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Effect of GGBS on Fiber Reinforced Concrete

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ABSTRACT

Ever since the term high-performance concrete was introduced into the industry, it had widely used in large- scale concrete construction that demands high strength, high flow ability, and high durability. A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfill all of the properties. So the different pozzolanic materials like Ground Granulated Blast furnace Slag (GGBS), which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce high performance concrete. So we have performed XRD tests on GGBS to know the variation of different constituent within it. Also it is very important to maintain the water cement ratio within the minimal range, for that we have to use the water reducing admixture i.e. super plasticizer, which plays an important role for the production of high performance concrete. So we herein the project have tested on Ground granulated blast furnace slag, to obtain the desired needs. Also X-ray diffraction test was conducted on GGBS used to analyze their content ingredients. We used synthetic fiber (i.e. Recron fiber) in different percentage i.e. 0.0%, 0.1%, 0.2%, 0.3% to that of total weight of concrete and casting was done. In our study it was used two types of cement, Portland slag cement and ordinary Portland cement. We prepared mortar, cubes, cylinder, prism and finally compressive test, splitting test, flexural test are conducted. Finally porosity and permeability test conducted. Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a large number of trial mixes are required to select the desired combination of materials that meets special performance.

Keywords : Ground Granulated Blast furnace Slag (GGBS); Recron Fiber; Portland Slag Cement; High Performance Concrete.

I. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementetious materials, water, aggregate and sometimes admixtures in required proportions.

As our aim is to develop concrete which does not only concern on the strength of concrete, it also having many other aspects to be satisfied like less porous, capillary absorption, durability. So for this we need to go for the addition of pozzolanic materials along with super plasticizer with having low water cement ratio. The use of GGBS is many, which is having good pozzolanic activity and is a good material for the production high performance concrete. Also now a days one of the great application in various structural field is fiber reinforced concrete, which is getting popularity because of its positive effect on various properties of concrete.

Earlier Researches

Oner A and Akyuz S (2007) studied on optimum level of ground granulated blast furnace slag (GGBS) on compressive strength of concrete. In their study GGBS was added according to the partial replacement method in all mixtures. A total of 32 mixtures were prepared in four groups according to their binder content. Eight mixes were prepared as control mixtures with 175, 210, 245 and 280 kg/m3 cement content in order to calculate the Bolomey and Feret coefficients (KB, KF). For each group 175, 210, 245 and 280 kg/m3 dosages were determined as initial dosages, which were obtained by removing 30 percent of the cement content of control concretes with 250, 300, 350, and 400 kg/m3 dosages. Test concretes were obtained by adding GGBS to concretes in an amount equivalent to approximately 0%, 15%, 30%, 50%, 70%, 90% and 110% of cement contents of control concretes with 250, 300, 350 and 400 kg/m3 dosages. All specimens were moist cured for 7, 14, 28, 63, 119, 180 and 365 days before compressive strength testing. The test results proved that the compressive strength of concrete mixtures containing GGBS increases as the amount of GGBS increase. After an optimum point, at around 55% of the total binder content, the addition of GGBS does not improve the compressive strength. This can be explained by the presence of unreacted GGBS, acting as a filler material in the paste.

Ganesh Babu K and Sree Rama Kumar V (2000) studied on efficiency of GGBS in Concrete. According to them the utilization of supplementary cementetious materials is well accepted because of the several improvements possible in the concrete composites and due to the overall economy. This method recognizes that the ``overall strength efficiency factor (k)" of the pozzolana is a combination of the two factors-the ``general efficiency factor (ke)" and the percentage efficiency factor (kp). The evaluations have shown that at 28days, the overall strength efficiency factor (k)" varied from 1.29 to 0.70 for percentage replacement levels varying from 10% to 80%. It was also seen that the overall strength efficiency factor (k) was an algebraic sum of a constant ``general efficiency factor (ke)," with a value of 0.9 at 28 days, and a percentage efficiency factor (kp), varying from +0.39 to -0.20, for the cement replacement levels varying from 10% to 80% studied.

