# A STUDY OF CONCRETE USING STEEL FIBER AND GGBS AS A PARTIAL REPLACEMENT OF CEMENT

**Mohammed Khalid Khan,Samata Mishra,** Professor, Department of Civil Engineering, Raajdhani Engineering College, Bhubaneswar, India

## ABSTRACT

This experimental investigation is being carried out to examine the various strengths of concrete that has had some of the cement replaced with ground granulated blast furnace slag (GGBS) and steel fibre added. In this study, M30 grade concrete is replaced with ground granulated blast furnace slag (15, 25, 35, and 45%) by weight. Steel fibres with varied percentages of 0.45 x 25mm dimensions are also added (1 percent, 1.5 percent, 2 percent, and 2.5 percent). Flexural strength testing on a 150mmx150mmx700mm-size beam was used to gauge the strength of the concrete. Concrete made with GGBS and steel fibre has undergone technical and economic study. Finally, the strength performance of ordinary concrete and slag blended fibre reinforced concrete are compared.

**Keywords:** Steel fiber, GGBS, Partial Replacement, Flexural strength, cost analysis.

## INTRODUCTION

Cement, sand, aggregate, and water are the basic, naturally occurring, inexpensive, and readily accessible constituents of concrete. Cement is the second most used material in the world after water. However, the increased production of cement generates two significant environmental issues for which civil engineering solutions must be found. We are aware that CO2 emissions are extremely destructive and cause several environmental impacts. By-products for the production of pig iron include ground granulated blast furnace slag (GGBS), which is produced by quenching molten slag or rapidly cooling it with water. Here, molten slag is created and water is used to instantly tap and cool it. The creation of "Granulated slag" is facilitated by the quick quenching of molten slag. Granulated slag is converted into Ground Granulated Blast Furnace Slag (GGBS). One of the byproducts produced when coal is burned in coal-fired power plants is fly ash. Finely-distributed mineral admixture, which is available in both incompact and compact forms, is used to gather fine particles that ascend with flue gases. By better filling in gaps between cement particles, this ultra-fine material will produce a concrete that is very dense, has higher compressive strengths, and has a very low permeability.

## MATERIALS AND METHODS

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

- 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.**
- • Steel fibres are discrete, brief lengths of steel that fall between the range of 30 to 150 in terms of their length to diameter (or aspect ratio). The workability of the concrete is decreased by the addition of steel fibres. The steel fibres are 0.45 x 25 mm in size, have a 45 aspect ratio, and weigh 7.85 g/cm3. Pay at StewolsPvt. Ltd. in Nagpur.
- GGBS conforming to IS 12089-1981 was used in the investigation and is procured from Sri Sat guru Associates, Bhopal.
- Fine Aggregate- Locally available river sand passing through 4.75 mm IS sieve conforming to grading zone-II of IS: 383-1970 was used with a specific gravity of 2.74.
- Coarse Aggregate- Crushed stone aggregate with combinations of 12 mm and 10 mm in 60% and 40% respectively from a local source having the specific gravity of 2.74 conforming to IS: 383-1970 was used.

- Water- Potable water is used for mixing and curing concrete.
- Super Plasticizers- In order to improve the workability to high performance concrete, super plasticizer in the form of sulphonated Naphthalene Polymers complies with IS 516 – 1959 and ASTM C 642 type F as a high range water reducing admixture (VARAPLAST PC 100) was used.

## CONCRETE MIX DESIGN

Mix design is made for M30 grade concrete accordance with the Indian Standard Recommended Method IS 10262-2009.

