An Experimental Study on Effect of Concrete Performance in Addition of GGBS and Partial Replacement of Cement by Glass Fiber

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Abstract: The aim of this study is to evaluate the performance of M35 grade of concrete in addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber. Ground-granulated blast-furnace slag is pozzolanic materials that can be utilized to produce highly durable concrete composites. In this study Ground-granulated blast-furnace slag has been used to OPC which varies from 5% to 10% at interval of 2.5% by total weight of OPC and similarly partial replacement of OPC (43 grade) by glass fiber which varies from 0% to 0.4% at interval of 0.1% by total weight of OPC. All mixes (trial mix, control mix and variation mix) were prepared for M35 grade of concrete. This study investigates the performance of concrete mixture in terms of slump, compressive strength for 7days and 28 days, Flexural strength of beam 28 days and Splitting tensile strength of Cylinder for 28 days respectively.

***Key Words**:- Concrete, Ground-granulated blast-furnace slag, Workability, CompressiveStrength, Flexural Strength, Splitting Tensile Strength*

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1. INTRODUCTION

Concrete is a mixture of cement, natural sand, coarse aggregate and water. Nowadays, the most concrete mixture contains supplementary cementitious material, which forms part of the cementitious component. These materials are by-products from other processes according to the industrial wastes. The benefits of SCMs are their ability to show cementitious property after replacement of certain amount of cement, thus cost reduces in using Portland cement. The fast growth in industrialization has resulted in tons and tons of by-product or waste materials, which can be used as SCMs such as Ground-granulated blast-furnace slag, fly ash, silica fume, steel slag etc. Further be noted that use of the by-products not only helps to utilize these waste materials but enhances the properties of concrete in fresh and hydrated states also.

2. LITERATURE REVIEW

Manju, Shanmuganathan, Sri Harish, Praveen (2019), studies to obtain the suitability of GGBS as replacement of OPC in concrete. The cement in the plain concrete mixes was directly replaced by the equal weights of 20%, 40% and 60% of GGBFS to obtain corresponding GGBFS based concrete. Concrete is a homogeneously mixed product of cement, fine aggregate, coarse aggregate and water. It found that by replacing 40% of cement with GGBS and steel fibre helped in enlighting the strength ofthe concrete substantially compared to Control concrete. The study concluded that GGBFS powder to provide an alternative source for natural cement. GGBFS to be used in concrete to replace the cement in different percentage of 20, 40, 60, 80 and 100% to be caste the specimen in cube and cylinder.

Gowmekha, Sabarija.A, Jagadesh (2018), investigated that the performance of concrete mixture containing variable percentages of GGBS and constant percentage of fly-ash(FA) in terms of fresh state characteristics like workability, hardened properties like compressive strength, split tensile strength, flexural strength, elastic modulus and absorption characteristics like water absorption and porosity. Result show that concrete containing GGBS and FA as partial replacement of cement showed improved workability, strength properties and durability characteristics.

P. Akshaya Raj (2018),studied for fibre content on M-25 grade concrete. M-Sand was also used as Fine aggregate in concrete, as an alternative way to reduce the depletion of River sand. Four different volumes of glass fibre were added 0.3%, 0.6%, 0.9% 1.2%. The properties of Fresh concrete are influenced by slump flow, J-Ring test, L-Box test, U-Box test, V-Funnel test. After the process of curing the compressive strength is conducted on hardened concrete as 7days and 28 test on Compressive testing machine (CTM). Due to the addition of Glass fibre into SCC the workability reduces, to increase the workability TECHMIX-550 is used as Super plasticizer.

Er. Arvind Singh Gaur, Er. Sachin Kumar (2017), appraised the performance of partial replacement of cement (OPC- 43 grade) with Ground-granulated blast- furnace slag and Fine aggregate by Marble slurry a mineral admixture in concrete. GGBS is achieved by appeasingmelted iron slag in water or steam, to produce a glassy, granular product that is then dried and ground into the fine powder. And Marble slurry is a waste product from marble industries constitutes one of the environmental problems all over world. In this invetigation, partial replacement of OPC (43-grade) by GGBS up to 20% by total weight of OPC and Fine aggregates up to 40% by Marble slurry. This study investigates the performance of concrete mixture in terms of compressive strength of cube, flexural strength of beam and splitting strength of cylinder for 7 days and 28 days respectively.

