An Experimental Study on the Properties of Glass Fibre Reinforced and Ground Granulated Blast Furnace Slag Concrete

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***Abstract**:*

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 few additional properties to the concrete. GFRC is a concrete that uses glass fibres for 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. From this work it is concluded that the effective percentage of replacement for 0.33% of glass fibre is 45% for both compressive strength and split tensile strength. The effective percentage of replacement for 0.67% glass fibre is 30%.

Keywords –*Cement, coarse aggregate, compressive strength,Glass fibre reinforced concrete, split tensile strength*

I. INTRODUCTION

Fresh concrete or plastic concrete is freshly mixed material which can be moulded in any shape hardens into a rock like mass known as concrete. The utility and elegance as well as durability of concrete structures built during first half of the last century was with OPC and reinforcement. The availability of constant material of concrete and knowledge that virtually any combination of constituent leads to mass of concrete has great contempt. The hardening is caused by chemical reaction between water and cement which continues for a long time, consequently concrete grows stronger with age. The harden concrete may be consider as synthetic stone in which voids of larger particle (coarse aggregate) filled by smaller particle (fine aggregate) and voids of fine aggregate are filled by cement.

In a concrete mix cementing material and water from a paste called cement water paste which in addition to filling the voids of fine aggregate, coats the surface of fine and coarse aggregates and binds them together it cures, thereby cementing the particles of aggregates together in a compact mass. The strength, durability and other characteristics of concrete depends on the properties of mix ingredients on the properties of mix, the method of compaction andother control during placing,compaction and curing. The advances in concrete technology have paved theway to make the best use of locally available materials by judicious mix proportioning and proper workmanship so as to produce concrete satisfying performance requirement. The key to generate a strong durable and uniform concrete i.e high performance concrete lies in the careful control of its basic process composition.

M ADAMS JOE et .al(1)The present paper focuses on M40 concrete with various percentage cement with GGBS adding 1% of steel fibre considering cost of construction drawn attention of investigators to explore new replacement of concrete. Ten mixes studied using conplast SP 430 cubes ,cylinder, prism were tested for compressive split tensile and flexure with replacement level 10 % ,20%,30% ,40% and 50% . Is found that 40% replacement of cement with GGBS helped in improving strength of concrete.

MARIA RAJESHet.al (2)This paper focuses on the use of ground granulated blast furnace slag as partial replacement of OPC.GGBS is obtained from steel industry is a glassy granular material which is then dried and ground into fine powder. It increases the long term strength, durability and resistance to attack in peaty/acidic environment. From the experimental results it was found that the compressive strength of mix 1 (30%GGBS) was found to be 52.5Mpa for 28 days after hot curing .Compressive strength of mix 2 (40% GGBS) was found to be 58.5Mpa for 28 days after hot curing. The compressive strength of mix 3(50% GGBS) was found to be 55.5Mpa for 28 days after hot curing. From the experimental results it was found that the split tensile strength of mix 1 (30%GGBS) was found to be 10.2Mpa for 28 days after hot curing .Compressive strength of mix 2 (40% GGBS) was found to be 11.5Mpa for 28 days after hot curing. The compressive strength of mix 3(50% GGBS) was found to be 10.8Mpa for 28 days after hot curing. From the experimental results it was found that the flexural strength of mix 1 (30%GGBS)was found to be 12.5Mpa for 28 days after hot curing .Compressive strength of mix 2 (40% GGBS) was found to be 13.5Mpa for 28 days after hot curing. The compressive strength of mix 3(50% GGBS) was found to be 12.5Mpa for 28 days after hot curing.

NIKHIL. A. GADGE et.al (3)This paper focuses on the compressive strength performance of the blended concrete containing different percentage of slag and steel fibre as partial replacement of OPC.The cement in concrete is replaced accordinglywith the percentage of 10%, 20%, 30% and 40% by weight of slag and 0.5%,1% ,1.5%,2% by weight of steel fibre. Concrete cubes are tested at the age of 3,7 and 28 days of curing .Finally the strength performance of slag blended fibre reinforced concrete is compared with the performance of conventional concrete. From the experimental investigation it has been observed that, the optimum replacement of GGBFS powder to cement and steel fibre without changing much the compressive strength is 20% and 1.5% respectively for M20, M30 and M40 grade respectively.