Scope and Objective of present work: The objective of the present work is to develop concrete with good strength, less porous, less capillarity so that durability will be reached. For this purpose it requires the use of different pozzolanic materials like rice husk ash, ground granulated blast furnace slag, and GGBS along with fiber. So the experimental programme to be undertaken;

- ✓ To determine the mix proportion with GGBS with fiber to achieve the desire needs.
- ✓ To determine the water/ binder ratio, so that design mix having proper workability and strength.
- ✓ To investigate different basic properties of concrete such as compressive strength, splitting tensile strength, flexural strength etc. and comparing the results of different proportioning.

II. METHODS AND MATERIAL

1. Ground Granulated Blast Furnace Slag

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. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumino silicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportions varies.
The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The glass content of GGBS affects the hydraulic property, chemical composition determines the alkalinity of the slag and the structure of glass. The compressive strength of concrete varies with the fineness of GGBS.

Ground granulated blast furnace slag now a days mostly used in India. Recently for marine out fall work at Bandra, Mumbai. It has used to replace cement to about 70%. So it has become more popular now a day.

Chemical composition (%) of GGBS:

SiO_2	39.18
Al_2O_3	10.18
Fe_2O_3	2.02
CaO	32.82
MgO	8.52

Na_2O	1.14
K_2O	0.30

2. Super plasticizing Admixture

A substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture (HRWRA) is also referred as Super plasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. These can be added to concrete mix having a low- to-normal slump and water cement ratio to produce high slump flowing concrete. The effect of super plasticizers lasts only for 30to 60 minutes, depending on composition and dosage and is followed by rapid loss in workability.

One of the important factors that govern the issue water–cement ratio during the manufacture of concrete, lower the water-cement ratio lower will be the capillary pores and hence lower permeability and enhanced durability. Although Super plasticizer are essential to produce a truly high performance concrete (HPC) characterized by low water-cement ratio and workability level without high cement content. Concrete are being produced with w/c ratio of as low as 0.25 or even 0.20 enabled the production of highly durable high performance concrete. The workability also increases with an increase in the maximum size of aggregate. But smaller size aggregate provides larger surface area for bonding with the mortar matrix, which increases the compressive strength. For concrete with higher w/c ratio use of larger size aggregate is beneficial.

High range super plasticizer was used in all the concrete mixes to achieve good workability. Super plasticizers are added to reduce the water requirement by 15 to 20% without affecting the workability leading to a high strength and dense concrete. To achieve the uniform workability, the admixture dosage was adjusted without changing the unit water content. This ensured the identical W/C ratio for a particular cementetious content and the effect of pozzolanic material replacement can directly be studied on the various properties of concrete.

CEMENT:

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. There are different types of cement, out of that I have used two types i.e.,

• Ordinary Portland cement
• Portland slag cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three type, 33 grade, 43 grade, 53 grade. One of the important benefit is the faster rate of development of strength.

Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion and grinding the mixture to get a thorough and intimate mixture between the constituents. This type of cement can be used for all purposes just like OPC. It has lower heat of evolution and is more durable and can be used in mass concrete production.

3. Aggregate

Aggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

1. Fine aggregate
2. Coarse aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, whereas fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted. In case of close reinforcement 10mm size also used.

Recron Fiber:

Recron Fiber fill is India's only hollow Fiber specially designed for filling and insulation purpose. Made with technology from DuPont, USA, Recron Fiber fill adheres to world-class quality standards to provide maximum comfort, durability, and ease-of-use in a wide variety of applications like sleep products, garments and furniture. Reliance Industry Limited (RIL) has launched Recron 3s Fibers with the objective of improving the quality of plaster and concrete.

Application of RECRON 3s Fiber reinforced concrete used in construction. The thinner and stronger elements spread across entire section, when used in low dosage arrests cracking. RECRON 3s prevents the shrinkage cracks developed during curing making the structure/plaster/component inherently stronger.

