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EXPERIMENTAL INVESTIGATI ON THE PROPERTIES OF M30 GRADE OF CONCRETE USING STEEL FIBERS AND GGBS (GROUND GRANULATED BLAST FURNACE SLAG) AS PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT
This 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 addition of steel fiber. In this investigation M30 grade of concrete is replaced with ground granulated blast furnace slag (15%, 25%, 35%, and 45%) by weight and addition of steel fiber having dimensions (0.45 x 25mm) in different percentage (1%, 1.5%, 2%, and 2.5%).Strength of concrete was determined by performing compressive strength test on (150mmx150mmx150mm) size cubes and split tensile strength test on (300mmx150mm) size cylinder. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of conventional concrete.

Keywords: Steel fiber, GGBS, Partial Replacement, Compressive strength, split Tensile strength.

I. INTRODUCTION
Concrete has basic naturally, cheaply and easily available ingredients as cement, sand, aggregate and water. After the water, cement is second most used material in the world. But this rapid production of cement creates two big environmental problems for which we have to find out civil engineering solutions. We know that CO_2 emission is very harmful which creates lots of environmental changes whatsoever. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of "Granulated slag". Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. Fly ash is one of the residues created during the combustion of coal in coal-fired power plants. Fine particles rise with flue gasses and are collected with finely-divided mineral admixture, available in both incompact and compacted forms. This ultra-fine material will better fill voids between cement particles and result in a very dense concrete with higher compressive strengths and extremely low permeability.

II. 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 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 25mm, aspect ratio of 45, and density of 7.85 g/cm3. Collect from StewolsPvt. Ltd. Nagpur.
- GGBS conforming to IS 12089-1981 was used in the investigation and is procured from Sri Sat guru Associates, Bhopal.

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- 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.

III. CONCRETE MIX DESIGN

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

A total of 17 concrete mixes for each mixes were prepared; one of the mixes was made of 100% ordinary Portland cement (no GGBS and no steel fiber content). The remaining 16mixes were prepared by adding GGBS ground granulated blast furnace slag (15%, 25%, 35%, and 45%) by weight and addition of hook ended steel fibres (HESF) having dimensions (0.45 x 25mm) in different percentage (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.

Mix	GGBS %	Steel Fiber %	Quantity (Kg/m^3)				
			Cement	GGBS	Steel Fiber	Coarse Aggregate	Fine Aggregate
M1	0	0	380	0	0	1283	711
M2	15	1	319.2	57	3.8	1283	711
M3	25		281.2	95	3.8	1283	711
M4	35		243.2	133	3.8	1283	711
M5	45		205.2	171	3.8	1283	711
M6	15	1.5	317.3	57	5.7	1283	711
M7	25		279.3	95	5.7	1283	711
M8	35		241.3	133	5.7	1283	711
M9	45		203.3	171	5.7	1283	711
M10	15	2	315.4	57	7.6	1283	711
M11	25		277.4	95	7.6	1283	711
M12	35		239.4	133	7.6	1283	711
M13	45		201.4	171	7.6	1283	711
M14	15	2.5	313.5	57	9.5	1283	711
M15	25		275.5	95	9.5	1283	711
M16	35		237.5	133	9.5	1283	711
M17	45		199.5	171	9.5	1283	711

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IV. EXPERIMENTAL PLAN

The experimental program was designed for the workability and for the mechanical properties i.e. the compressive strength, split tensile strength and flexural strength of concrete and also modulus of elasticity of concrete with M30 grade of normal concrete. The program consists of casting and testing of total 17 cubes, 17 beam 17 cylinders specimen of standard size cube of 150mm x 150mm x 150mm, and standard cylinder of 150 mm diameter and 300 mm height were cast with and without Steel fiber and GGBS.Compressive testing machine (CTM).

Mixing

On the watertight platform, the concrete mixture was prepared by hand mixing. The cement, GGBS were thoroughly mixed in the dry state and the sand was added to the mixture. The mixture was again thoroughly mixed and placed over the Coarse aggregate. Then water was added carefully with chemical admixture during mixing. Mixing was carried out until a workable mixture was obtained.

Casting

After proper mixing, the mix poured in to the cube moulds of size 150 x 150x 150 mm, and standard cylinder of 150 mm diameter and 300 mm height and then compacted manually using tamping rods. In this work we mainly prepared 17 different mixes of M30 Grade namely conventional aggregate concrete (CAC), concrete made by replacing cement with GGBS and by adding Steel fiber.

