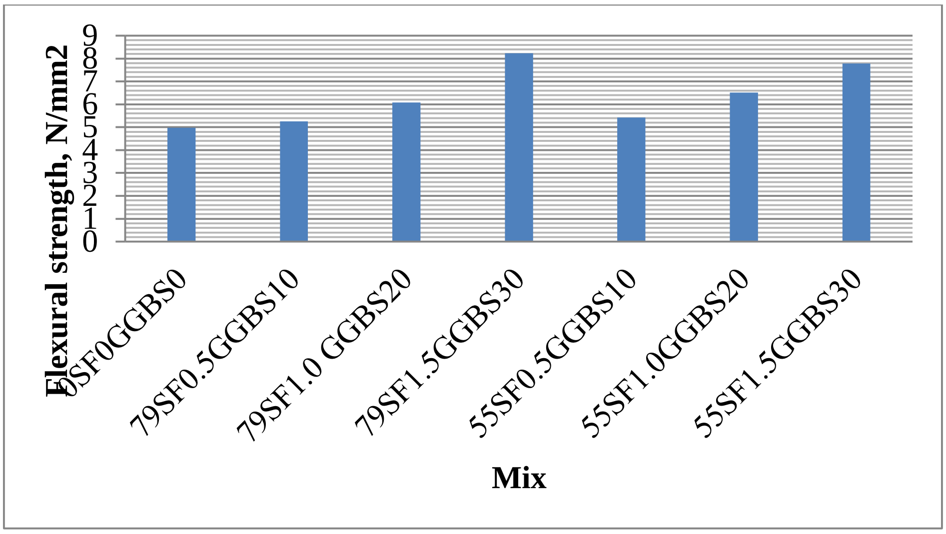

Fig. 16: Flexural Strength of M30 grade at 28 days

5.4 Split tensile strength test

The split tensile strength is the indirect measurement to determine the strength of concrete. Cylinders of size 150 mm diameter and 300 mm in height were casted for various percentages of GGBS and steel fiber. The test results show that there is an increase in the strength only up to 10 % GGBS and 1.5 % fiber with aspect ratio 79 beyond the strength decreases and it was also observed that the strength showed increased only after 28 days of curing period.

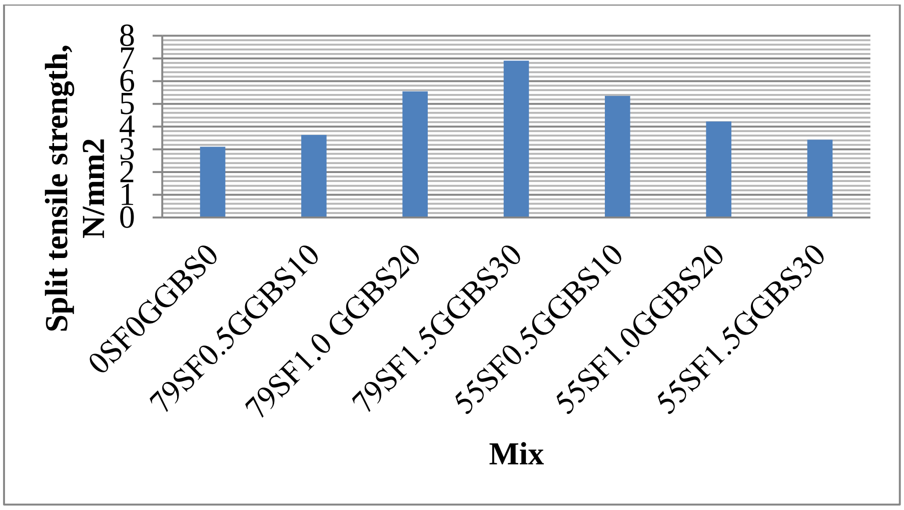

Fig. 17: Split Tensile Strength of M30 grade at 28 days

The maximum value of split tensile strength at 10 % GGBS and 1.5 % fiber with aspect ratio 79 is 6.90 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % GGBS and 1.5 % fiber with aspect ratio 79.

6. COST ANALYSIS

Material estimation includes costs for water, cement, natural sand, GGBS, steel fiber and coarse aggregate for a particular design mix. According to the mix design calculation, we achieved the weight of water, cement, natural sand, GGBS, steel fiber and coarse aggregate for concrete. As the water is largely available in India, its costs can, therefore, be neglected. The current study shows that replacement of cement using GGBS and steel fiber can be made as much as 10 % and 1.5 % (by weight).

Calculation:

Ratio = 1: 1.87: 3.37

Total = 1 + 1.87 + 3.37 = 6.24

Vol. of cement = (1/6.24) x 1.57 = 0.2516 m^3

1m^3 of cement = 1440 Kg

For 1m^{3}of M30 grade cement requires=0.2516 x 1440 = 362.3 Kg

No. of cement bags= 362.3/50 = 7.24 = 7.5 bags
Vol. of sand = (1.87/6.24) x 1.57 = 0.4704 m^3
For 1m^3 of M30 grade sand requires= 0.4704 x 1600 = 752.79 Kg
Vol. of coarse aggregate= (3.37/6.24) x 1.57 = 0.796 m^3
For 1$m^3$of M30 grade coarse aggregate requires = 0.796 x 1600 = 1274.91 Kg
Quantity of GGBS = 362.3 Kg x 0.1 = 36.23 Kg
Cement quantity after replacement = 326.07 kg = 6.52 bag

From the above table we note that the use of GGBS and steel fiber in concrete saves money up 2.20 % over the conventional cement concrete. This is a significant saving of money. There are good prospects of obtaining a good concrete strength at relatively cheaper cost even while replacing part of the cement GGBS and steel fiber. Figure 5.1 shows the comparison of costs between conventional concrete and M30 mixture.

