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Research Article

STUDY ON STRENGTH PROPERTIES OF CONCRETE USING GGBS AND STEEL FIBER AS PARTIAL REPLACEMENT OF CEMENT

DHANYA R [1], ARASAN G.V [2*], GANAPATHY RAMASAMY [2]

[1]Assistant professor, Department of civil engineering, SRM University, Chennai, India

[2]Post-graduate, Department of civil engineering, SRM University, Chennai, India

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ABSTRACT

In this modern scenario, expectations from concrete have increased exponentially. Various physical parameters of concrete like strength, durability, serviceability and expected service life needs improvement. This paper deals with the study of the strength parameters of concrete by partial replacement of cement by ground granulated blast furnace slag (GGBS). The tests were conducted as per Bureau of Indian standards (BIS) to evaluate the suitability of GGBS as a partial replacement of cement. The steel fiber was used to increase the toughness of the concrete. Various strength parameters such as compressive strength, split tensile strength of concrete for a grade of M25 was tested and recorded. The partially replaced concrete showed an increase in strength as compared to conventional concrete. Various mix combinations with a partial replacement of 10%, 20%, 30% and 40% by the weight of cement by GGBS was taken and 0.5%, 1% and 1.5% steel fiber of hooked end type of aspect ratio 50-60 were used. The test results show that the partial replacement of cement by both GGBS and steel fiber has an increase in the strength of concrete. Considering all the strength parameters into account it was found that a 30% replacement of GGBS with 1% steel fiber is optimum for M25 mix.

INTRODUCTION

Ground granulated blast furnace slag is used for a long time in due to its economy in production of cement. Addition of slag in cement increases the durability properties of concrete and it also reduces the porosity of concrete. (Al-Otaibi, 2008).

Blast furnace slag, a nonmetallic product consisting of silicates and alumina-silicates of calcium, come from the blast furnace production of iron from ore through the process of water- jetting and water-immersing of the molten blast-furnace slag for granulation. A 55-59% replacement of cement by GGBS was found to produce an optimum strength of concrete (Oner and Akyuz, 2007). The corrosion resistance (mainly due to chlorine), durability and binding power of concrete is improved by using GGBS. It modifies the pore structure of concrete and results in a more hardened concrete and also abrasion resistance (Rao, *et al*., 2016). The permeability and penetration of chloride ions in concrete is reduced. It can also influence the electrochemical pore solution in cement system by the addition of GGBS to concrete (Cheng, *et al*., 2005) . The resistance to sulfate attack on concrete can also be reduced by the addition of GGBS to concrete for both moderate and severe environment (O'Connell, 2012).

Concrete is good in compression and weak in tension. Steel fiber in the concrete improves its mechanical characteristics. The modern development of steel fiber reinforced concrete (FRC) started in the early sixties (Rana, 2013). The steel fibers are the mostly used fiber, in fiber reinforced concrete. Many studies show that addition of steel fiber to

***Corresponding authors email: srvnn38@gmail.com; g.v.arasan@gmail.com**

the concrete lowers the workability of concrete. Therefore to solve this problem super-plasticizer is added, without affecting other properties of concrete (Neeraja, 2013). FRC has been successfully used in construction due to its excellent flexural-tensile strength (Siddhart and Munnur, 2015). Steel fiber in concrete improves malleability and its load carrying capability. The mechanical properties of steel fiber reinforced concrete are much improved by the use of hooked fibers than straight fibers. Due to the addition of 1.5 percent steel fiber the flexural strength was increased by 67 percent, the splitting tensile strength by 57 percent and the impact strength 25 percent (Shetty, 2006).

MATERIAL PROPERTIES

In this experiments Portland cement of grade 53 was used, Natural river sand was used as a fine aggregate of size not more than 4.75 mm, coarse aggregate of size varying from 12 mm to a maximum of 20 mm was used and GGBS was used as a partial replacement of cement for various volume ratio. The properties of these materials were determined by conducting test as per IS code. The test results are presented in Table 1.

STEEL FIBER

Adding steel fibre to a plain concrete has no effect on its pre-cracking behaviour but does substantially enhance its post cracking response, which leads to greatly improved toughness and impact behaviour. The physical properties are presented in Table 2.

MIX PROPORTIONS

The mix design was carried out as per the method featured in IS: 10262 (Indian standard code of practice for plain and reinforced concrete, 2000). The grade of concrete chosen was M25 with water cement ratio 0.45 and it was designed to obtain a target strength of 31.6 MPa at 28 days.