Fig. 1: Casting of Cubes

Fig. 2: Casting of Cubes and cylinders

Curing

Curing is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals.

The cubes were taken out after 1 day of casting and then kept in respective solutions for curing at room temperature with a relative humidity of 90% the cubes are taken out from curing after 7days, 14 days and 28 days for testing.

V. TEST CONDUCTED

Workability test

The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

Fig. 3 Workability test conducted in lab

Compressive strength test

The compressive strength test was carried out conforming to IS 516-1959 to obtain compressive strength for 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, 14 days and 28days are conducted.

Fig. 4: compressive strength test machine

Fig. 5: cube after compressive load

Split tensile strength test

Split tensile strength test was conducted on concrete cylinders of 150 mm diameter and 300 mm height. 17 cylinders were prepared for each combination. A control mix was also prepared for the split tensile strength. The cylinders were subjected to compression load along two axial lines which are diametrically opposite. The load was applied continuously at a constant rate. The split tensile strength was found for 28 days.

Fig. 6: Specimen loading for split tensile strength test

VI. RESULTS AND DISCUSSIONS

1. Workability test

Slum cone test was executed to determine the workability factor of GGBS and steel fiber concrete. Fig. below shows that with increase in GGBS content up to 35%, the workability first increases and on further addition of GGBS content shows decrease in workability. When M30 grade concrete is replaced with GGBS and fiber,

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incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix.

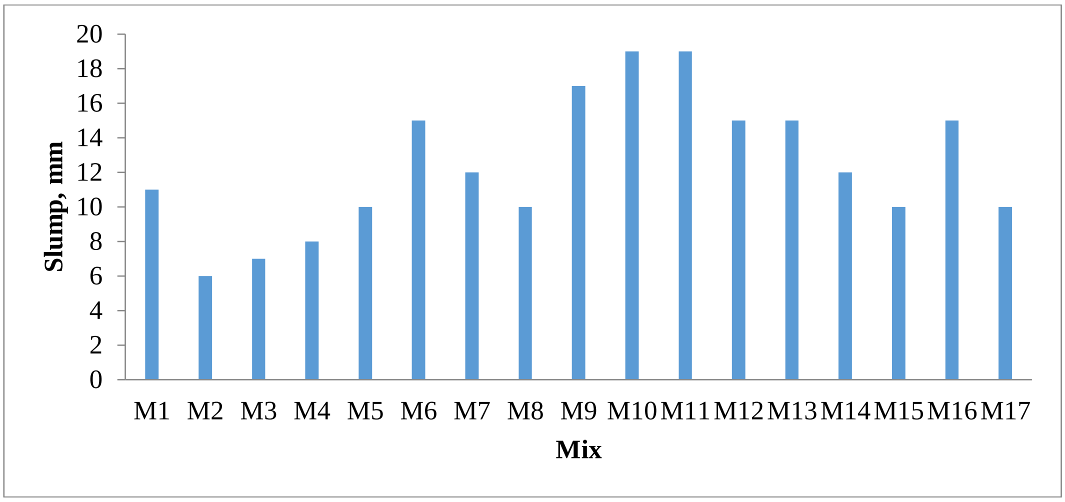

Table 6: Slump Test Result

2. **Compressive strength test**

For 7 days of curing

Fig. 8 showed result of compressive strength of concrete with fibers using M30 grade of concrete. It is observed that compressive strength increases with the increase of GGBS as compared to the normal concrete. Compressive strength of concrete with GGBS and steel fiber is increased up to the 25 % and then decreases. The maximum value of compressive strength recorded at 25 % GGBS and 2.5 % fiber is24.46 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %, when OPC used.