RONAK PATELet.al(4)The present research is based on the use of glass fibre in the conventional concrete. Glass fibre reinforced concrete (GFRC) is a material made up of cementious matrix composed of cement , sand ,water and admixture, in which short length glass fibre are dispersed. The addition of glass fibre into the concrete mixture marginally improves compressive strength at 28 days. It is observed from the experimental results, that compressive strength of concrete splitting strength of concrete, flexural strength of concrete with the addition of percentage of glass fibre. The 0.1% of addition of glass fibre into the concrete shows better results in mechanical properties and durability.

XIANGMING et.al(5)From this study it has been found that partial replacing OPC by slag PFS or GGBS resulted in longer setting time but better workability with GGBS.As the replacement level increases the setting of GGBS paste further delayed but workability of concrete was enhanced . As the replacement level further increased, it developed lower strength than PC concrete up to 21days. Than it managed to gain higher splitting tensile strength than PC concrete at the replacement levels up to 70% by mass at 28 days .GGBS can reduce drying shrinkage and the reduction effects became more significant as replacement level increased with GGBS performing better.

II. EXPERIMENTAL INVESTIGATION

Experimental work is done in to achieve two major objectives to investigate the improvement in compressive strength of glass fiber reinforced GGBS concrete and to investigate the cracking strength and reserve strength of concrete.

A. Materials Used

1) Cement

Cement used is ordinary Portland cement (OPC 53 grade) as a binding material As per IS 12269-1970. The preliminary tests like normal consistency (amount of water to be added), specific gravity, initial and final setting times and compressive are conducted. Sieve analysis for the grading curve and fineness test were conducted as well as the determination of its moisture and with specific gravity(2.86)

Table:1 Test Results on Cement

Specific Gravity	2.86
Normal Consistency	33%
Initial Setting Time	40 min
Final Setting Time	10 hours
Fineness	5%
Compressive Strength (1:3)	44

2) Coarse Arregate

The crushed granite, passing through 20 mm and retained on 4.75mm sieve, some preliminary test are conducted as per IS 383-1978.

Table:2 Test Results on Coarse Aggregate

Specific Gravity	2.87
Fineness Modulus	0.5%
Water Absorption	1%

3) Fine Aggregate

The river sand with zone II, passing through 4.75mm sieve as per IS 383-1978

Table:3 Test Results on Fine Aggregate

Specific Gravity	2.57
Moisture Content	6.01%
Surface Texture	Smooth
Shape	Diamond
Zone	II

4) Water

Portable water as per IS 456-2000

5) Glass fibers

In the present work we used glass fiber of density 2680kg/m^3. We added glass fiber 0.33% & 0.67% of volume of concrete.

B. Selection of Mix Proportions

Selection of Water-Cement Ratio

Different cements, supplementary cementitious materials and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water-cement ratio. The water-cement ratio given in

Table 5 of IS 456 for respective environment exposure conditions may be used as starting point.

Selection Of Water-Cement Ratio
From Table 5 of IS 456:Water- cement ratio = 0.50.

Selection of Water Content
From Table 2, 10262:2009; Water concrete = 180lit

Calculation of Cement Content
Cement content = 360kg/m^3

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content
Coarse aggregate: 0 .62& Fineaggregate: 0.38

Mix Calculations

a) Volume of concrete = 1m^3
b) Volume of cement= 0.126m^3
c) Volume of water = 186lit
d) Mass of coarse aggregate= 1217.78 kg/m^3
e) Mass of fine aggregate= 667.99kg/m^3

Mix Proportion
Cement = 360 kg/m^3
Fine Aggregate = 667.99kg/m^3
Coarse Aggregate = 1217.78 kg/m^3
Water = 186 liters
Water-Cement Ratio = 0.55

Mix Proportion =1:1.86:3.38

Number of Concrete Cube = 9

Amount Of Concrete Per One Cube
Cement= 1.485 kg/m^3
Fine aggregate = 2.658 kg/m^3
Coarse aggregate= 4.855 kg/m^3
Water= 2227.5ml

C. Addition of Glass Fibers

In the present work we used a glass fiber density of 2680kg/m^3. We added glass fiber 0.33% & 0.67% of volume of concrete. The mass of fibers are calculated below,

