© 2017 IJSRSET | Volume 3 | Issue 3 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Experimental Study of Properties of Fiber Reinforced Concrete using GGBS

Vijay Madhavrao Takekar*1, Prof. G. R. Patil2

*1P.G. Student, Department of Civil Engineering, JSPM'S Rajarshri Shahu College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India

2Associate Professor, Department of Civil Engineering, JSPM'S Rajarshri Shahu College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India

ABSTRACT

Present paper focuses on Grounded Blast Furnace Slag (GGBS) as an option for binder and filler materials in case of Ordinary Portland Cement (OPC). The experimental result analyses are investigated for structural properties of fiber reinforced concrete equipped with GGBS. Concrete grade M-50 was taken for study. GGBBS with 0%, 10%, 20%, 30% and 40% by weight of ordinary cement was added successively; also 1.5% of steel fiber was kept constant. Variables included aggregate size (10mm, 12mm and 20mm) with percentage of GGBS in order to study the effect on compressive strength, tensile strength and flexural strength. 150mmX150mmX150mm size of cube and 100mmX100mmX500mm size of beam were tested for strength performance in form of compressive and flexural strength respectively. Samples with duplication of GGBS were cured for 56 days in comparison to normal cement which requires up to 28 days. Experiments with these samples were carried out to study the strength characteristics of the concrete. Results indicate that as the percentage of GGBS increases, the workability of GGBS fiber reinforced concrete also increases. The result also includes effect of cost and compressive strength for GBBS fiber reinforced concrete.

Keywords: Ground Granulated Blast Furnace Slag (GGBS), Concrete Grade M-50, Flexural Strength, Compressive Strength, Workability

I. INTRODUCTION

Currently the research has increased in the field of admixtures like micro silica, fly ash to boost the performance of concrete. With increase in technology demand, the construction and design needs to be equipped with concrete of high strength characteristics. It therefore becomes obligatory to find some other option in place for micro silica without affecting the characteristic and quality of the high strength concrete. Ground Granulated Blast Furnace Slag (GGBS) is a better alternative to micro silica.

GGBS, an industrial waste, replaces a part of ordinary cement to form GGBS concrete. Better economic and environmental merits are acquired if ground granulated blast furnace slag as partial replacement for concrete mix. Compressive strength of concrete is increased by GGBS, which has some pozzolanic properties. Concrete fibres are further added to reduce brittleness. Properties of concrete like toughness and its durability are increased by fibre reinforcement. An experimental investigation done by [1], highlights reduction in brittleness of high strength concrete when replaced by cement with GGBS reinforced steel fibre (40% GGBS + 1% steel fibre) for M-50 grade concrete gave good results, beyond there was gradual reduction in strength. In concrete, steel fibre reduces the cracks.

FRC performances are controlled by vital variables like fibre content and fibre efficiency [2]. A good alternative for cement is GGBS, which acts as a binder to replace 50 to 60% of cement. Initially, concrete with GGBS shows poor performance for 28 days compared to normal concrete, but as the time increases up to 56 days, it shows good results with GGBS concrete, thereby increasing the strength more significantly beyond 56 days [3]. Fineness property of GGBS proves to be advantageous, as it is denser than concrete mix ordinary Portland cement. In concrete, the pours are filled by

GGBS, which acts as filler material. Particle of GGBS with 3 µm diameter provides short term strength to mortar. The GGBS with increased diameter have micro aggregated effect on long term strength of mortar [4].

Even though the cement properties of GGBS are weaker than Portland cement, but for cement hydration process, GGBS exhibits micro crystal core effect. Hydration process of cement decreases, when GGBS acts in an alkaline medium, which proves to be advantageous. Author [5] highlighted the increase in surface area of the GGBS, increased the compressive and flexural strength.

II. RESEARCH SIGNIFICANCE

The present research indicates high strength concrete under flexure to study the behavioural characteristics of GGBS FRC. GGBS, the substitute for cement and effect of size of aggregate on concrete was performed. Compressive strength of GGBS and concrete cost is also studied. When concrete is reinforced with randomly distributed steel fibre, the flexural strength is improved which toughens the high strength concrete including GGBS. In this respect, various percentages of GGBS along with addition of various size aggregates to achieve high strength concrete are observed.

