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Experimental Investigation on Partially Replacing the Fine Aggregate by using Ground Granulated Blast Furnace Slag in Cement Concrete

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Abstract

Demand for natural sand in concrete mixing is increasing day by day. So, to reduce the utilization of natural resources usage of the industrial soil waste or secondary materials for the production of cement and concrete is encouraged in the field of construction. One of the secondary materials and by product of steel manufacturing industries is the Grounded Granulated Blast Furnace Slag (GGBS). In this work it is investigatedthat the possibility of utilizing GGBS in cement concrete as a partial substitute for sand, for reducing the environmental problems related to the fine aggregate mining and waste disposal of slag. In this work, the percentage of GGBS replacement is 0,5,10 and 15% to natural sand for the standard w/c ratio of 0.4 is considered. In this work, the influence of above said percentages of GGBS in concrete on compressive strength, split tensile strength and flexural strength at 28 days curing period were studied. The compressive, flexural and split tensile strengths are compared with the conventional concrete. The results show that the compressive strength of 15% GGBS is 18.36% higher than the conventional concrete, whereas the split tensile and flexural strengths are slightly lesser than the conventional concrete.

Keywords: *GGBS; Fine Aggregate; Workability; Compressive strength; Split tensile strength; Flexural Strength.*

1. Introduction

After water concrete is the second-most-used substance in the world, and is the most widely used building material. Concrete is a composite material consists of fine and coarse aggregates bonded together with fluid cement that hardens over time. Due its wide usage in the world, the consumption of natural resource which is sand as fine aggregate has become very high and it's availability may become scarce in future [1]. In order to avoid this problem, one can try the usage of Grounded Granulated Blast Furnace Slag (GGBS) which is a secondary material from the steel manufacturing industries as fine aggregate. 7.8 million tons of GGBS is produced in India in iron manufacturing industries. Recent options for the management of GGBS include recycling and regeneration of metal. Another option of utilizing GGBS is by partial replacement of sand. So, it is possible to reuse a waste by product material beneficially. Gaurav singh et.al. (2015) studied the possibility of using GBFS as fine aggregate in M25 concrete for sustainable infrastructure and concluded that 40% to 50% replacement of sand with GBFS is giving higher compressive strength in normal conditions and 50% to 60% replacement is giving higher compressive strength under marine conditions. Baskaran P et al (2017) partially replaced fine aggregate with various proportions of GGBS in M25 grade concrete, and analyzed the compressive strength split tensile strength and flexural strength of the concrete after 28 days of curing. The results show

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that the 15% GGBS mix is performing well. G.Lizia Tankam et.al. (2022) studied GGBS based alkali activated fine aggregate in concrete and did experiments for compressive strength, tensile strength and flexural strength. These mechanical properties are more than 90% of the strengths obtained for a conventional concrete prepared with natural sand [2]. Dodda srinivas et.al. (2020) studied the mechanical properties of partial and full replacement of fine aggregate in high performance concrete (M60) with GGBS. Results compared with River sand based concrete and M-sand based concrete. It is concluded that 100% replacement is giving better strengths (compressive, tensile and flexure) than other partial replacements. Ashita sing et.al. (2019) studied on optimization of cement and fine agrregate by blast furnace slag in M30 grade concrete [3]. It is concluded that cement can be replaced by GGBS upto 55% and sand can be replaced by GGBS upto 50% without affecting compressive strength. Sanbir Manhas and Amir Moohmend (2018) studied the partial replacement of fine aggregate with GGBS in M20 concrete and the results shows that 35% replacement of GGBS with sand is giving higher compressive strength and split tensile strength values. In literature mostly the partial replacement of GGBS is tried with M20, M25, M30 and high performance concrete. It looks at lower percentage replacement of GGBS with FA is giving better compressive strengths for lower grade concretes and for high performance concrete (M60), even 100% replacement of GGBS is giving better compressive strengths than partial replacement of GGBS. In the earlier study [5] for M30 grade concrete it is tried with 0%, 25%, 35% and 60% replacement of GGBS with FA. So to understand the strength behavior of M30 concrete with lower percentage replacement of GGBS with FA is tried in this work. Hence the objective of this study is compressive strength, tensile strength and flexural strength investigation on M30 grade concrete with 0%, 5%, 10% and 15% replacement of FA by GGBS [4].

2. Methodology

The materials used in concrete are coarse aggregate, fine aggregate, cement and GGBS and are shown in Figure 1.