0.33% of Volume of Concrete
Mass of fibre = (0.33x2680)/100 = 8.844 kg/m^3

0.67% of Volume of Concrete
Mass of fibre = (0.67x2680)/100 = 17.956 kg/m^3

FOR ONE CUBE
The volume of one cube is 3.375x10^{-3}. So,the mass of fibre for one cube when added 0.33%, 0.67%.
0.33% of Volume of Concrete
Mass of fiber = 8.844x3.375x10^{-3} = 0.029 kg/m^3

0.67% of Volume of Concrete
Mass of fibre = 17.956 x 3.375x10^{-3} = 0.0606 kg/m^3

D. Addition of GGBS

Replacement of cement by GGBS with percentages of 15%, 30%, 45%, 60% of volume of cement. The mass of GGBSare calculated below.

15% Replacement of Cement By GGBS
Weight of cementitious material = 1.485kg/m^3
Weight of cement = 1.262kg/m^3
Weight of GGBS = 0.222kg/m^3

30% Replacement of Cement By GGBS
Weight of cementitious material = 1.485kg/m^3
Weight of cement = 1.039kg/m^3
Weight of GGBS = 0.445kg/m^3

45% Replacement of Cement By GGBS
Weight of cementitious material = 1.485kg/m^3
Weight of cement = 0.816kg/m^3
Weight of GGBS = 0.668kg/m^3

60% Replacement of Cement By GGBS
Weight of cementitious material = 1.485kg/m^3
Weight of cement = 0.984kg/m^3
Weight of GGBS = 0.891kg/m^3

E. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, percentage of volume and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix. It is important that the fibers are dispersed uniformly throughout the mix, this can be done by the addition of the fibers before the water is added. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, other suitable methods must be adopted

Type of concrete	AspectRatio	Relative strength	Relative toughness
Plain concrete	0	1	1
With Randomly Dispersed fibers	25	1.5	2
	50	1.6	8
	75	1.7	10.5

III. TEST ON FRESH CONCRETE

A. Workability of Concrete

It can be defined as the ease with which concrete can be mixedplaced, compacted, transported and cured. It can be measured by two popular methods.
(1) Slump test and (2) Compaction factor test

1) Slump Test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability nor it is always representative of placability of concrete. However it is used conveniently as a control test and gives an indication of uniformity of concrete from batch to batch. Repeated batches of same mix brought to the same slump, will have the same water content and water cement ratio provided the weights of aggregates, cement and admixtures are uniform and aggregate grading is within acceptable limits. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. Quality of concrete can also be further assessed by giving a few tapping's or blows by tamping rod to the base plate

Fig 3.1 Slump Cone

2) Compaction Factor Test

It is designed primarily for use in laboratory but it can also be used in field. It is more precise and sensitive than the slump test and is primarily useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete are insensitive to concrete. This test works on the principle of determining degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. Degree of compaction, called the compacting factor is measured by density ratio i,e the ratio of density actually achieved in the test to the density of same concrete fully compacted.

Fig 3.2 Compaction factor apparatus

B. Test on hardened concrete

1) Compression Testing of cubes

In the present investigation the cubes were casted with fiber reinforcement, and tested. The dimensions of the cube are 150x150x150mm in accordance to IS 456-2009.The casted cubes for curing and tested after 3days,7days ,28 days and the capacity of concrete cube noted in KN that is force (P) by placing on any one side of the cube .The cross sectional area(A) of cube is 225cm2.Finally the division compressive force by cross sectional area of cube gives the compressive strength of that particular cube .This work is carried out for all grade M25 after 3days, 7days and 28 days. The mathematical representation of compressive strength,

$\boldsymbol{\sigma = P/A}$

Fig 3.3 Compression test

2) Tensile Strength

Generally split tensile strength will be predicted by using cylinders of diameter 150 mm and depth or height 300 mm placing longitudinally and applying force by machine.The mathematical representation of split tensile strength is

$$\sigma_T = 2P/\pi h$$

In the present investigation the cylinders were casted with glass fibre reinforcement and tested. The dimension of the cylinder was 50 mm diameter and 300mm height. The casted cylinders kept for curing and tested after 3days,7days and 28days and capacity of concrete cylinders were noted in KN i.e placing axially under testing machine. The cross sectional area (A) of cube is 178 cm^2. Finally the division of tensile force by cross sectional area gives tensile strength of that particular cylinder. This work is carried out for M25 grade of concrete by replacing OPC with 15%,30%,45% and 60% of GGBS and glass fibre used are in 0.33% and 0.67%.The tensile strength will be around 8% of compressive strength. The mathematical representation compression.