COMPRESSIVE STRENGTH RESULT

Cubes of size 150 × 150 × 150 mm were cast according to the M25 mix.The cube specimens were tested after 7, 14and 28 days of curing. The load is applied gradually till the specimen fails. The compressive strength results of various mix proportions are tabulated in Table 3. The line graph showing the variations in compressive strength of various mixes are shown (Fig. 1 and 2)

Compressive strength = (Maximum load/

Table 1. Material properties

Ctonstituents	Test	Results	Limitations from IS code
Cement	Specific gravity	3.18	3 to 3.25
	Standard consistency in %	31	26 to 33%
	Initial setting time in minutes	45	Not less than 30 minutes
Coarse aggregate	Fineness modulus	7.41	6.50 to 8
	Specific gravity	2.76	2.5 to 3
	Bulk density	1716 Kg/m^3	1600 to 1800 Kg/m^3
Fine aggregate	Fineness modulus	3.335	2 to 4
	Specific gravity	2.68	2.5 to 3
	Bulk density	1650 Kg/m^3	1520 to 1680 Kg/m^3
GGBS	Specific gravity	2.95	2.5 to 3.5
	Bulk density	1275 Kg/m^3	1200 to 1400 Kg/m^3
	Physical form	Powder form	Powder

Table 2. Physical properties

Physical properties	Results
Length (cm)	5
Diameter (mm)	1
Specific gravity	7.85
Aspect Ratio	50

Table 3. Compressive strength of concrete specimens M25

Mix	Specification	Mix ratio	Compressive strength (N/mm^2)		
			7^{th} day	14^{th} day	28^{th} day
M1	0% GGBS	1 : 1.54 : 2.53	20.4	28.4	32.2
M2	10% GGBS	1 : 1.54 : 2.53	21.4	29.4	32.5
M3	20% GGBS	1 : 1.54 : 2.53	22.1	30.4	33.3
M4	30% GGBS	1 : 1.54 : 2.53	23.8	31.5	34.8
M5	40% GGBS	1 : 1.54 : 2.53	19.3	25.5	28.4
M6	0.5% Steel fiber	1 : 1.54 : 2.53	23.2	30.4	33.5
M7	1% Steel fiber	1 : 1.54 : 2.53	27.1	34	38.8
M8	1.5% Steel fiber	1 : 1.54 : 2.53	25.5	31.5	35.6
M9	30% GGBS & 1% Steel fiber	1 : 1.54 : 2.53	27.26	34.5	39.8

Cross sectional area) in N/mm^2 (Indian standard recommended guideline for concrete mix design, 2009).

SPLIT TENSILE STRENGTH RESULTS

Cylinder of size 300 × 150 mm was used for the experiment. The specimen was placed in the compressive strength testing machine in the horizontal position and axial load was applied. The maximum load was recorded and the split tensile strength was recorded. Formula used for finding the split tensile strength is given below. The tensile strength of various mix proportions are tabulated in Table 4. The line graph showing in variations of split tensile strength of various mix are shown in Figure.

$T = 2P/\pi DL$

Where, P = applied load

D= diameter of the specimen

L = length of the specimen (Indian standard specification for coarse and fine aggregate from natural source for concrete, 1970).

TEST FOR DURABILITY

Chemical attack on concrete often leads to deterioration and results in the failure of the structure. Hence it is necessary to test the durability of the concrete against chemical reactions. Six cubes were casted for each specification of concrete. The casted cubes were cured in clean water for seven days. After curing, the cubes were dried for 24 hours. The dry weights of the cubes were noted down. Then the cubes were cured in the respective chemical for 60 days. The concentrations of the chemicals were maintained at 5% at their respective pH levels. The weight of the cubes after 60 days of curing in chemical was noted down. The percentage loss in weight of the cubes was determined. The loss in weight of the concrete cubes due to acid attack is shown in Table 5. The loss in weight of the concrete cubes due to sulphate attack is shown in Table 6.

CONCLUSION

This experiment was used to find the optimum possible replacement of cement by GGBS and Steel

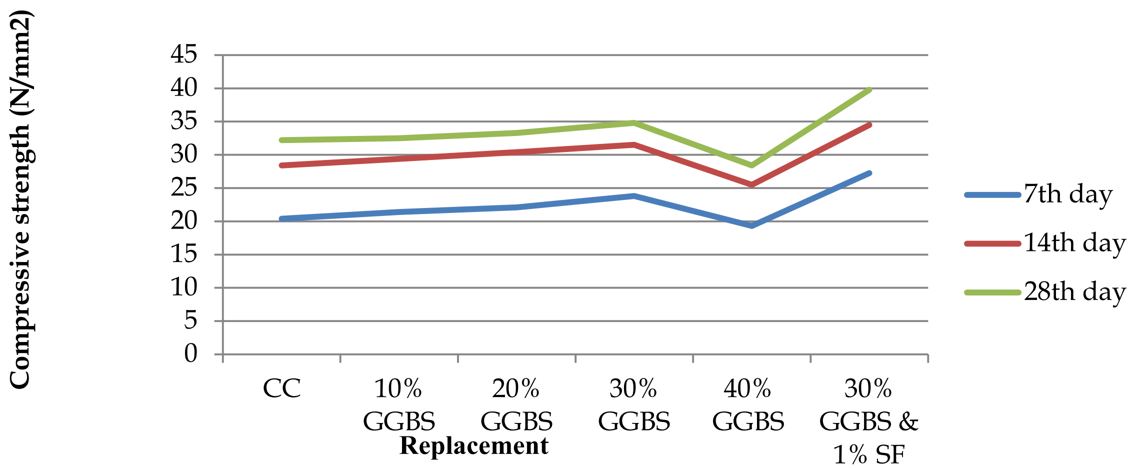

Fig. 1 Variations in compressive strength of concrete.