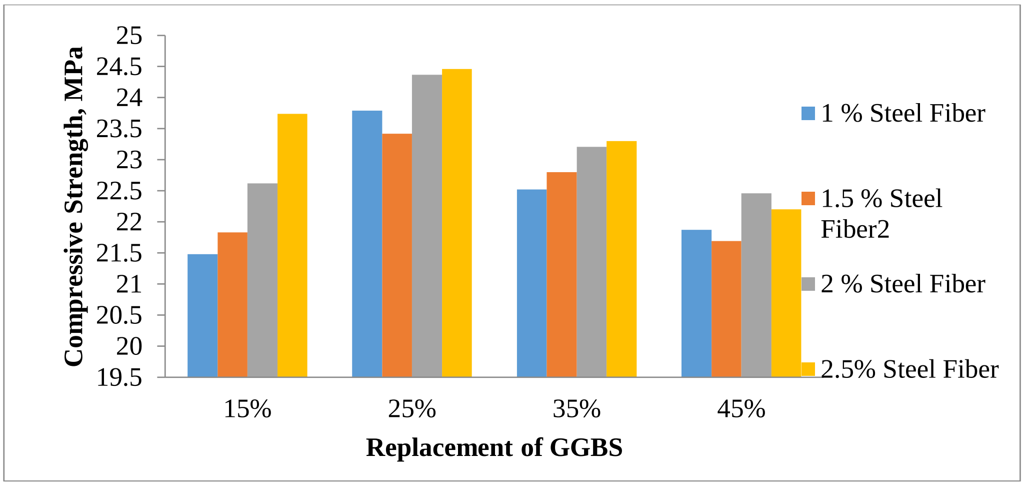

Fig. 7Compressive Strength of M30 grade concrete at 7 days curing

For 14 days of curing

Fig. 9 showed result of compressive strength of concrete with fibers using M30 grade of concrete. It is observed that compressive strength increases with the increase of GGBS as compared to the normal concrete. Compressive strength of concrete with GGBS and steel fiber is increased up to the 25 % and then decreases. The maximum value of compressive strength at 25 % GGBS and 2.5 % fiber is 28.66 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 % steel fiber.

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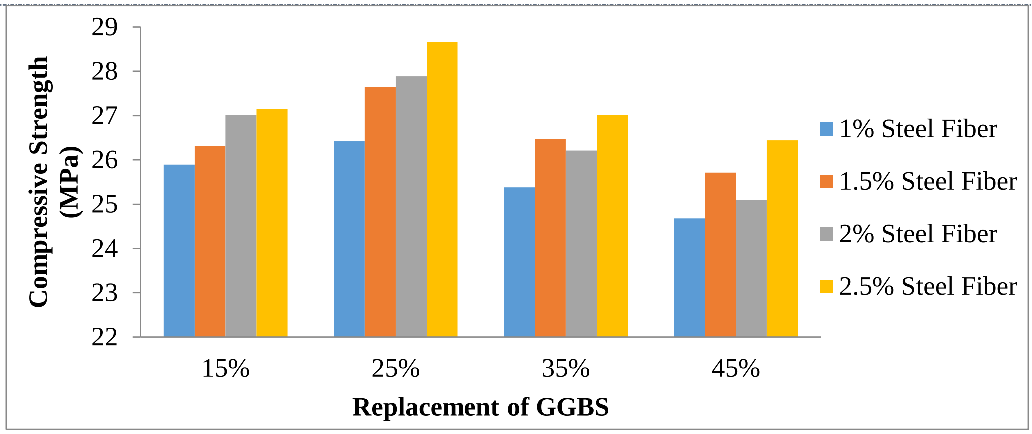

Fig. 8: Compressive Strength of M30 grade concrete at 14 days curing

For 28 days of curing

Fig. 9 showed result of compressive strength of concrete with fibers (hook end type) using M30 grade of concrete. It is observed that compressive strength increases with the increase of GGBS as compared to the normal concrete. Compressive strength of concrete with GGBS and steel fiber is increased up to the 25 % and then decreases. The maximum value of compressive strength at 25 % GGBS and 2.5 % fiber is 42.79 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %.