Further when the loads imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly. Addition of RECRON 3s in concrete and plaster prevents/arrests cracking caused by volume change (expansion & contraction).

A cement structure free from such micro cracks prevents water or moisture from entering and migrating throughout the concrete. This in turn helps prevent the corrosion of steel used for primary reinforcement in the structure. This in turn improves longevity of the structure. The modulus of elasticity of RECRON 3s is high with respect to the modulus of elasticity of the concrete or mortar binder. The RECRON 3s Fibers help increase flexural strength. RECRON 3s Fibers are environmental friendly and non-hazardous. They easily disperse and separate in the mix.

Only 0.2-0.4% by cement RECRON 3s is sufficient for getting the above advantages. Thus it not only pays for itself, but results in net gain with reduced labour cost & improved properties. So we can briefly summarize the advantages of Recron 3s fiber as,

- Control cracking
- Increase flexibility
- Reduction in water permeability
- Reduction in rebound loss in concrete
- Safe and easy to use

Specification of Recron:

Density	1.5d
Cut length	6mm,12mm,24mm
Tensile strength	About 6000 kg/cm^2
Melting point	250^o C
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	Good

4. Experimental Investigation

GGBS is a non-metallic product essentially consists of silicates and alumino silicates of calcium and other bases. The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The granulated material when further

Ground to less than 45 micron will have specific surface of about 400-600 m^2/kg (Blaine). But here in our present study we have delved into the use of GGBS in different percentages in mortar testing, where we have used GGBS passing through 75 micron sieve. Here the specific surface of about 275-550 m^2/kg. We are going to use of GGBS as partial replacement of cement because of its advantages like lower energy cost, higher abrasion resistance, lower hydration heat evolution, higher later strength development.

Synthetic fiber i.e. Recron fiber is used in concrete for the production of fiber reinforced concrete. We are going to use Recron fiber in different percentage i.e., 0%, 0.1%, 0.2%, 0.3% to the weight of concrete and study the 7 days and 28 days compressive strength, splitting tensile and flexural strength of concrete to that of normal concrete with maintaining the water cement ratio in the range of 0.35-0.41. Then with different percentages of GGBS i.e., 10%, 20%, 30% fixing constant fiber percentage at 0.2% cubes, cylinders and

prisms were casted and tested to analyze the change in compressive, splitting tensile and flexural strength. We used two types of cement for our study i.e. Portland slag cement and ordinary Portland cement (53 grade). XRD test was being conducted to idealize the chemical composition GGBS. Finally Porosity and Capillary absorption test was conducted on different specimens to analyze the effect of GGBS on concrete.
Different material used in this study are given below for the strength evaluation of concrete using different pozzolanic material, fiber and super plasticizer.

Cement:

For the experiment following two types cements were used,
a. Portland Slag Cement
b. Ordinary Portland cement (53 grade)

The chemical composition and different properties are shown below. Fineness – 340 m^2/kg
Specific gravity- 2.96
Initial setting time - 120 min
Final setting time – 240 min

Properties of Portland slag cement:

Specific gravity	2.96
Initial setting time (min)	125
Final setting time (min)	235

Properties of Ordinary Portland cement:

Specific gravity	3.1
Initial setting time (min)	90
Final setting time (min)	190

Fine Aggregate:

In this study it was used the sand of Zone-II, known from the sieve analysis using different sieve sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ) adopting IS 383:1963.

Properties of Fine Aggregate:

Properties	Results Obtained
Specific Gravity	2.65
Water Absorption	0.6%
Fineness modulus	2.47

Coarse Aggregate:

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% of 10mm size and 40% of 20mm.

Properties of Coarse Aggregate:

Specific Gravity	2.67
Water Absorption	0.4%
Fineness modulus	4.01

Fiber:

In this project work it was used Recron fiber. It is a type of synthetic fiber. In different weight fraction (0.0%, 0.1%, 0.2%, 0.3%) to concrete it was used.