There were 17 different concrete mixtures created, one of which contained only regular Portland cement (no GGBS and no steel fibre content). The remaining 16 mixtures were made by GGBS ground granulated blast furnace slag being added in various weight percentages (15, 25, 35, and 45%) and by adding steel fibres with a 0.45 x 25mm dimension in various percentages (1, 1.5, 2 and 2.5%) to the weight of concrete.
The amount of water, coarse aggregate and fine aggregate were calculated for all the mixes and are reported in the table 3.6 shown below

***Table 1: Mixture proportions of GGBS and Steel fibers blended concretes.***

| Specimen | GGBS % | Steel Fiber % | Quantity ($Kg/m^3$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Cement | GGBS | Steel Fiber | Coarse Aggregate | Fine Aggregate |
| 1 | 0 | 0 | 380 | 0 | 0 | 1283 | 711 |
| 2 | 15 | | 319.2 | 57 | 3.8 | 1283 | 711 |
| 3 | 25 | | 281.2 | 95 | 3.8 | 1283 | 711 |
| 4 | 35 | 1 | 243.2 | 133 | 3.8 | 1283 | 711 |
| 5 | 45 | | 205.2 | 171 | 3.8 | 1283 | 711 |
| 6 | 15 | | 317.3 | 57 | 5.7 | 1283 | 711 |
| 7 | 25 | | 279.3 | 95 | 5.7 | 1283 | 711 |
| 8 | 35 | 1.5 | 241.3 | 133 | 5.7 | 1283 | 711 |
| 9 | 45 | | 203.3 | 171 | 5.7 | 1283 | 711 |
| 10 | 15 | | 315.4 | 57 | 7.6 | 1283 | 711 |
| 11 | 25 | | 277.4 | 95 | 7.6 | 1283 | 711 |
| 12 | 35 | 2 | 239.4 | 133 | 7.6 | 1283 | 711 |
| 13 | 45 | | 201.4 | 171 | 7.6 | 1283 | 711 |
| 14 | 15 | | 313.5 | 57 | 9.5 | 1283 | 711 |
| 15 | 25 | | 275.5 | 95 | 9.5 | 1283 | 711 |
| 16 | 35 | 2.5 | 237.5 | 133 | 9.5 | 1283 | 711 |
| 17 | 45 | | 199.5 | 171 | 9.5 | 1283 | 711 |

**EXPERIMENTAL PLAN**

The experimental programme was created to evaluate the workability and mechanical qualities of concrete, such as its flexural strength and elastic modulus, in comparison to conventional concrete and GGBS concrete of grade M30. The programme involves casting and testing a total of 17 conventional 150mm x 150mm x 700mm beams, both with and without GGBS and steel fibre. Concrete made with GGBS and steel fibre has undergone technical and experimental investigation. All specimens are tested using the UTM and the compressive testing machine (CTM).

**Mixing**

The concrete mixture was made on the waterproof platform by hand mixing. Sand was added to the mixture after the cement and GGBS had been fully mixed in the dry condition. The mixture was once more well combined before being spread over the coarse aggregate. Following that, water was gradually added while mixing chemical admixture. Up till a usable combination was achieved, mixing was done.

**Casting**

After thoroughly mixing, the mixture was placed into a beam with dimensions of 150 mm x 150 mm x 700 mm, and it was then manually compacted with tamping rods. In this work, we primarily created 17 various M30 Grade mixes, including conventional aggregate concrete (CAC), concrete manufactured by substituting GGBS for cement, and concrete with varying percentages of steel fibre added.

**Curing*igure. 1: Casting of Beam***

Curing is a technique used to speed up the hardening of concrete under humidity and temperature conditions that support the gradual and appropriate setting of the constituent cement. The qualities of hardened concrete, such as their strength, watertightness, wear resistance, volume stability, and resistance to freezing and thawing, are significantly influenced by curing. If poorly or insufficiently cured, concrete that has been specified, batched, mixed, laid, and finished may nevertheless fail. Curing is typically the final stage of a concrete job and is regrettably frequently overlooked even by experts.

After one day of casting, the beams were removed from the mould and placed in the appropriate solutions for curing at room temperature with a relative humidity of 90%. The beams were then removed from curing after 28 days for testing.