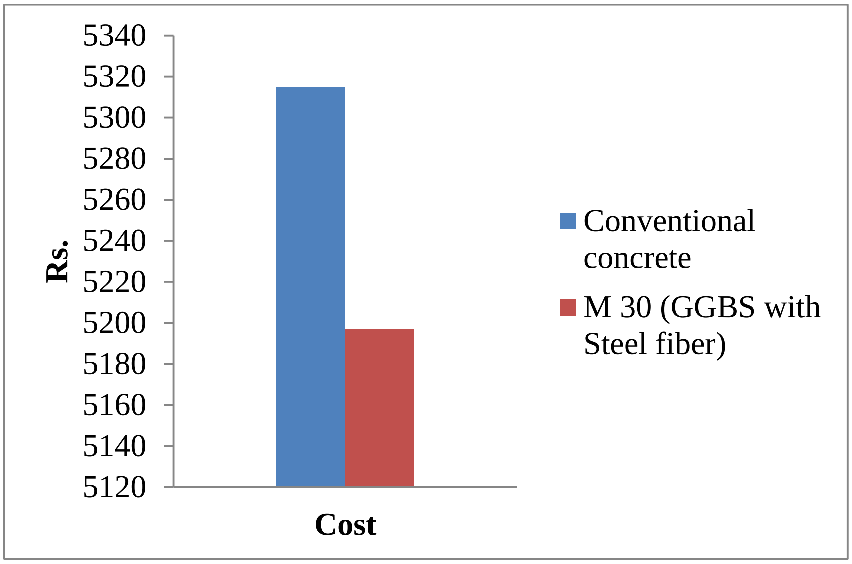

Fig. 4.7: Cost Comparison

7. CONCLUSION

In my thesis, I have performed a planned experiment and the result shows that the variation in the compressive, flexural and tensile strength with respect to changes in the GGBS and fiber content. The purpose of introducing GGBS and steel fibers by partial replacing cement is to increase the strength and performance of the concrete. And also durability properties of concrete can be enhanced by introducing the steel fibres.

The following conclusions could be drawn from the present investigation.

i. Slump cone test shows that with an increase in GGBS content, the workability increases but the addition of steel fiber in concrete decreases the slump value.
ii. Addition of GGBS and steel fibers in concrete leads to low workability.
iii. Use of GGBS as cement replacement increases consistency.
iv. The increment of GGBS and steel fiber content up to 10 % and 1.5 % given good result in terms of compressive strength, Tensile strength and flexural strength.
v. Increase in the steel fibers results in increasing the tensile strength and toughness of the composite
vi. Plain concrete is a brittle material and fails suddenly. Addition of steel fibers to concrete changes its brittle mode of failure into a more ductile one and improves the concrete ductility. The compressive strength and split tensile strength of concrete increases with fiber content.
vii. Addition of steel fibers reduces bleeding and it improves the surface integrity of the concrete. Also, it increases the homogeneity and reduces the probability of cracks.
viii. This experimental investigation helps to know the properties and behaviour of steel fiber reinforced concrete.
ix. From the mechanical properties, the optimum replacement by GGBS and steel fiber was found to be 10 % & 1.5 % with aspect ratio 79 and beyond all the strength values decreased when compared to normal concrete.
x. The maximum values of compressive strength at 10 % GGBS and 1.5 % fiber are 23.79, 27.64 and 38.15 N/mm^2 at the age of 7, 21 and 28 days.
xi. The maximum values of flexural strength at 10 % GGBS and 1.5 % fiber are 8.23 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % and 1.5 %.
xii. The maximum values of split tensile strength at 10 % GGBS and 1.5 % fiber are 6.9 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 10 % and 1.5 %.
xiii. The increases in flexural strength are directly proportional to the fiber content and also the flexural deflection decreases with increase in steel fiber as compared to the normal concrete.
xiv. The use of GGBS and steel fiber in concrete saves money up 2.2% over the conventional cement concrete for one cubic meter of volume. This is a significant saving of money. There are good prospects of obtaining a good concrete strength at a relatively cheaper cost even while replacing part of the cement GGBS and steel fiber.

xv. We can save maximum cost in mass concrete work or in construction where a large volume of concrete is used by replacing the cement with GGBS and steel fiber.

xvi. Concrete made with GGBS cement sets more rapidly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material but also continues to gain strength over a longer period in production condition.

xvii. Provides high resistance to chloride ingress reducing the risk of reinforcement corrosion and provides protection against sulphate attack hence can be used in effluent and sewage treatment plant (to avoid sulphate attack), in marine work and many more.

xviii. We all know that plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Hence these fibers act as crack arrestors and prevent the propagation of the cracks

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