Ground granulated blast furnace slag (GGBS):

As pozzolanic activity greatly depends on fineness, so GGBS passing through 75 micron whose fineness of order of 275-550 m2/kg was used. Specific gravity test was conducted using Le-Chatelier apparatus and found to be 2.77. X-Ray diffraction test was conducted shown below.

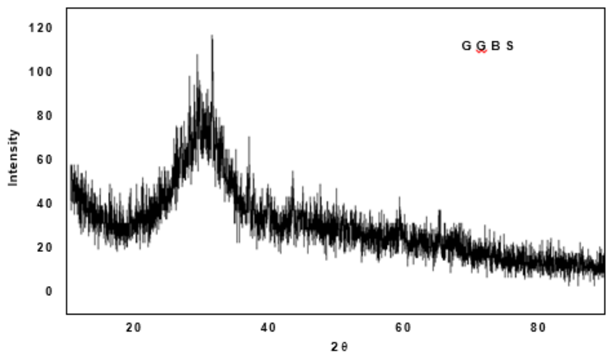


Figure 1. X-Ray Diffraction test of GGBS

III. RESULTS AND DISCUSSION OF XRD TEST:

XRD was conducted on GGBS, to idealize the different chemical composition of these pozzolanic material. Test was performed at an angle 45^0 with 2θ equal to 90^0 and different graphs are obtained, which were analyzed using "X-pert High Score" software.

In case of GGBS from the graph it is inculcated that compound purely in amorphous form. Here we got the formation of $Mg_2Al_2O_4$ corresponding to no. 74-1133 and Mg_2SiO_4 with no.74-1680.

EFFECT OF GGBS ON PROPERTIES OF CEMENT:

To know the properties of GGBS on mortar we performed different tests

- Consistency test
- Compressive strength

The amount of water required to produce a standard cement paste to resist a specified pressure is known as normal or standard consistency. In other word it is the limit of water required at which the cement paste resist the penetration of standard plunger (1 mm diameter) under a standard loading up to a distance of 5-7 mm from the base of Vicat apparatus. The consistency of cement depends on its type and fineness. More water is required in cement with higher fineness value. The water quantity was calculated by [(P/4) + 3] % of 800 gm. Consistency test was performed with both GGBS of different percentage content. That is GGBS with 0, 10, 20, 30, 40 %. Then mortars of standard size were casted with different percentage of GGBS (0%, 10%, 20%, 30%, 40%) with the replacement of cement. Portland slag cement and sand of zone- II was used in this experiment. Then compression test was conducted of mortars in Compression testing machine.

TEST RESULTS

Effect of GGBS in normal consistency of cement:

% of cement replaced by GGBS (%)	Consistency (%)
0	**31.0**
5	**32.0**
7.5	**33.0**
10	**34.5**
20	**36.5**

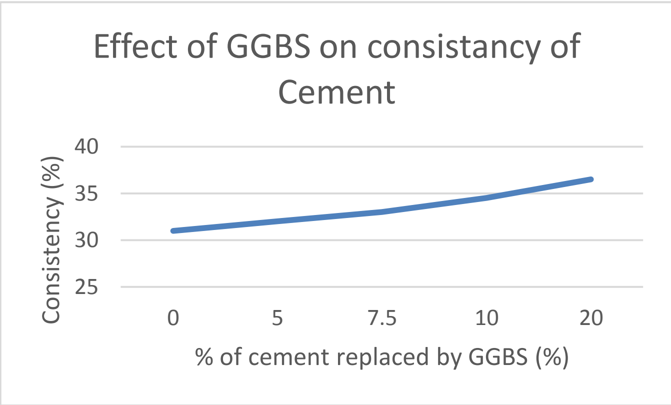


Figure 2. Effect of GGBS on Compressive strength of cement:

% of GGBS with cement replacement	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
5	13.52	28.63
7.5	15.117	30.85
10	11.23	17.65
20	4.74	7.46