III. EXPERIMENTAL INVESTIGATION

A. Materials

In this experimental work, there are various materials used like fine aggregate: natural river sand, coarse aggregate, OPC 53 Grade, water and steel fibers.

- *Cement:* Pertaining to IS 12269-197 [6], Ordinary Portland Cement of 53 Grade is used. The specific gravity of cement was maintained at 3.15. After conducting appropriate test in conjunction to IS 12269-1987, the results of physical properties of cement are obtained as shown in Table I.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

Sr. No.	I. Physical Properties of Cement According to IS 12269:1987	
	Properties	**Cement**
1	Fineness: Specific Surface	3.75
2	Specific gravity	3.15
3	Standard consistency of cement (%)	24
4	Setting time (min) A. Initial B. Final	 135 240

- *GGBS*: The data for GGBS is procured from Sona Alloys Pvt. Ltd. Ground granulated blast furnace is a by-product from the blast furnace used to make iron and purify metals. The compressive strength is increased by pozzolanic reaction of GGBS. The physical properties of GGBS as per IS 4031-1988 [7] are shown in Table II below.

TABLE III. PHYSICAL PROPERTIES OF GGBS

Sr. No.	Physical Properties of GGBS According to IS 4031:1988	
	Properties	**GGBS**
1	Fineness: Specific Surface	4.25
2	Specific gravity	2.87
3	Standard consistency of cement (%)	34
4	Setting time (min) A. Initial B. Final	 180

- *Fine Aggregate*: To satisfy grade zone II of IS 383-1970 [15], locally available river sand is used as fine aggregate. The fineness modulus and specific gravity are taken as 2.9 and 2.8 respectively.
- Coarse Aggregates: Coarse aggregate in angular (crushed) form is considered with reference to IS 383-1970. Various sizes of aggregates are used particularly of 10mm, 12mm and 20mm for experimental study. IS 383-1970 specification are considered for sieve analysis. Fitness modulus and specific gravity are 6.25 and 2.61 respectively.
- Water: For casting and curing operation work, clean portable water is used.
- Steel Fiber: Steel fibers with hooked end are used in the entire experimentation. ISO 9001:2000 [9] certified hook ended steel fibre pertaining to ASTM A820 [10] type 1 standards are used for experimentation. Fibber material was procured from Stewols India Pvt. Ltd. Nagpur. Details of fibre material are indicated in Table III below:

TABLE IIIII. PHYSICAL PROPERTIES OF STEEL FIBERS

Sr. No.	II. Physical Properties of Steel Fibres	
	Properties	**Results**
1	Diameter of fibre D_f (mm)	1
2	Length of fibre L_f (mm)	50
3	Aspect ratio (L_f/D_f)	50
4	Modulus of elasticity (Gpa)	200

B. Mix Proportion

Mix proportion design was conducted under IS 10262-2009. Mix proportion values are highlighted in Table IV below.

TABLE IVV. MIX PROPORTION

III. Mix Proportion as per IS 10262-2009					
Unit of batch	**Water (litres)**	**Cement (Kg)**	**F.A. (Kg)**	**C.A. (Kg)**	**Size of aggregate (mm)**
Cubic meter content	157.60	450.2	757.46	1059.6	20
Ratio	0.35	1	1.68	2.35	
Cubic meter content	166.20	474.88	736.40	1030.17	12
Ratio	0.35	1	1.53	2.169	
Cubic meter content	169.6	484.57	729.08	1019.9	10
Ratio	0.35	1	1.505	2.105	

C. Specimen Preparation and Curing

For each group of aggregate 36 specimens in total were casted. For mixture, three groups were prepared, each having 18 cubes and 18 beams of size 150 mm X 150 mm X 150 mm and 100 mm X 100 mm X 500 mm respectively. The specimens are mentioned in Table V below.

In laboratory, the entire concrete mixtures were mixed by hand mixing for a period of 4 minutes. To obtain uniform concrete mixture in dry condition, the constituent materials along with various mix proportions were mixed meticulously. To obtain uniform cohesive concrete, the calculated water quantity obtained from water – cement ratio was mixed meticulously. When the steel fibers were sprinkled in concrete to achieve uniform fiber dispersion utmost care was taken in order to avoid balling of fibers. After obtaining the sample of uniform fresh concrete, it was filled in the specimen molds. Three layers each were prepared for casting process of cubes and beams. A table vibrator was used to compact each layer till the top surface was leveled and was smoothened with the help of a trowel.