Niya Susan Varghese And Arya Aravind (2017), evaluate the mechanical properties of GGBFS as partial cement replacement in micro and macro polypropylene fibre reinforced concrete. Cement replaced with 40% GGBFS with 1% micro polypropylene fibre and 2% macro polypropylene fibre shows higher compressive strength. Bond strength of various mixes was determined by using pullout test.

V. Vinod, B. Susheel and K. Mahindra (2017), studied to investigate some material which can be effective in supporting cement when added along with it shows similar characteristics. GGBS is a leftovermaterial, which is required to be disposed. Instead, it can be used as a supporting material to cement in certain quantities to reduce the amount of cement in constructions in order to cut down the contrary effects on the environment. The source objective is to study the strength properties of concrete by partially replacing cement with GGBS. Concrete testing cubes were prepared by replacing the cement with GGBS in four different proportions (5%, 10%, 15% and 20%). The concrete cubes casted with the above proportions andtested for the compressive strength and the values obtained were compared with those of control specimens at the end of 7, 14 and 28 day curing periods.

The Maximum increment in strength was found when cement was replaced by GGBS by 15%. Hence there is a huge scope for exploration of other materials, which can act as replacement for the cement.

Kumar Shantveerayya and Vikas Nikkam (2016), Glass fibre reinforced concrete, i.e, GFRC concrete is one which is manufactured by adding glass fibre to the nominal concrete with partial replacement of OPC by GGBS in order to incorporate physical properties to the concrete. GFRC is a type of concrete in which glass fibres are used as reinforcement instead of steel. Since the fibres cannot rust like steel, there is no need for a protective concrete cover thickness to prevent rusting. Concrete of grade M25 was used with the addition of glass fibreof 0.33% and 0.67% by weight of concrete with partial replacement of GGBS in 15%, 30%,45% and 60% by weight of cementitious material. The cubes and cylinders were casted to test compressive and split tensile strength of concrete at 3days, 7days and 28 days of curing. The study concluded that the effective percentage of partial replacement for 0.33% of glass fibre is 45% for both compressive strength and split tensile strength. The effective percentage of cement replacement for 0.67% glass fibre is 30% and the workability of concrete increases by addition of GGBS but the concrete shows reduction of workability due to adding glass fibre.

3. EXPERIMENTAL PROGRAM

Concrete is a composite material which is prepared with mix of cement, fine aggregate, coarse aggregate and water. It can be widely used for any type of structure as per choice, demand and percentage constituents of concrete can be changed as per load and strength requirement by infrastructure. Concrete is economical as compared to steel structure and it has low cost of maintenance also as well as easy mechanism for work.

Aggregate is amultifarious material that repals compressive stress and brings bulk to the compound material. For effective filling, aggregate should be much smaller than the finished item, but have a wide variety of sizes. There are mainly two type of aggregate, which used for this study, are given as Coarse Aggregate and Fine Aggregate

3.1. COARSE AGGREGATE

The aggregate most of which are retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification.
According to size, coarse aggregate is designated as graded aggregate in nominal size i.e. 40 mm, 20 mm, 16 mm and 12.5 and 10 mm etc. For an example - a graded aggregate of nominal size 20 mm means an aggregate most of which passes 20 mm IS sieve.

Table 3.1 Properties of Coarse Aggregate 10mm & 20mm

Properties	Coarse Aggregate	
	10mm	20mm
Density (OD)	1352 kg/m3	1476 kg/m3
Density (SSD)	1478 kg/m3	1560 kg/m3
Bulk Density (Dry)	1525 kg/m3	1481kg/m3
Sp. Gravity (OD)	2.63	2.62
Sp. Gravity (SSD)	2.65	2.65
Water Absorption	0.46%	0.46%

3.2. FINE AGGERGATE

Fine Aggregates are those most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as: According to size the fine aggregate may be described as coarse sand, medium sand and fine sand. IS specifications classify fine aggregates into four types according to its grading from grading Zone-1 to grading Zone-4. These grading zones classified as per percentage passing material from various sieves and there are mainly four zones and they all have different passing percentage.