## II. TEST CONDUCTED Flexural strength test

According to I.S. 516-1959, a flexural strength test was performed on beam specimens under two point stress. The failure flexural loads were used to calculate the average ultimate flexural tensile stress. Cast beam specimens with dimensions of 150 mm x 150 mm x 700 mm were used for the flexural strength test. After 28 days of curing, the beam specimens underwent testing.


*Figure. 2: Specimen loading for flexural strength test*

**Elastic modulus for concrete**

The most frequent test performed on hardened concrete is the Elastic Modulus for Concrete test, in part because it is a simple procedure. Concrete isn't actually elastic; upon unloading, it doesn't completely return to its previous dimensions. As a result, while designing reinforced concrete structures conventionally, the elastic constants must be taken into account.

The modulus of elasticity of FRC can be determined using the formula given by I.S. 456 (I.S. 456-2000) depending upon strength of concrete ($f_{ck}$)

$E_{fc} = 5000\sqrt{f_{ck}}$ Mpa

Where, $f_{ck}$ is Compressive strength of concrete at 28 days

## III. RESULTS AND DISCUSSIONS Flexural strength test

For each of the different dosages, 17 beams with the dimensions 150mm × 150mm × 700 mm were prepared. A temping rod was used for compaction of concrete in prisms. All beams were taken out of the mould 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 using the loading tests setup. The report shows that the strength gave good performance for25 % replacement which is more than normal concrete.