TABLE V. SPECIMEN DETAILS

IV. Specimen Details				
Size of Aggregates(mm)	**Specification of Concrete**	**Notation**	**Cubes**	**Beams**
10	Normal Concrete (N.C.), Steel Fiber (S.F.)	A 10	3	3
	N.C. + 1.5% S.F.	A 10-0	3	3
	N.C. + 1.5%S.F. + 10% GGBS	A10-10	3	3
	N.C. + 1.5%S.F. + 20% GGBS	A10-20	3	3
	N.C. + 1.5%S.F. + 30% GGBS	A10-30	3	3
	N.C. + 1.5%S.F. + 40% GGBS	A10-40	3	3
12	Normal Concrete (N.C.), Steel Fiber (S.F.)	A 12	3	3
	N.C. + 1.5% S.F.	A 12-0	3	3
	N.C. + 1.5%S.F. + 10% GGBS	A12-10	3	3
	N.C. + 1.5%S.F. + 20% GGBS	A12-20	3	3
	N.C. + 1.5%S.F. + 30% GGBS	A12-30	3	3
	N.C. + 1.5%S.F. + 40% GGBS	A12-40	3	3
	Normal Concrete (N.C.), Steel Fiber (S.F.)	A 20	3	3
	N.C. + 1.5% S.F.	A 20-0	3	3
	N.C. + 1.5%S.F. + 10% GGBS	A20-10	3	3
20	N.C. + 1.5%S.F. + 20% GGBS	A20-20	3	3
	N.C. + 1.5%S.F. + 30% GGBS	A20-30	3	3
	N.C. + 1.5%S.F. + 40% GGBS	A20-40	3	3

After completion of casting process, the entire specimen was kept in the curing room for one entire day. The temperature of 20 ± 2 0C was maintained to de-mould and cure the concrete specimen. ASTM C192-88 standards were followed for curing the test specimens.

IV.SPECIMEN TESTING

A. Properties of Fresh Concrete

Slum cone test was executed to determine the workability factor of GGBS concrete. Standard cylinders were used to find the wet density by measuring weight and volume of wet concrete. The results were evaluated and are mentioned in Table VI below.

B. Test conducted on Hardened Concrete

Normal and GGBS FRC specimens were taken for destructive testing to compute the strengths of the individual. Tests were carried out in three batches, results were recorded and final result was evaluated form the average of the recorded values.

C. Compressive strength of Cube

IS 516-1959 standard [11] was referred to perform compressiveness test. Compressive force was applied on the cube till the failure was observed in the cube due to compressive force. The experimental setup along with the loading arrangement meeting the IS standard 516-1959 is shown in Fig.1 below.

Figure 1: Compressive Testing

Cube specimen was tested with a calibrated stiff CTM of capacity 2000 kN, and the load application rate was 140 Kg/cm^2/minute in accordance with the IS standards. Dial gauge with least count 0.01 mm was used while testing to monitor the deflection.

D. Flexural Strength

As per IS standards 516-1959, flexure specimens had undergone two-point bending beam tests, with the experimental setup as shown in Fig.2 below.

Figure 2 : Testing of Flexural Strength

To achieve accurate results for deflection as per rate of maximum load setup, dial gauge was connected to the neutral of the axis on the beam, suggested by P.N. Balguru, 2000. Flexure specimen was tested with a calibrated stiff CTM of capacity 600 kN, and the load application rate was 400 Kg/ minute for a beam of size 150 mm in accordance with the IS standards. The deflection was continuously monitored with the help of dial gauge instead of ram – displacement observed from the machine. To determine the amount of energy for beam deflection is obtained by standard test method.

V. RESULT AND DISCUSSION

A. Properties of Fresh Concrete

Slum cone test was executed to determine the workability factor of GGBS concrete. Standard cylinders were used to find the wet density by measuring weight and volume of wet concrete. Table VI below shows that with increase in GGBS content, the workability increases. When M – 50 grade concrete is replaced with GGBS, workability increases in the range of 30% to 40%. Results are highlighted in the Table VI below. Percentage increase in slum is compared with plain concrete.