Table 3.2 Properties of Fine Aggregate

Properties	Natural fine aggregate
Density (OD)	1625 kg/m3
Density (SSD)	1675 kg/m3
Bulk Density (Dry)	1625 kg/m3
Bulk Density (SSD)	1675 kg/m3
Sp. Gravity (OD)	2.63

Sp. Gravity (SSD)	2.65
Water Absorption	1.15%

3.3. CEMENT

A cement is a constituent that sets, hardens and can bind other materials together. Characterize cements used in construction as hydraulic or non-hydraulic, liable upon the ability of the cement to be used in the presence of water.

Table 3.3 Properties of Cement (OPC grade-43)

Chemical Composition	Value
CaO	62%-67%
SiO2	17% - 25%
Al2O3	3% - 8%
Fe2O3	3%-4%
MgO	0.1%-3%
SO3	1%-3%
Na2O	0%-0.5%
Gypsum (CaSO4.2H2O)	2.50%
Specific Gravity	3.15

3.4. GROUND-GRANULATED BLAST-FURNACE SLAG

Ground-granulated blast-furnace slag is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation.

Table 3.4 Physical Properties of Ground-granulated blast-furnace slag

Physical Properties	Range
Bulk Density	750-850 kg/m^3
Surface Area	8000cm^2/gm
Particle Shape	Irregular
Particle Size	N/A
d50	<7 micron
d95	<20 micron
Specific Gravity	2.9

Table 3.5 Chemical Properties of Ground-granulated blast-furnace slag

Chemical Properties	Composition %
CaO	30-34
Al2O3	18-25
Fe2O3	0.8-3.0
SO3	0.1-0.4
MgO	6-10
SiO2	30-36

3.5. GLASS FIBER

Glass wool, which is usually known as “fiberglass” today, however, was designed in 1938 by Russell Games Slayter of Owens-Corning as a substantial to be used as insulation. It is sold under the trade name Fiberglas, which has become a genericized trademark. Glass fiber also called fiber glass. The material is made from extremely fine fibers of glass. Fiberglass is a lightweight, enormously strong, and strong material.

Table 3.6 Properties of Glass Fiber

Fiber	Density t/m^3	Tensile strength IN(M pa)	No of fiber (million /kg)
AR	2.6	1700	220

3.6. CHEMICAL ADMIXTURE

Chemical admixtures are known as the constituents in concrete other than ordinary portland cement, water, and aggregate that further added to the mix instantaneously before or during mixing. There are various type of chemical admixture which are used in construction and they are retarding admixture, accelerating admixture, water reducing admixture, air-entraining admixture, Superplasticizing admixture and retarding superplasticizing admixture.

Table 3.7 Properties of Chemical Admixture

Properties	Sulphonated Napthalene Formaldehyde (Value)
Type of admixture	Super plasticizer chloride free, as per ASTM C 494 & IS: 9103
SP.GRAVITY@27ºC	1.20 +/- 0.04
DRY MATERIAL %	41- 45 %
CHLORIDE %	NIL
ALKALIES	NIL
ASH CONTENT	10.00 - 14.00%
PH	7-9
COLOUR	Faint Black Brown Liquid

3.7. SIEVE ANALYSIS:

3.7.1. FINE AGGREGATE GRADING

As per IS-383:1970,Banas Sand of zone - II was recommended for concrete mix.The Sieves recommended for Gradation of Banas Sand are 10mm, 4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron and 150 micron.