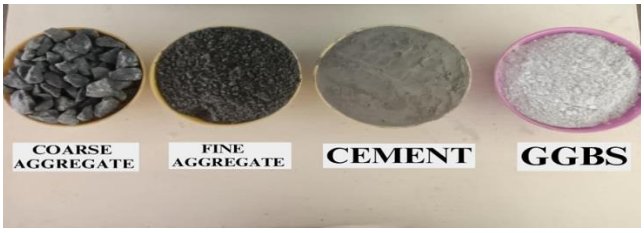

Figure 1 Materials Used in This Work

The tests conducted on fine aggregate and coarse aggregate are specific gravity, fineness modulus, bulk density and water absorption [6]. The specific gravity, fineness modulus, bulk density and water absorption of fine aggregate are 2.727, 2.81, 1711.6 kg/m^3 and 0.91% respectively and all these values are within the standards as per IS 383-2016. Similarly the specific gravity, fineness modulus, bulk density and water absorption for coarse aggregate are 2.753,7.16, 1596.05 kg/m^3 and 0.15% respectively and all the values are within the limits as per IS code. According to the value of fineness modulus, the aggregate size indicates it is in between 10 mm to 20 mm. Specific gravity, consistency, initial setting time, final setting time and soundness of 53 grade OPC are 3.14,33%,31 minutes, 600 minutes and 1 mm respectively and all these values are within the limits as per IS codal provisions. The tests conducted on GGBS are specific gravity, fineness modulus and moisture content and these values are 2.88, 2.06 and 0.067% respectively. As per IS10262-2019 concrete mix proportion is obtained as 1:1.54:2.56 for M30 grade concrete with water cement ratio of 0.4. With the above mix proportion, fresh concrete is prepared and conducted slump cone test to find out workability of concrete. As per IS1199-1959 for 0.4 w/c ratio the slum value is obtained as 4.7 cm. Once after curing of concrete for 28 days, the hardened concrete tests i.e. the compressive strength, split tensile strength, flexural strength and rebound hammer tests were conducted on 36 specimens. The concrete cube samples of 10% replacement of FA by GGBS are shown in the Figure

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2 to determine compressive strength using compression test apparatus.

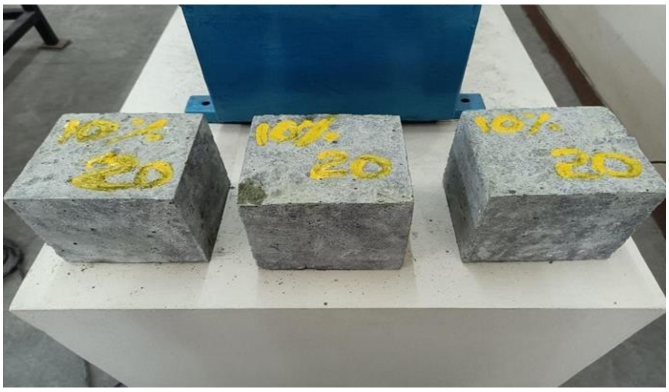

Figure 2 Cube Samples Of 10% FA Replaced By GGBS

The concrete cylinder samples of 10% replacement of FA by GGBS are shown in Figure 3 to conduct compression test experiments and to determine split tensile strength of concrete.

Figure 3 Cylinder Samples Of 10% FA Replaced By GGBS

The concrete beam samples of 5% replacement of FA by GGBS are shown in Figure 4 to conduct experiments and to determine flexural strength of concrete.

Figure 4 Beam Samples Of 5% FA Replaced By GGBS

To assess the likely compressive strength of concrete, rebound hammer test is conducted for all the cubes prepared using rebound hammer test machine.

3. Results and Discussion

The compressive strength test conducted using compression test apparatus on 0%, 5%, 10% and 15% replacement of FA by GGBS concrete cubes of total 12 specimens and results are tabulated as shown in Table 1. The test results shows that when the fine aggregate content is replaced by GGBS with 5% and 15% the compressive strength attained is higher value and more or less same. For all 5%, 10% and 15% replacements the compressive strength attained is also greater than nominal M30 concrete value and it can be depicted from Figure 5. The split tensile strength is calculated by conducting compression test using compression test apparatus on 0%, 5%, 10% and 15% replacement of FA by GGBS concrete cylinders of total 12 specimens. As shown in Figure 6, the test results shows that when the fine aggregate content is replaced by GGBS with 5%, 10% and 15% the Split tensile strength attained is lesser than nominal M30 concrete value but still satisfied the IS standard limits. The flexural strength is calculated by conducting bending test using compression test apparatus on 0%, 5%, 10% and 15% replacement of FA by GGBS concrete beams of total 12 specimens. As shown in Figure 7, the test results shows that when the fine aggregate content is replaced by GGBS with

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5%, 10% and 15% the Flexural strength attained is lesser than nominal M30 concrete value. But 15% GGBS sample flexural strength is satisfied the IS456-2000 standards.