TABLE VI. PROPERTIES OF FRESH CONCRETE

V. Properties of Fresh Concrete				
Concrete	**Slump (mm)**	**Wet density W_d (Kg/m^3)**	**% increase in slump**	**% increase in W_d**
A 10	10	2589.12	-	-
A10-0	5	2596.02	-50	0.26
A10-10	5	2601.35	-50	0.47

A10-20	8	2609.21	-20	0.77
A10-30	10	2611.48	0	0.86
A10-40	16	2616.85	60	1.07
A12	12	2590.33	-	-
A12-0	10	2592.16	-16.67	0.071
A12-10	16	2596.44	33.33	0.235
A12-20	20	2626.47	66.67	1.39
A12-30	24	2631.17	100	1.57
A12-40	15	2633.65	25	1.67
A 20	15	2639.12	-	-
A20-0	8	2639.62	-46.67	0.0189
A20-10	10	2695.17	-33.33	0.0212
A20-20	15	2690.86	0	0.0196
A20-30	24	2698.14	60	0.0223
A20-40	30	2718.45	100	0.0301

B. Compressive Strength

UTM was used to carry out the strength by compressive test on the cube of size 150 mm X 150 mm X 150 mm. According to IS standard 516-1959, the compressive strength was calculated by the formula:

$$f_{cs} = \frac{p_c}{A}$$

Where, f_{cs} is the compressive strength of specimen, p_c is the compressive load, A is the cross sectional area of the cube. The compressive strength and its corresponding increase in compressive strength is highlighted in Table VII below.

TABLE VII. COMPRESSIVE STRENGTH-CONCRETE

VI. Compressive Strength-Concrete

Concrete	Compressive strength (N/mm^2)	% increase in compressive strength	Cost comparison w.r.t normal concrete (%)	Cost comparison w.r.t FRC (%)
A 10	57.88	-	-	-
A10-0	59.13	2.16	17.21	-
A10-10	60.50	4.53	8.89	-7.16
A10-20	61.11	5.58	0.55	-14.23
A10-30	55.81	-3.57	-7.71	-21.33
A10-40	50.17	-13.33	-16.02	-28.43
A12	57.84	-	-	-
A12-0	59.21	2.37	6.34	-
A12-10	60.52	4.63	6.02	-7.30
A12-20	61.82	6.88	0.34	-14.35
12-30	51.22	-11.45	-8.68	-21.59
A12-40	51.07	-11.7	-17.03	-28.61
A 20	57.02	-	-	-
A20-0	58.90	3.30	16.05	-
A20-10	60.52	6.14	17.86	-7.16
A20-20	62.02	8.77	0.69	-14.58
A20-30	52.81	-7.38	-8.23	-21.65
A20-40	51.20	-10.21	-17.35	-28.35

C. Flexural Strength

A test was performed to determine the strength of each of specimen of size 100 mm X 100 mm X 500 mm which was supported by a span of 400 mm and at every third point of span two point loads were applied. Until the first crack was observed, the deflection at centre was recorded continuously. All the beams were loaded till they underwent failure. According to IS standard 516-1959, the flexural strength is calculated by the formula,

$$f_{fs} = \frac{p_m l}{wd}$$

Where, f_{fs} is the flexural strength, p_m is the maximum load applied on the specimen, l is the length, w is the width of the beam and d is the depth of the beam. Three values are recorded and the average of this was considered for flexural strength

TABLE VIII. FLEXURAL STRENGTH-GGBS FRC

VII. Flexural Strength-GGBS FRC

Aggregate	GGBS Content %+ S.F Content%	Flexure Strength (Mpa)
10 mm	0	5.33
	0+1.5	5.40
	10+1.5	5.45
	20+1.5	5.48
	30+1.5	5.26
	40+1.5	4.96
12.5 mm	0	5.31
	0+1.5	5.36
	10+1.5	5.43
	20+1.5	5.48
	30+1.5	5.10
	40+1.5	5.02
20 mm	0	5.29
	0+1.5	5.37
	10+1.5	5.48
	20+1.5	5.53
	30+1.5	5.10
	40+1.5	5.00

The values of the flexural strength were calculated as per IS standard 456-2000, which is given by the formula:

$$f_{fs} = 0.7\sqrt{f_{cs}}$$

Where, f_{fs} is the flexural strength and f_{cs} is the compressive strength of the specimen taken into consideration.