$$\sigma_T = P/A$$

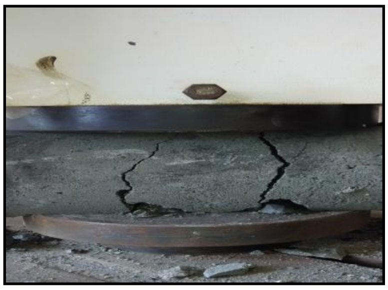


Fig 3.4 Universal testing machine

IV. RESULTS AND DISCUSSION

A. *Slump Test Results*

Table: 4 Slump Value For 0.33% of GFRC.

GGBS	15%	30%	45%	60%
Slump in mm	108	115	120	117

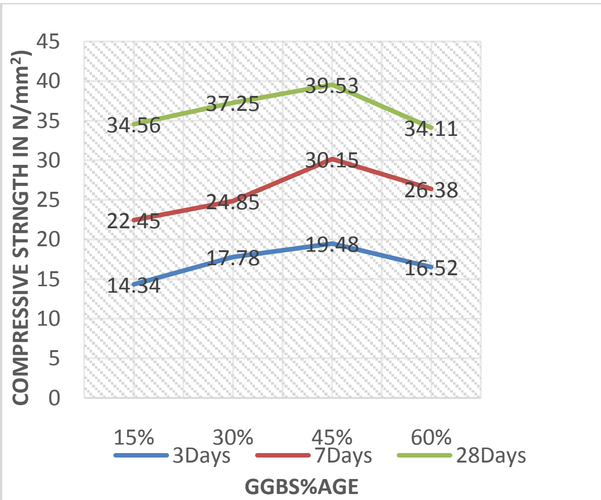
Table: 5 SlumpValue For 0.67% of GFRC

GGBS	15%	30%	45%	60%
Slump in mm	105	111	118	114

B. *Compressive Strength Results*

Table: 6 Compressive Strength of Glass Fibre Reinforced GGBS Concrete For 0.33% of Glass Fibre.

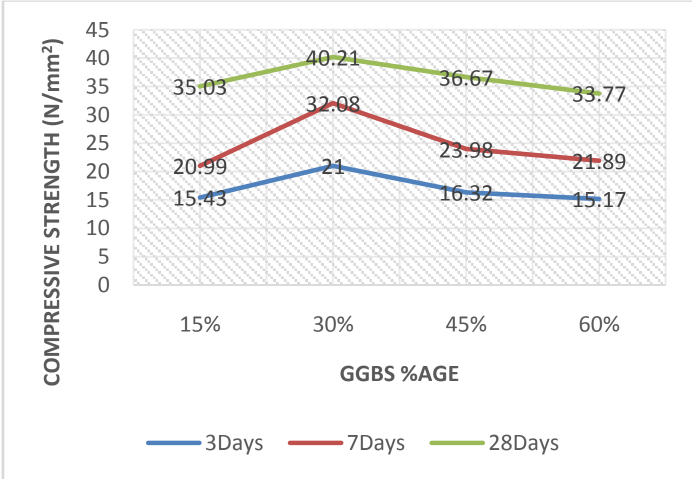
Grade	Curing Day/ GGBS	Compressive strength (N/mm^2) for 0.33 % GF			
	GGBS %	15%	30%	45%	60%
M 25	3 days	14.34	17.78	19.48	16.52
	7 days	22.45	24.85	30.15	26.38
	28 days	34.56	7.25	39.53	34.11



Graph 1:From the Graph it is Concluded that the Effective GGBS Replacement is at 45%.