Table 3.8 Sieve Analysis of Fine Aggregate (IS 383/2386)

Sieve Size	Retained (gm)	% Retained weight	Cumulative % Retained	Cumulative % Passing	Limit as per IS 383
10 mm	0	0	0	100	100
4.75 mm	11.5	1.15	1.15	98.85	90-100
2.36 mm	17	1.7	2.85	97.15	75-100
1.18 mm	73.5	7.35	10.2	89.8	55-90
600 micron	507.5	50.75	60.95	39.05	35-59
300 micron	315.5	31.5	92.45	7.55	8.0-30
150 micron	66	6.6	99.5	0.5	0-10
PAN micron	8.75	0.875			
Total	1000	100	267.1		

Fineness Modulus = 267.10/100 = 2.67

3.7.2. COARSE AGGREGATE GRADING (10MM)

As per IS-383:1970,The Sieves recommended for gradation of gunawata coarse aggregate are 12.5mm, 10mm,4.75mm and 2.36mm.

Table 3.9 Sieve Analysis of 10 mm Aggregate (IS 383/2386)

Sieve Size	Retained (gm)	% Retained weight	Cumulative % Retained	Cumulative % Passing	Limit as per IS 383
12.5 mm	0	0	0	100	100
10 mm	40.5	2.03	2.03	97.98	85-100
4.75 mm	1561	78.05	80.08	19.93	0-20
2.36 mm	298.5	14.93	95	5	0-5
1.18 mm	100	5	100	0	0
600 micron	0	0	100	0	0
300 micron	0	0	100	0	0
150 micron	0	0	100	0	0
PAN	0	0			
Total	2000	100	577.1		

Fineness Modulus = 566.96/100 = 5.67

3.7.3. COARSE AGGREGATE GRADING (20MM)

As per IS-383:1970,The Sieves recommended for gradation of gunawata coarse aggregate are 40mm, 20mm, 10mm, and 4.75mm.

Table 3.10 Sieve Analysis of 20 mm Aggregate (IS 383/2386)

Sieve Size	Retained (gm)	% Retained weight	Cumulative % Retained	Cumulative % Passing	Limit as per IS 383
40 mm	0	0	0	100	100
20 mm	103.5	5.18	5.18	94.83	85-100
10 mm	1523	76.15	81.33	18.68	0-20
4.75 mm	352	17.6	98.93	1.07	0-5
2.36 mm	21.5	1.08	100	0	0
1.18 mm	0	0	100	0	0
600 micron	0	0	100	0	0
300 micron	0	0	100	0	0
150 micron	0	0	100	0	0
PAN	0	0			
Total	2000	100	685.43		

Fineness Modulus = 754.58/100 = 7.58

3.8. CONTROL MIX

Control mix was designed as per IS 10262:2009 specification and recommendation are given below

Table 3.11 Control Mix Proportion for M35 (for 1 cum of concrete)

S. No.	Materials	Weight (Kg/m3)
1	Cement (OPC-43)	410
2	Coarse Aggregate (20mm)	708
3	Coarse Aggregate (10mm)	477
4	Fine Aggregate	669
5	Water	168
6	Admixture @ 1% of cement	4.10
7	W/C Ratio	0.41

3.8.1. PROPORTION OF GROUND-GRANULATED BLAST-FURNACE SLAG AND GLASS FIBER WITH CONTROL MIX

In this blend of control mix, two variations had been made with cement. First one was to add few percentage of Ground-granulated blast-furnace slag to cement which varies from 0% to 25% at interval of 5% and second one was to replace few percentage of cement with Ground-granulated blast-furnace slag which varies from 0% to 25% at interval of 5% for both concrete mixes of M35.

Table 3.12 Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber into OPC for M35 grade of concrete.

S. No.	Mix Name	Cement (Kg)	GGBS (Kg)	GF (Kg)	Coarse Aggregate (Kg)		Fine Aggregate (Kg)	Water (Kg)	Admixture (Kg)
					20 mm	10 mm			
1	OPC+GGBS+GF (100+0+0)	410	0	0	708	477	669	167	4.1
2	OPC+GGBS+GF (99.9+2.5+0.1)	410	10.25	0.41	708	477	669	167	4.1
3	OPC+GGBS+GF (99.8+5+0.2)	409	20.5	0.82	708	477	669	167	4.1
4	OPC+GGBS+GF (99.7+7.5+0.3)	409	30.75	1.23	708	477	669	167	4.1
5	OPC+GGBS+GF (99.6+10+0.4)	408	41	1.64	708	477	669	167	4.1

4. TESTING OF CONCRETE

Following Test adopted for testing of concrete.