Table 1 Compressive Strength Test Results

% of GGBS replaced the FA	Sample No.	Compressive strength N/mm²	Average compressive strength N/mm²
0%	1	39.76	39.36
	2	39.32	
	3	38.99	
5%	1	47.07	46.86
	2	45.71	
	3	47.81	
10%	1	45.91	45.43
	2	45.65	
	3	44.74	
15%	1	48.35	46.59
	2	45.62	
	3	45.81	

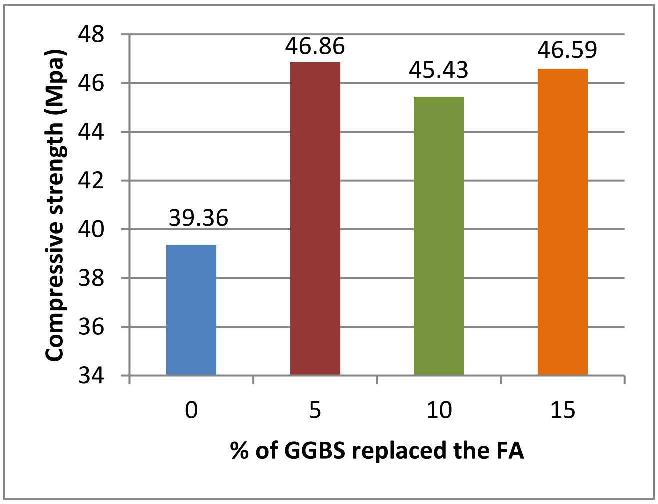

Figure 5 Average Compressive Strength

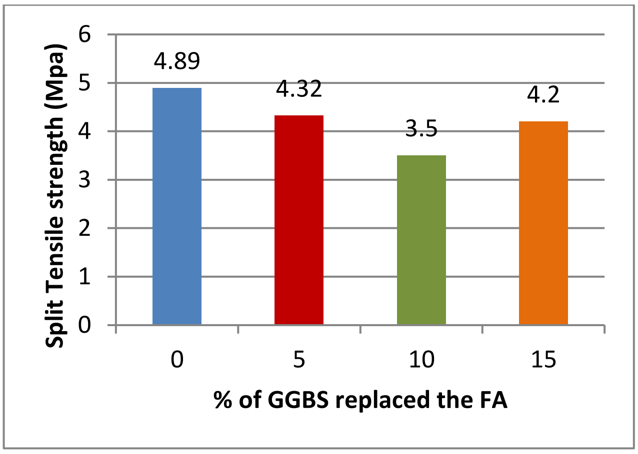

Figure 6 Average Split Strength

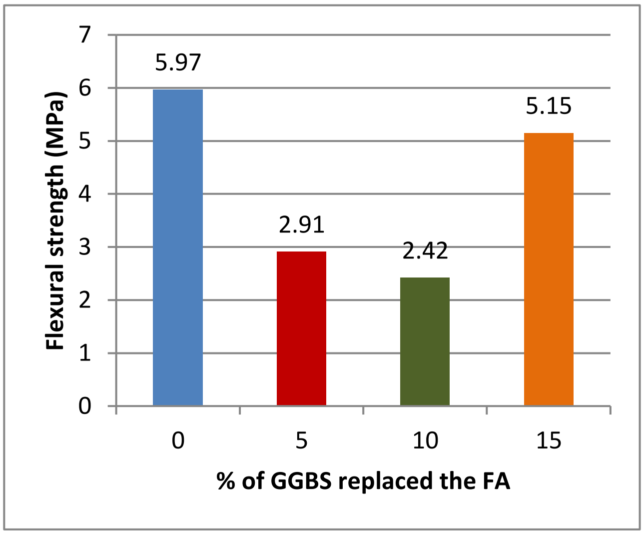

Figure 7 Average Flexural Strength

The rebound hammer test results for all samples are tabulated in Table 2.

Table 2 Rebound Hammer Test Results

% of GGBS	Average Crushing value N/mm²	Average rebound number
0	30.53	35.9
5	31.72	29.3
10	23.709	23.7
15	38.83	33.3

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The test results shows that out of all mixes the average crushing value for 15% GGBS mix has more crushing value even compared to nominal M30 concrete.

Conclusion

The concrete samples were prepared for the M30 grade concrete with partial replacement of fine aggregate by GGBS with various percentages of 0%, 5%, 10% and 15%. The specimens were casted and curing is done for 28 days then tested. The results are presented below. From the above results following conclusions were made.

- The compressive strength attained for partial replacement of fine aggregate with GGBS is found to be higher values than the conventional concrete. The compressive strength attained for 5% GGBS sample is 46.86 N/mm^2 and for 15% GGBs sample also nearly the same.
- The maximum split tensile strength for partial replacement of fine aggregate with GGBS samples are found to be slightly lesser than the conventional concrete, but still giving satisfied results as per IS 456-2000 standards.
- The maximum flexural strength for partial replacement of fine aggregate with GGBS is found to be lesser than the conventional concrete. However, the 15% GGBS sample satisfied the IS 456-2000 standards.

And hence it is concluded that the performance of 15% GGBS sample shows reasonably good compared to 5% and 10% GGBS samples.

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