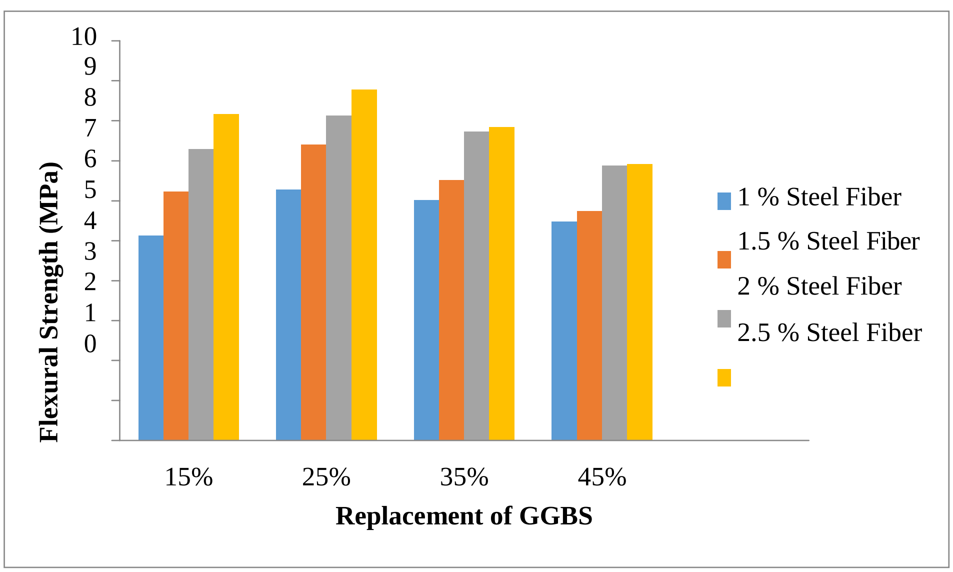


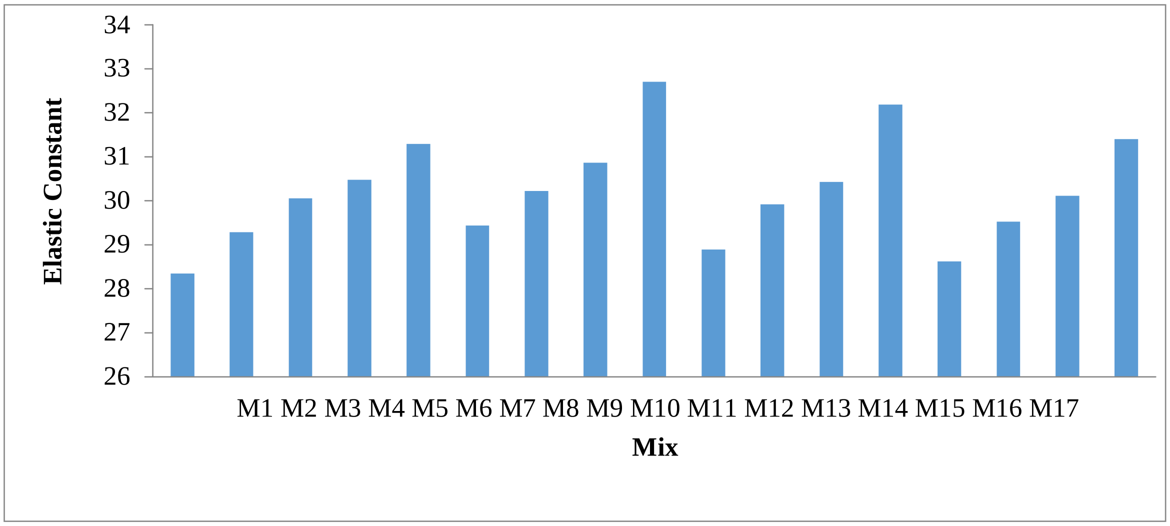

*Figure. 3: Flexural Strength of M30 grade at 28 days curing*

The maximum value of flexural strength at 25 % GGBS and 2.5 % fiber is 8.78 N/mm$^2$.Further addition of GGBS shows that flexural strength gradually decreases. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %.

**Elastic modulus**
In the analysis of structure elastic constant viz. E, μ & G are always required.

The modulus of elasticity can be determined using the formula given by I.S. 456 (I.S. 456-2000) Depending upon strength of concrete (fck)
Efc= $5\sqrt{fck}$GPa

Where, fck is Compressive strength of concrete at 28 days




**COST ANALYSIS**
***Fig. 4: Variation of Modulus of Elasticity***
***Table 2 Cost of material per cubic meter of concrete for M30***

| **Material** | **Rate** | **Conventional Concrete** | | **M 30 (Optimum Steel fiber(2.5 %) and GGBS (25 %) Concrete)** | | **% Saving** |
|---|---|---|---|---|---|---|
| | | **Quantity** | **Cost** | **Quantity** | **Cost** | |
| Cement | 400 per bag (50 Kg) | 7.5 bags | Rs 3000 | 5.4 bags | Rs 2174 | 1.91 % |
| Steel fiber | Rs12/ kg | 0 | 0 | 9.05 Kg | Rs108.6 | |
| GGBS | Rs 6/Kg | 0 | 0 | 90.57 Kg | Rs 543.42 | |
| Fine Aggregate | Rs 860/$m^3$ | 0.4704 $m^3$ | Rs 404.54 | 0.4704 $m^3$ | Rs 404.54 | |
| Coarse Aggregate | Rs 2400/$m^3$ | 0.796 $m^3$ | Rs 1910.4 | 0.796 $m^3$ | Rs 1910.4 | |
| Super Plasticizer | Rs. 40/Kg | 0 | 0 | 1.8 Kg | Rs. 72 | |
| | | | Rs 5314.94 | | Rs5212.96 | |

From the above table we note that the use of GGBS and steel fiber in concrete saves money up 1.91 % over the conventional cement concrete for 1$m^3$ volume. 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. Replacement of cement with GGBS and steel fiber can save huge cost where mass concreting has to be done.

**CONCLUSION**

The variation in the, flexural and modulus of elasticity with respect to changes in the GGBS and fiber content is observed. The purpose of introducing GGBS and steel fibers by partial replacing cement is to increase 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.