- Slump Test
- Compressive Strength Test
- Flexural Strength Test
- Spliting Tensile Strength Test

4.1. SLUMP TEST

Slump testing procedure was conducted as per IS 1191:1959. In this test The mould was being placed on a smooth, horizontal, rigid and non-absorbent surface, such as a carefully levelled metal plate, the mould being firmly held in place while it is being filled.

4.2. COMPRESSIVE STRENGTH TEST

IS Code 516:1959 use for method of tests for compressive strength of concrete. The size of specimens 150mm x 150mm x 150mm. The specimens were tested after deep curing for 7 days and 28 days.

Compressive strength = P/A (Unit = N/mm2 or MPa)
Where: P = Load
A = Area of Specimen

4.3. FLEXURAL STRENGTH TEST

IS Code 516:1959 use for method of tests for flexural strength of concrete The size of beam 700mm x 150mm x 150mm.The specimens were tested after deep curing for 28 days. The central point loading method was used for this testing.
Flexural Strength = 3PL/2bd2 = 3PL/2d3 (b=d,due to size of b and d are equal)
(Unit = N/mm2 or MPa)

Where, P = Load,
L = Distance From Centre of Two Support,
b = Depth of Specimen,
d = Width of Specimen

4.4. SPLITTING TENSILE STRENGTH TEST

IS Code 5816:1999 use for method of test splitting tensile strength of concrete.The size of 300 mm(length) x 150mm(diameter).The specimens were tested after deep curing for 28 days.
Splitting Tensile Strength = 2P/πld (Unit = N/mm2 or MPa)

Where: P= Load ,
l= Length of Cylinder ,
d = Diameter of Cylinder

5. RESULTS AND ANALYSIS

There have been various mixes of different type i.e. two variations with cement had been made. First one was to add few percentage of Ground-granulated blast-furnace slag to cement which varies from 0% to 10% at interval of 2.5% and second one was to replace few percentage of cement with glass fiber which varies from 0% to 0.4% at interval of 0.1% for concrete mix of M35 grade. Tests had been conducted for result of slump, density,compressive strength, flexural strength & splitting tensile strength

5.1. RESULT OF FRESH CONCRETE

5.1.1 WORKABILITY (SLUMP) TEST RESULTS

Workability shows the behavior of the fresh concrete during time of mixing, handling, delivery and placement at the point of placement of concrete and then at time of

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compaction and finishing of the surface. It is a measurement for the deformability of the fresh concrete. Slump of all mixes are taken and shown in tabulated form and graphical form. Design is done on the basis of slump 100mm-125mm and the slump was found 125 mm for M35 grade concrete. Many variations have been identified while checking for slump of different concrete mixes. There are several tabulations and graphs are given as follows:

Table 5.1 Slump comparison at Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber into OPC for M35 grade of concrete.

S. No.	Percentage of cement + Ground granular blast-furnace slag + Glass fibre	Slump (mm)
1	OPC+GGBS+GF (100+0+0)	125
2	OPC+GGBS+GF (99.9+2.5+0.1)	133
3	OPC+GGBS+GF (99.8+5+0.2)	146
4	OPC+GGBS+GF (99.7+7.5+0.3)	144
5	OPC+GGBS+GF (99.6+10+0.4)	139

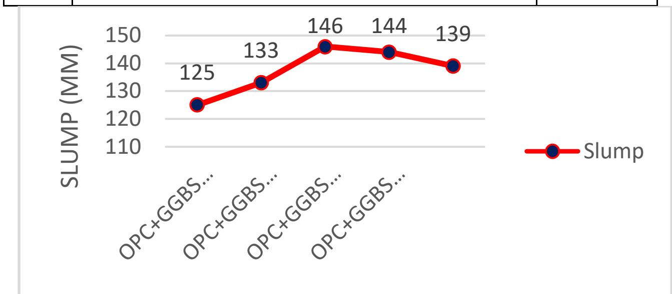

Fig. 5.1 Graphical representation of slump comparison at Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber into OPC for M35 grade of concrete.