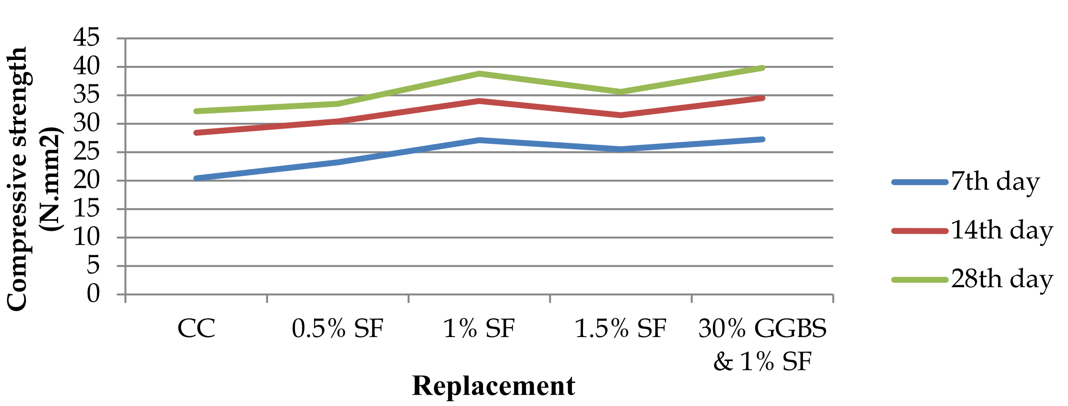

Fig. 2 Variations in compressive strength of concrete.

Table 4. Tensile strength of concrete specimens M25.

Mix	Specification	Mix ratio	Tensile strength (N/mm^2)		
			7th day	14th day	28th day
M1	0% GGBS	1 : 1.54 : 2.53	2.18	2.56	3.41
M2	10% GGBS	1 : 1.54 : 2.53	2.30	2.68	3.49
M3	20% GGBS	1 : 1.54 : 2.53	2.41	2.74	3.57
M4	30% GGBS	1 : 1.54 : 2.53	2.48	2.82	3.69
M5	40% GGBS	1 : 1.54 : 2.53	2.25	2.58	3.34
M6	0.5% SF	1 : 1.54 : 2.53	2.28	2.63	3.50
M7	1% SF	1 : 1.54 : 2.53	2.53	2.92	3.7
M8	1.5% SF	1 : 1.54 : 2.53	2.19	2.45	3.34
M9	30% GGBS & 1% SF	1 : 1.54 : 2.53	2.74	3.21	4.02

Table 5. Loss in weight due to acid attack.

Specification	Chemical	Mix ratio	Avg. weight of specimens (kg)	Weight of specimens after 60 days (kg)	Loss in weight
0% (Conventional concrete)	Conc. H_2So_4	1 : 1.54 : 2.53	8.36	8.09	3.22%
10% GGBS		1 : 1.54 : 2.53	7.87	7.57	3.81%
20% GGBS		1 : 1.54 : 2.53	8.1	7.75	4.32%
30% GGBS		1 : 1.54 : 2.53	7.95	7.57	4.77%
40% GGBS		1 : 1.54 : 2.53	7.85	7.45	5.09%
0.5% SF		1 : 1.54 : 2.53	8.4	8.09	3.67%
1% SF		1 : 1.54 : 2.53	8.63	8.21	4.79%
1.5% SF		1 : 1.54 : 2.53	8.77	8.18	6.72%
30% GGBS & 1% SF		1 : 1.54 : 2.53	7.95	7.52	5.4%

Table 6. Loss in weight due to sulphate attack

Specification (coral sand)	Chemical	Mix ratio	Avg. weight of specimens (kg)	Weight of specimens after 60 days (kg)	Loss in weight (%)
0% (Conventional concrete)	Na_2So_4	1 : 1.54 : 2.53	7.86	7.66	2.54%
10% GGBS		1 : 1.54 : 2.53	7.95	7.7	3.14%
20% GGBS		1 : 1.54 : 2.53	8	7.7	3.75%
30% GGBS		1 : 1.54 : 2.53	7.84	7.54	3.82%
40% GGBS		1 : 1.54 : 2.53	7.93	7.61	4.03%
0.5% SF		1 : 1.54 : 2.53	8.1	7.85	3.08%
1% SF		1 : 1.54 : 2.53	7.78	7.48	3.85%
1.5% SF		1 : 1.54 : 2.53	7.93	7.58	4.41%
30% GGBS & 1% SF		1: 1.54 : 2.53	7.89	7.59	3.8%

fiber in concrete to produce a better concrete. The following conclusion are made for GGBS at 30% and 1% Steel fiber with respect to conventional concrete.

1. The compressive strength and Split tensile strength of concrete increased about 22% and 20% respectively.

2. Considering all the test results it can be said that for M25 mix, 30% replacement of cement by GGBS and 1% Steel fiber is considered as optimum.

3. The partial replacement of cement by GGBS not only provides the economy in construction but it also utilization of the GGBS which is generated in huge quantities.

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