Table: 7 Compressive Strength of Glass Fibre Reinforced Concrete For 0.67% of Glass Fibre

Grade	Curing Day/ GGBS	Compressive strength (N/mm^2) for 0.67 % GF			
	GGBS %	15%	30%	45%	60%
M 25	3 days	15.43	21	16.32	15.17
	7 days	20.99	32.08	23.98	21.89
	28 days	35.03	40.21	36.67	33.77

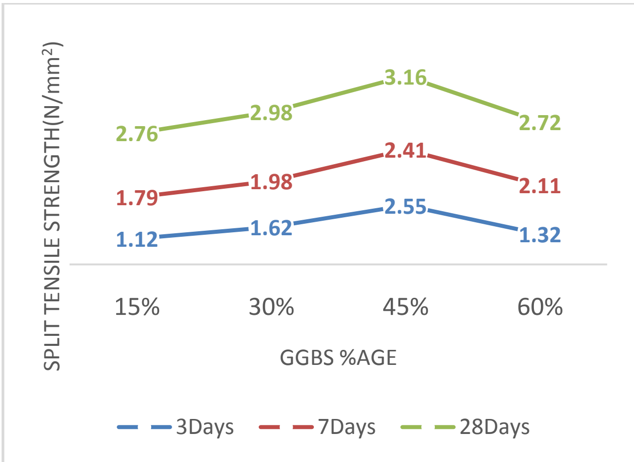


Graph 2: From the Graph it is Concluded that the Effective GGBS %age is 30%.

C. *Tensile Strength Results*

Table 8: tensile Strength of Glass Fibre Reinforced GGBS Concrete for 0.33% of Glass Fibre.

Grade	Curing Day/ GGBS	Split tensile strength (N/mm^2) for 0.33% GF			
	GGBS %	15%	30%	45%	60%
M 25	3 days	1.12	1.62	2.55	1.32
	7 days	1.79	1.98	2.41	2.11
	28 days	2.76	2.98	3.16	2.72

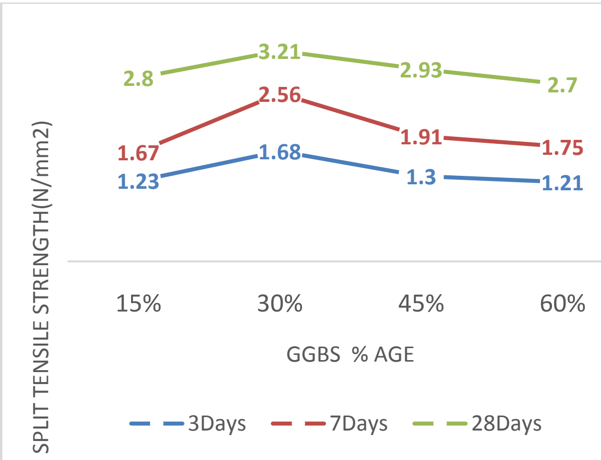


Graph 3: From the Graph it is Concluded that the Effective GGBS %Age is 45%.

Table 9: Tensile Strength of Glass Fibre Reinforced Concrete For 0.67% of Glass Fibre

Grade	Curing Day/ GGBS	Split tensile Strength (N/mm^2) for 0.67% GF			
	GGBS %	15%	30%	45%	60%

M 25	3 days	1.23	1.68	1.3	1.21
	7 days	1.67	2.56	1.91	1.75
	28 days	2.8	3.21	2.93	2.7



Graph 4: From the Graph We Concluded that the Effective GGBS %age is 30%.

V. CONCLUSION

From the study it was found that the workability of concrete increases by the addition of GGBS but the concrete shows reduction of workability due to the addition of glass fibre.

1. The slump of this concrete increases as the addition of GGBS in 0.33% and 0.67% of glass fibre concrete up to 45%, after that the slump value gets reduced.
2. The compressive strength value of cubes casted with 0.33% of glass fibre shows effective strength as the addition of GGBS is increased from 0% to 45%, after this further addition of GGBS shows decreasing value.
3. The compressive strength value of cubes casted with 0.67% of glass fibre shows effective strength as the addition of GGBS is increased from 0% to 30%, after this further addition of GGBS shows decreasing value.
4. The split tensile strength value of cylinders casted with 0.33% of glass fibre shows effective strength as the addition of GGBS is increased from 0% to 45%, after this further addition of GGBS shows decreasing value.
5. The split tensile strength value of cylinders casted with 0.67% of glass fibre shows effective strength as the addition of GGBS is increased from 0% to 30%, after this further addition of GGBS shows decreasing value.

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