5.2. RESULT OF HARDENED CONCRETE

Results of hardened concrete for density test, compressive strength test, flexural strength test and splitting tensile strength test were conducted which are given as under

5.2.1 DENSITY

The density of specimen was determined before testing the specimen of cube, beam & cylinder and before determination of density of specimen; surface of specimen was cleaned and swept with clean cotton cloths.Average weight of Cube, Beam and Cylinder are 8.415Kg (for 7 days) & 8.51 Kg (for 28 days), 12.85 Kg (for 28 days) and 39.37 Kg (for 28 days) respectively.

Table 5.2 Density comparison of M35 grade hardened concretein Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

S. No.	Percentage of cement + Ground granular blast-furnace slag + Glass fibre	Density of Hardened Conc. (Kg/m3)
1	OPC+GGBS+GF (100+0+0)	2432
2	OPC+GGBS+GF (99.9+2.5+0.1)	2438
3	OPC+GGBS+GF (99.8+5+0.2)	2443
4	OPC+GGBS+GF (99.7+7.5+0.3)	2451
5	OPC+GGBS+GF (99.6+10+0.4)	2457

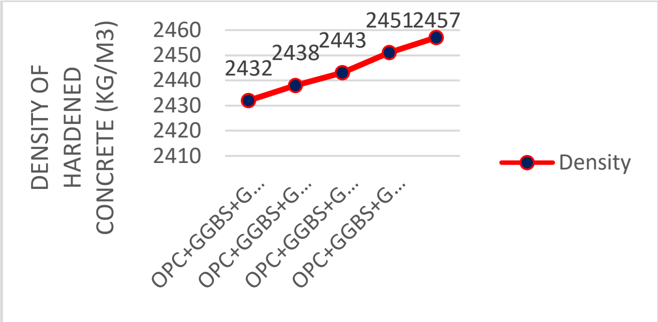

Fig. 5.2 Graphical representation of density comparison in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber into OPC for M35 grade of concrete.

5.2.2. COMPRESSIVE STRENGTH

The compressive strength of GGBS mixes was measured with cube specimen of size 150mm(length) x 150mm(width) x 150mm(depth).The specimens were tested after curing for 7 days and 28 days fully immersed in water tank as per IS 516:1959 for method of tests for strength of concrete.

Table 5.3 Compressive strength comparison (7 days and 28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

S. No.	Percentage of cement + Ground granular blast-furnace slag + Glass fibre	7 Days (N/mm2)	28 Days (N/mm2)
1	OPC+GGBS+GF (100+0+0)	29.33	43.26
2	OPC+GGBS+GF (99.9+2.5+0.1)	29.61	43.58
3	OPC+GGBS+GF (99.8+5+0.2)	29.75	43.77
4	OPC+GGBS+GF (99.7+7.5+0.3)	29.60	43.54
5	OPC+GGBS+GF (99.6+10+0.4)	29.36	43.27

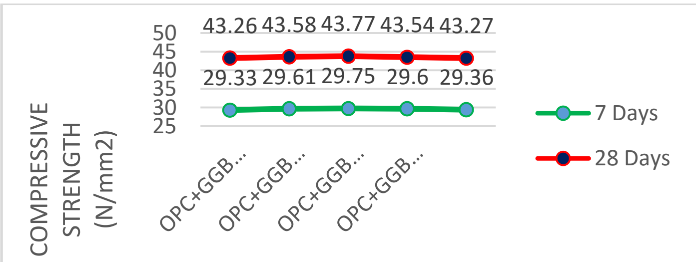

Fig 5.3 Graphical representation of compressive strength ccomparison (7 days and 28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber into OPC for M35 grade of concrete.

5.2.3. FLEXURAL STRENGTH

The Flexural strength of GGBS mixes was measured with beam specimen of size 700mm(length) x 150mm(width) x 150mm(depth).The specimens were tested after curing for 28 days fully immersed in water tank as per IS 516:1959 for method of tests for strength of concrete. The centre point loading method was used for this testing.