1. Use of GGBS as cement replacement increases consistency.
2. Increment of GGBS and steel fiber content up to 25 % and 2.5 % given good result in terms of flexural strength.
3. Increase in the steel fibers results in increasing the tensile strength and toughness of the composite.
4. 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 addition of GGBS and steel fiber increases the flexural strength of concrete at optimum content..
5. Addition of steel fibers reduces bleeding and it improves the surface integrity of concrete. Also it increases the homogeneity and reduces the probability of cracks.
6. This experimental investigation helps to know the properties and behaviour of steel fiber reinforced concrete.
7. From the mechanical properties, the optimum replacement by GGBS and steel fiber was found to be 25 % & 2.5 % and beyond 25 % all the strength values decreased when compared to normal concrete.
8. The maximum values of flexural strength at 25 % GGBS and 2.5 % fiber are 8.78 $N/mm^2$. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %.
9. 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.
10. The elastic modulus of concrete shows better increase in strength up to 15-28% after attaining the full strength of concrete.
11. We note that the use of GGBS and steel fiber in concrete saves money up 1.91 % 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. For mass concreting work we can use concrete with GGBS and steel fiber as partial replacement of cemnt.

**REFERENCES**


[1] Pooja, Shreenivas Reddy Shahapur, Maneeth PD, Brijbhushan S, “Evaluation of Effect of Steel Fibres on M45 grade of Concrete by Partial Replacement of Cement with Fly ash and GGBS”, International Journal for Research in Applied Science & Engineering Technology, Vol. 5, Issue 8, PP: 1949-1956.

[2] T. Subbulakshmi, B. Vidivelli, K. Nivetha, “Strength Behaviour of High Performance Concrete using Fibres and Industrial by Products”, International Journal of Engineering Research & Technology, Vol. 3, Issue 8, PP: 1219-1224.

[3] SuchitaHirde, Pravin Gorse, “Effect of Addition of Ground Granulated Blast FurnaceSlag (GGBS) on Mechanical Properties of Fiber Reinforced Concrete”, International Journal of Current Engineering and Technology, Vol. 5, Issue 3, PP: 1677-1682.

[4] Nandhini.J, Kalingarani.K, “Effect of Hybrid Fibres on Flexural Behaviour of Reinforced Concrete Beams with Blended Cement”, International Journal of Research in Advent Technology, Vol.4, Issue 6, PP: 70-73.