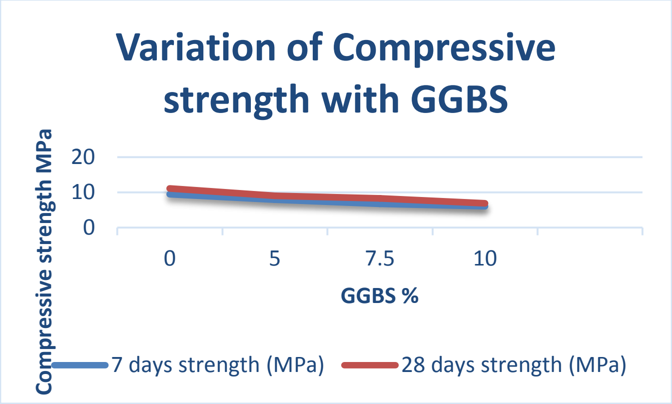


Figure 3. Compressive test on cube

Figure 4. Split Tensile test on cylinder

Figure 5. Flexural test on Beam

DISCUSSION:

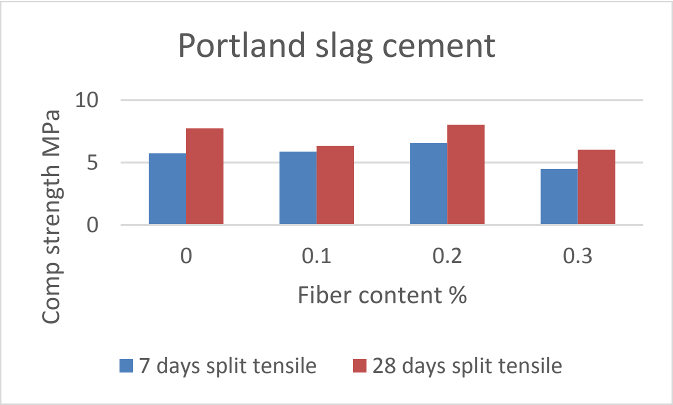
It is observed here that the consistency percentage is increasing as the percentage of GGBS increases as a cement replacement, But the change is not so abrupt so we can use the GGBS as upto 7.5% as partial replacement.

The variation of compressive strength of mortar mix with different proportion of GGBS partial replacement of cement is shown in fig. It was observed that 3 days and 7 days compressive strength reduces about 11.176 MPa to 4.74 MPa and 24.31 to 17.65 respectively, as GGBS percentage increases from 0 to 10%. If percentage of GGBS was further increased the compressive strength reduces greatly. Finally when the GGBS percentage increased to 20% the strength reduces by about 60% and 70% in 3 days and 7 days respectively of its initial values.

TEST RESULT:

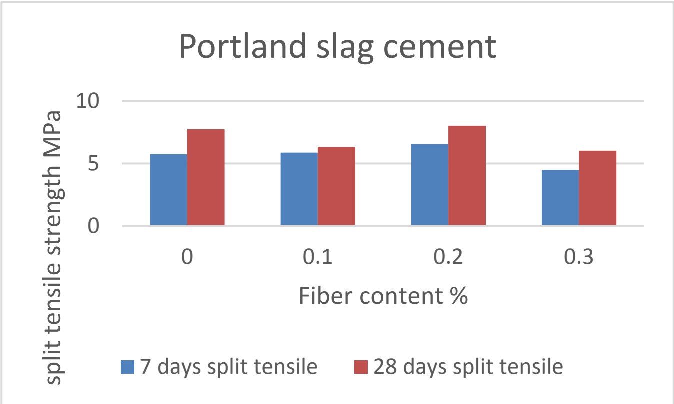
Effect of Recron fiber on Compressive strength using slag cement:

Fiber content (%)	**7 days compressive strength (N/mm^2)**	**28 days compressive strength (N/mm^2)**
0.0	**29.036**	**37.77**
0.1	**24.63**	**27.406**
0.2	**26.43**	**32.148**
0.3	**17.2**	**25.48**