Table 5.4 Flexural strength comparison (28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

S. No.	Percentage of cement + Ground granular blast-furnace slag + Glass fibre	28 Days (N/mm2)
1	OPC+GGBS+GF (100+0+0)	5.10
2	OPC+GGBS+GF (99.9+2.5+0.1)	5.28
3	OPC+GGBS+GF (99.8+5+0.2)	5.39
4	OPC+GGBS+GF (99.7+7.5+0.3)	5.55
5	OPC+GGBS+GF (99.6+10+0.4)	5.67

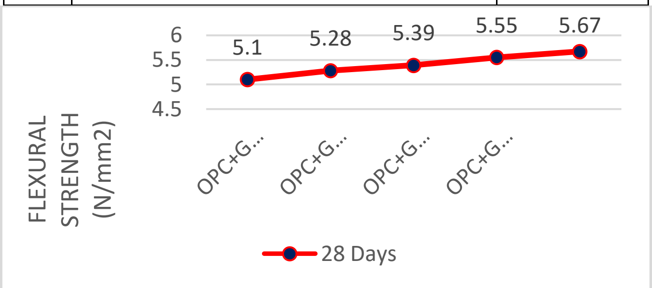

Fig 5.4 Graphical Representation of comparison (28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

5.2.4. SPLITTING TESNILE STRENGTH

The split tensile strength of GGBS mixes was measured with cylinder specimen of size 300mm(length) x 150mm(diameter).The specimens were tested after curing for 28 days fully immersed in water tank as per IS 5816:1999 for method of test splitting tensile strength of concrete.

Table 5.5 Splitting tensile strength comparison (28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

S. No.	Percentage of cement + Ground granular blast-furnace slag + Glass fibre	28 Days (N/mm2)
1	OPC+GGBS+GF (100+0+0)	2.95
2	OPC+GGBS+GF (99.9+2.5+0.1)	2.99
3	OPC+GGBS+GF (99.8+5+0.2)	3.05
4	OPC+GGBS+GF (99.7+7.5+0.3)	3.14
5	OPC+GGBS+GF (99.6+10+0.4)	3.27

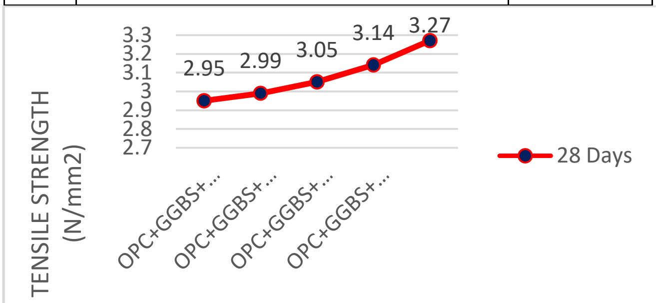

Fig 5.5 Graphical Representation of comparison of splitting tensile strength comparison (28 days) of M35 grade concrete in Addition of Ground-granulated blast-furnace slag and partial replacement of cement by glass fiber.

6. CONCLUSIONS

- Slump increased initially upto when addition of Ground granular blast furnace and OPC replacement by glass fiber increased upto 5% and 0.2% respectively. But the started decreasing as additional alterations made in the same ratio.
- Density increased gradually when addition of Ground granular blast furnace and OPC replacement by glass fiber increased upto 10% and 0.4% respectively.
- Compressive Strength increased initially upto when addition of Ground granular blast furnace and OPC replacement by glass fiber increased upto 5% and 0.2% respectively. However, it started decreasing as additional alterations made in the same ratio and finally achieved similar values as starting.
- Flexural strength of concrete increased constantly upto 11% when Ground granulated blast-furnace slag was additionally placed and OPC partial replaced by glass fiber.
- Tensile strength of concrete increased constantly upto 10.8% when Ground granulated blast-furnace slag was additionally placed and OPC partial replaced by glass fiber.
- Due to partial replacement of OPC by glass fiber, tensile strength increased 32% having 3.27 N/mm2. Initially it increased slowly but as partial replacement and addition GGBS ratio increased, tensile strength increased immediately.

7. REFERENCES

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