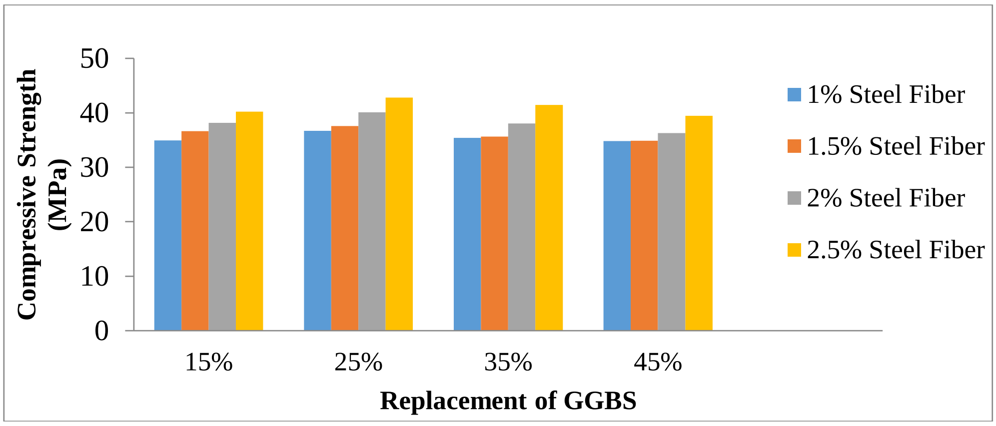

Fig. 9: Compressive Strength of M30 grade concrete at 28days curing

3. Split tensile strength test

The split tensile strength is the indirect measurement to determine the strength of concrete. Cylinders of size 150mm diameter and 300mm in height were casted for various percentages of GGBS and steel fiber. The test results shows that there is an increase in the strength only up to 25 % slag and beyond 25 % the strength decreases and it was also observed that the strength showed increased only after 28 days of curing period.

The maximum value of split tensile strength at 25 % GGBS and 2.5 % fiber is 8.95 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %.

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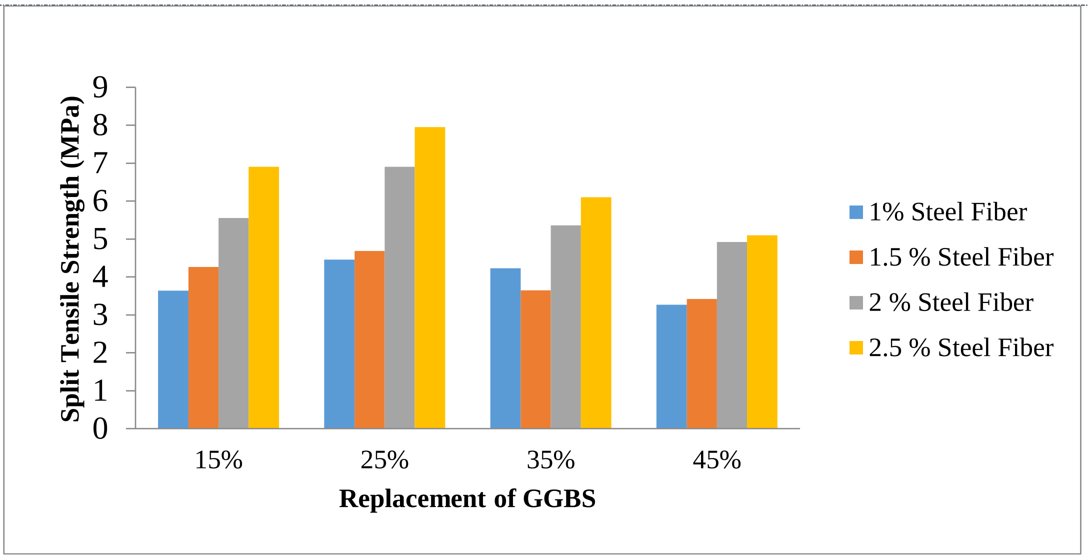

Fig. 10: Split Tensile Strength of M30 grade at 28 days curing

VII. CONCLUSION

The variation in the compressive, flexural and tensile strength 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. Slum cone test shows that with increase in GGBS content, the workability increases.
2. Decrease is observed in the workability, when adding GGBS and steel fibre in ordinary concrete.
3. Use of GGBS as cement replacement increases consistency.
4. Increment of GGBS and steel fiber content up to 25 % and 2.5 % given good result in terms of compressive strength, Tensile strength.
5. Increase in the steel fibers results in increasing the tensile strength and toughness of the composite
6. 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 increasing with fiber content.
7. 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.
8. This experimental investigation helps to know the properties and behaviour of steel fiber reinforced concrete.
9. 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.
10. The maximum values of compressive strength at 25 % GGBS and 2.5 % fiber are 24.46, 28.66 and 42.79 N/mm^2 at the age of 7, 14 and 28 days.
11. The maximum values of split tensile strength at 25 % GGBS and 2.5 % fiber are 8.95 N/mm^2. So the maximum percentage of the GGBS and steel fiber on the replacement of cement should be 25 % and 2.5 %.

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