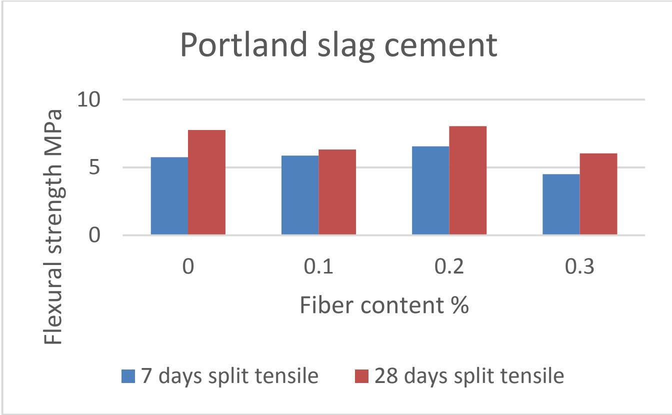
Effect of Recron fiber on Splitting Tensile Strength using slag:

Fiber content (%)	7 days split tensile strength (N/mm^2)	28 days split tensile strength (N/mm^2)
0.0	**2.523**	**2.873**
0.1	**2.12**	**2.452**
0.2	**2.569**	**3.018**
0.3	**1.533**	**2.280**



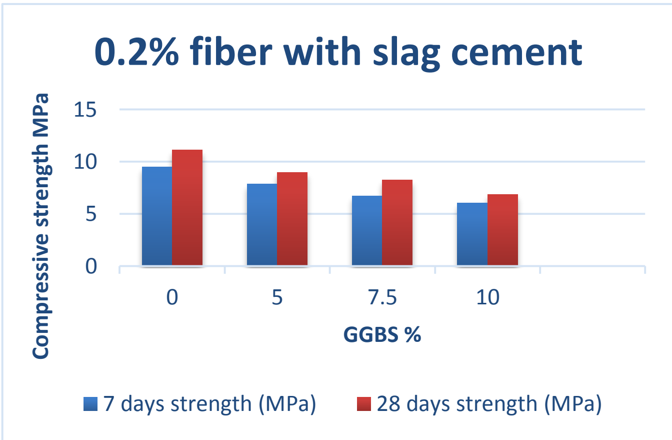
Effect of Recron fiber on Flexural Strength using slag cement:

Fiber content (%)	7 days Flexural strength (N/mm^2)	28 days Flexural strength (N/mm^2)
0.0	**5.750**	**7.75**
0.1	**5.875**	**6.33**
0.2	**6.560**	**8.04**
0.3	**4.501**	**6.04**



Effect of GGBS on Compressive strength with 0.2%fiber using slag cement:

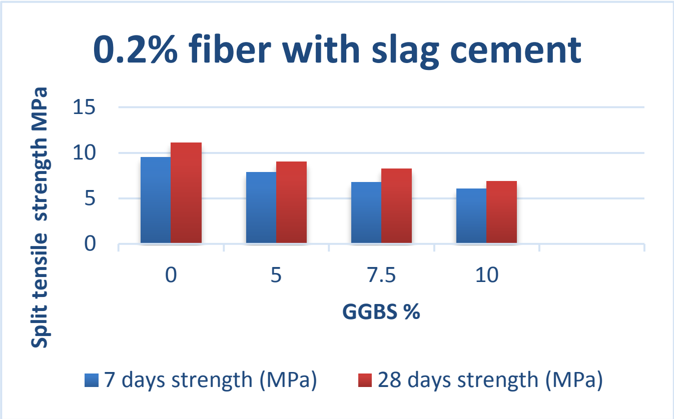
GGBS (%)	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
0	**26.43**	**32.148**
5	**23.55**	**30.813**
7.5	**26.07**	**34.814**
10	**21.778**	**29.03**



Effect of GGBS on Split Tensile strength with 0.2% fiber using slag cement:

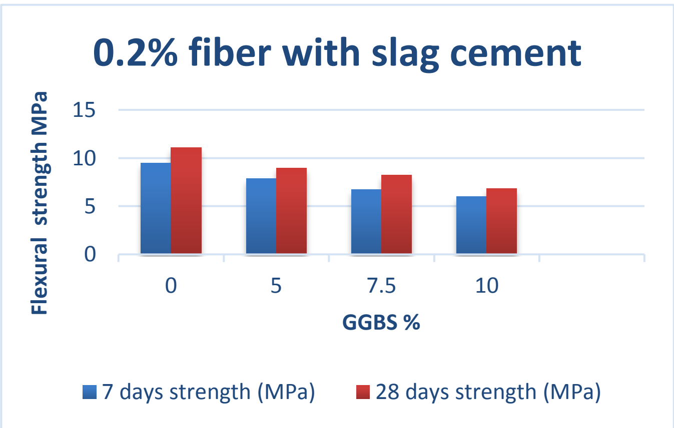
GGBS (%)	7 days Split Tensile strength (N/mm^2)	28 days Split Tensile strength (N/mm^2)
0	**2.569**	**3.018**

5	2.482	2.92
7.5	2.687	3.206
10	2.169	2.782



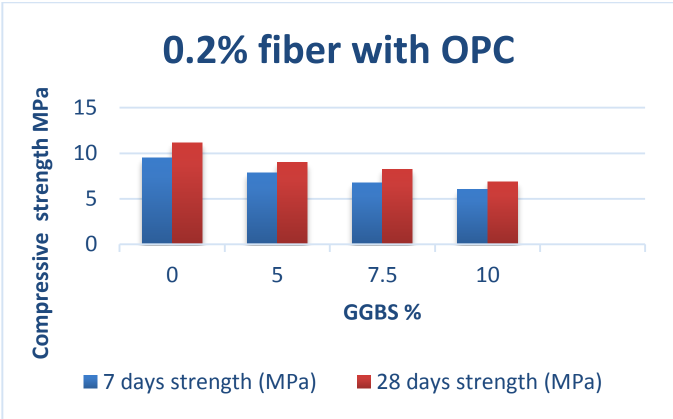
Effect of GGBS on Flexural strength with 0.2% fiber using slag cement:

GGBS (%)	7 days Flexural strength (N/mm^2)	28 days Flexural strength (N/mm^2)
0	6.56	8.04
5	6.50	8.00
7.5	6.625	8.458
10	6.04	7.875



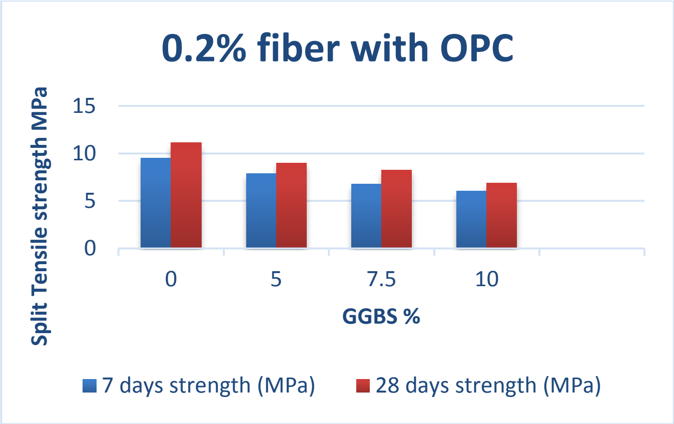
Effect of GGBS on Compressive strength with 0.2%fiber using OPC:

GGBS (%)	7 days Compressive strength (N/mm^2)	28 days Compressive strength (N/mm^2)
0	29.00	35.33
5	29.50	36.00
7.5	32.00	38.28
10	34.50	42.32