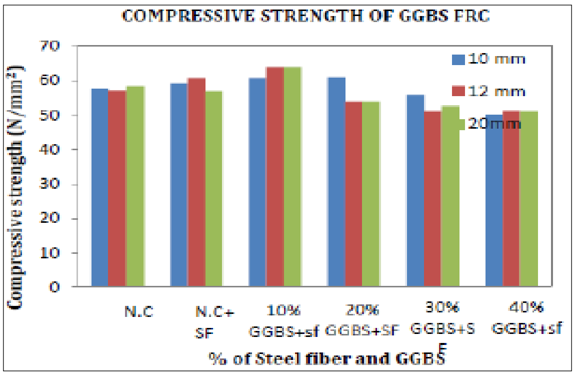

Figure 2: Compressive Strength of GGBS-FRC

VI.CONCLUSION

From the above result and analysis, following points have been formed for conclusion:

- With increase in GGBS content for FRC, the workability performance of GGBS fibre reinforced concrete increases. As the GGBS replacement level increases, the wet density of concreter also increases.
- It was observed that in every group of aggregate, with 20% GGBS replacement, there was considerable increase in compressive strength of the cube.
- At 20% replacement level, 10 mm aggregate achieved strength of 61.11 MPa, for 20% replacement of cement with GGBS, 12 mm aggregate achieved strength of 61.82 MPA and for 20% replacement, 20 mm aggregate achieved strength of 62.02 MPa.
- It was analysed that with 20% replacement of GGBS gave significant result for increase in strength as compared to ordinary cement, also for 10 mm aggregate, cost is reduced to 14% as compared to fibre reinforced concrete and for 40% replacement, less strength is achieved compared to normal cement but cost was reduced to 16% in comparison to normal concrete and 28% in comparison to FRC.
- The strength was increased in the range of 6% to 9% for 12mm and 20mm aggregates, while it cost remains same as normal cement but 14% of cost is saved as compared to FRC.
- For each group of aggregated concrete mix with 20% GGBS, there was 8% to 10% strength achieved was more compared to normal cement. The flexural strength was observed to have 10.26% strength for 20 mm aggregate for GGBS replacement with 20%.\
- Good performance was observed for flexural strength especially for 10% and 20% replacement cement with steel fibre, which is more than the normal concrete.

VII. ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to my guide and P.G. coordinator Prof. G.R. Patil, Department of Civil Engineering, for his valuable time, sustained guidance and useful suggestions, which helped me in completing the research work in time. I would like to express thank to past researchers and my heartfelt thanks to my beloved wife and parents for their blessings, my friends/classmates for their help and wishes for the successful completion of this research work.

VIII. REFERENCES

[1] Neeraja, “Experimental investigation of Strength Characteristics of Steel Fiber Reinforced Concrete”, International Journal of Scientific & Engg. Research, Vol-4, Issue-2, 2013.

[2] Balguru P.N., Shah S.P., “Fiber Reinforced Cement Composites”, Mc-Graw-Hill Publication, 2000, pp 1-447.

[3] K. Ganesh Babu, V. Shree Rama Kumar, “Efficiency of GGBS in Concrete”, Cement & Concrete Research, 2000, pp 1031-1036.

[4] Huiwen wan, Zhonghe shue, “Analysis of Geometric Characteristics of GGBS Particle and their Influence on Cement Properties”, Cement & Concrete Research 34, 2000, pp 133-137036.

[5] J.Jiang “The Summarization of Slag Powder Used In Cement and Concrete”, Concrete Cement Product, Vol. 3, pp 3-6

[6] IS 12269, “Indian Standard Code of Practice for Ordinary Portland Cement 53 Grade Specification”, Bureau of Indian Standard, Navi Delhi, 1987.

[7] IS 4031, “Indian Standard Methods of physical test for Hydraulic cement”, Bureau of Indian Standard, Navi Delhi, 1988.

[8] IS 383, “Specification of Coarse and Fine aggregate from natural source of concrete”, Bureau of Indian Standard, Navi Delhi, 1970.

[9] ISO 901:20089, “International Organisation for Standard”.

[10] ASTM A-820, “Standard Specification for steel fiber for fiber reinforce concrete”, 2011.

[11] IS 516, “Indian Standard methods of test for strength of concrete”, Bureau of Indian Standard, Navi Delhi, 1959.

[12] IS 415 “Plane and Reinforced Concrete, Code of Practice”, Bureau of Indian Standard, Navi Delhi, 2000.