[5] A.M. Shende; A.M. Pande, M. GulfamPathan, "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade", International Refereed Journal of Engineering and Science, Volume 1, Issue 1, PP: 43- 48.
[6] S.P.Sangeetha,Dr.P.S.Joanna, "Flexural Behaviour Of Reinforced Concrete Beams With GGBS", International Journal Of Civil Engineering And Technology, Volume 5, Issue 3, PP: 124-131.
[7] Christina Mary V, Kishore CH, "Experimental Investigation On Strength And Durability Characteristics of High Performance Concrete Using GGBS And Msand", ARPN Journal of Engineering and Applied Sciences, Vol. 10, Issue 11, PP: 4852-4856.
[8] Sowmya. S.M, PremanandKumbar, R. Amar,"An Experimental Investigation on Strength Properties of Concrete by Replacing Cement with GGBS and Silica Fume", International Journal of Research, Vol. 1, Issue 8, PP: 148-152.
[9] Sujit V. Patil, N. J. Pathak, "The Experimental Study on Compressive Strength of Concrete using AR Glass Fibers and Partial Replacement of Cement with GGBS with Effect of Magnetic Water", International Journal of Engineering Technology, Management and Applied Sciences, Vol.4, Issue 8, PP: 21-29.
[10] Prashant Y.Pawade, Nagarnaik P.B., Pande A.M, "Performance of steel fiber on standard strength concrete in compression", International Journal of Civil and Structural Engineering Volume 2, No 2, PP: 483-488.
[11] Nikhil A. Gadge, S. S. Vidhale, "Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber", International Journal of Modern Engineering Research, Vol. 3, Issue. 6, PP: 3863-3871.
[12] T. Subbulakshmi, B. Vidivelli, "Experimental Investigation on the Effect of Industrial Byproducts on the Strength Properties of High Performance Concrete", Journal of Mechanical and Civil Engineering, Volume 13, Issue 3, PP: 13-21.
[13] RoopaSaira Thomas, Jebitta Fancy Rajaselvi .P, "An Experimental Investigation on the Effects of Concrete by Replacing Cement with GGBS and Rice Husk Ash with the Addition of Steel Fibers",International Journal of Science and Research, Volume 5, Issue 2, PP: 2104-2109.
[14] Vijay MadhavraoTakekar, G. R. Patil, "Experimental Study of Properties of Fiber Reinforced Concrete using GGBS", International Journal of Engineering Technology, Management and Applied Sciences Volume 3, Issue 3, PP: 589-594.
[15] AnushaSuvarna, P.J. Salunke, T.N.Narkehde, "Strength Evaluation of Fiber Reinforced Concrete Using Pozzolanas", International Journal of Engineering Sciences & Research Technology, Vol. 4, Issue 10, PP: 196-201.
[16] NamaniSaikrishna, Syed Moizuddin, "Strength Properties of Steel Fiber Concrete by Partial Replacement of Silica Fume", International Journal of Research in Advanced Engineering Technology, Volume 6, Issue 1, Jan 2017, PP: 120-124.
[17] DasariVenkateswara Reddy, Prashant Y.Pawade, "Combine Effect Of Silica Fume And Steel Fiber On Mechanical Properties On Standard Grade Of Concrete And Their Interrelations", International Journal of Advanced Engineering Technology, Vol.3, Issue I, January, 2012, PP: 361-366.
[18] K.Vidhya, T.Palanisamy, R.ThamaraiSelvan, "An Experimental Study On Behaviour Of Steel Fibre Reinforced Concrete Beams", International Journal of Advanced Research Methodology in Engineering & Technology, Volume 1, Issue 2, March 2017, PP: 178-183.
[19] Mohammad Panjehpour, Abang Abdullah Abang Ali, RamazanDemirboga, "A Review For Characterization Of Silica Fume And Its Effects On Concrete Properties", International Journal of Sustainable Construction Engineering & Technology, Vol 2, Issue 2, December 2011, PP: 1-7.
[20] Vijay M. Mhaske, Rahul D. Pandit, A. P. Wadekar, "Study on Behaviour on High Strength Crimped Steel Fibre Reinforced Concrete for Grade M90", Journal of Ceramics and Concrete Sciences, Vol. 1, Issue 3, PP: 1-12.
[21] SubhashMitra, Pramod K. Gupta and Suresh C. Sharma, "Time- dependant strength gain in mass concrete using mineral admixtures", Indian Concrete Journal, Vol. 1, Issue 3, November, 2012, PP: 15-

22.
[22] A. Annadurai, A. Ravichandran, “Flexural Behavior of Hybrid Fiber Reinforced High Strength Concrete”, Indian Journal of Science and Technology, Vol 9, Issue 1, Jan 2016, PP: 116-122.
[23] Ram Kumar, Jitender Dhaka, “Review Paper on Partial Replacement Of Cement With Silica Fume And Its Effects on Concrete Properties”, International Journal For Technological Research In Engineering Volume 4, Issue 1, September-2016, PP: 83-85.
[24] Neeraja, “Experimental investigation of Strength Characteristics of Steel Fiber Reinforced Concrete”, International Journal of Scientific &Engg. Research, Vol-4, Issue-2, PP: 89-94.
[25] Vikrant S. Variegate, Kavita S. Kene (2012), “Introduction to Steel Fiber Reinforced Concrete on Engineering Performance of Concrete” International Journal of Scientific & Technology Research Volume 1, Issue 4, PP: 54-61.
[26] M. V. Mohod, “Performance of steel fiber reinforced concrete” International Journal of Engineering and Science, Vol. 1, issue 5, PP. 01 – 04.
[27] ISO 901:20089, “International Organisation for Standard”.
[28] ASTM A-820, “Standard Specification for steel fiberreinforce concrete”, 2011.