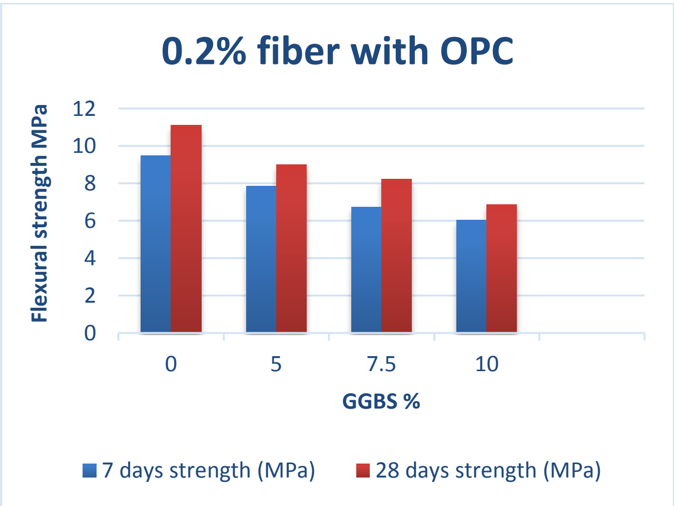
Effect of GGBS on Split Tensile strength with 0.2% fiber using OPC:

GGBS (%)	7 days Split Tensile strength (N/mm^2)	28 days Split Tensile strength (N/mm^2)
0	2.546	2.829
5	2.687	3.253
7.5	2.405	2.970
10	2.263	2.829



Effect of GGBS on Flexural strength with 0.2% fiber using OPC:

GGBS (%)	7 days Flexural strength (N/mm^2)	28 days Flexural strength (N/mm^2)
0	9.50	11.125
5	7.875	9.00
7.5	6.75	8.25
10	6.04	6.875



IV. CONCLUSION

In this present study with the stipulated time and laboratory set up an afford has been taken to enlighten the use of so called pozzolanic material like ground granulated blast furnace slag, rice husk and GGBS in fiber reinforced concrete in accordance to their proficiency. It was concluded that,

- Use of GGBS as cement replacement increases consistency. Although fineness greatly influenced on proper pozzolanic reaction still GGBS passing 75 micron sieve giving good strength of mortar. Using GGBS of 7.5% in Portland slag cement the strength is high.
- With the use of super plasticizer it possible to get a mix with low water to cement ratio to get the desired strength.
- In case of Portland slag cement with the use of Recron fiber, the 28 days compressive strength at 0.2% fiber content the result obtained is maximum. The 28 days splitting tensile and flexural strength also increases about 5% at 0.2% fiber content to that of normal concrete. Further if fiber percentage increases then it was seen a great loss in the strength.
- As the replacement of cement with different percentages with GGBS increases the consistency increases.
- With Portland slag cement keeping 0.2% Recron fiber constant and varying GGBS percentage the compressive, splitting tensile, flexural strength affected remarkably. Using 7.5% GGBS with 0.2% fiber percentage the 28 days compressive strength increases 7% more than concrete with 0.2% fiber only. 28days split tensile and flexural strength increases further, about 12% and 10% that of normal concrete.
- So it is concluded that 0.2% Recron fiber and 7.5% GGBS is the optimum combination to achieve the desired need.
- In case of OPC the compressive strength is increasing as the percentage of GGBS increases from 0-10% and 0.2% Recron fiber and it is about 20% more than strength of normal concrete with OPC.
- The splitting tensile strength increases about 15% at 5% GGBS and constant 0.2% Recron fiber, then decreases with increasing the GGBS percentage. Flexural strength is not giving good indication and goes on decreasing and it is about 40% decrement as the GGBS percentage increases to 30%.
- Ordinary Portland cement gives good compressive strength result as compared to Portland slag cement in case of mix with GGBS and 0.2% Recron.

V. SCOPE OF FURTHER WORK

The research work on pozzolanic materials and fiber along with pozzolanas is still limited. But it promises a great scope for future studies. Following aspects are considered for future study and investigation;

- Percentage and actual fineness of GGBS require as partial cement replacement for good strength development.
- Replacing cement with different percentage of GGBS to judge the optimum percentage of GGBS to be used to get better strength result.
- Research on Recron fiber and GGBS with greater fineness as a partial cement replacing material, by which we can minimize the cost and at the same time achieve the durability and strength for the production of High Performance Concrete.
- It requires a proper mixing proportions for the development of high strength, high performance concrete which may not be possible manually. So it needs some global optimization techniques to develop the desire result with greater accuracy and time saving.

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