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Research Paper

STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE WITH GGBS AND STEEL FIBRE

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This paper deals with the experimental investigation on concrete specimens. The size of the cube specimen 150 mm x 150 mm x 150 mm. The replacement materials of GGBS 20% by cement and Steel Fibre 1% by cement, high range water reducing admixture Conplast SP-430 is used for maintaining workability. Experimental results are reported including compressive strength of concrete specimens at 28 days, 56 days and 90 days, flexure strength and elastic modulus of concrete for 28 days of curing and also to analyse the durability characteristics of concrete for conventional concrete and the combination of GGBS and steel fibre concrete. The specimens are planned to test including the cubes under static incremental loading in compressive, flexural and elastic behaviour of respective specimens. The result obtained by the replacement materials for compressive strength, flexural strength and elastic modulus is compared with conventional concrete.

Keywords: Ground granulated blast furnace slag, Conplast SP-430 and hook ended steel fibre, Mechanical properties, Durability properties

INTRODUCTION

Concrete is a composite construction material composed of cement and other cementitious materials such as fly ash and slag cement, aggregate generally a coarse aggregate, fine aggregate and water and chemical admixtures. Ground Granulated Blast Furnace Slag is a non-metallic by-product produced in the process of iron making (pig iron) in a blast furnace and 300 kg of Blast furnace slag is generated when 1 ton of pig iron produced. In India, annual productions of pig iron is 70-80 million tons and corresponding blast furnace slag are about 21-24 million tons. Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10 and does not present a corrosion risk to steel in pilings or to steel embedded in concrete made with blast furnace slag cement or aggregates. The blast

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furnace slag could be used for the cement raw material, the roadbed material, the mineral admixture for concrete and aggregate for concrete, etc. Now in India, resources of natural sand are very lacking, it is necessary that the new fine aggregate was sought. The property of blast furnace slag is similar to natural sand, the price is cheap and the output is large too, could be regarded as the substitute of the natural sand. Fibres are generally used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact abrasion, and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibre. The amount of fibres added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed "volume fraction" (V_f). (V_f) typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fibres length (l) by its diameter (d).

RESEARCH SIGNIFICANCE

- Many researchers have studied the properties of ordinary Portland cement concrete and fibre reinforced concrete using GGBS as cement replacement material.
- No researchers have made an attempt with addition of steel fibres to binary blended concrete using GGBS as mineral admixture.
- Moreover only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of steel fibres.
- Hence, this study focuses on the mechanical properties and durability properties of the blended concrete containing 20% of GGBS and 1% steel fibre as a partial replacement of OPC by volume.

METHODOLOGY

Materials Investigation

In present work various materials are used; OPC 53 Grade cement, GGBS, fine aggregate, coarse aggregate, steel fibre, Chemical Admixture and water. All the admixtures used in the research are used in real life applications and have been purchased which already exists on the market. The cement used in this study is OPC 53 grade with the specific gravity 3.080. It is governed by IS: 12269-1987. GGBS used in this experimental work is procured from Astraa Chemicals, Chennai. The Specific gravity of ground granulated blast furnace slag is 2.9 governed by IS: 10289-1987. Partially replace 20% ground granulated blast furnace slag by the volume of cement. Fine aggregate used in this present study with the following properties. The specific gravity of fine aggregate is 2.657. Fineness modulus is 2.432. Conforming to zone-III is governed by IS: 383-1970. Coarse aggregate used in this present study with the following properties. The specific gravity of Coarse aggregate is 2.739. Its fineness modulus is 7.435. The Nominal Size of Aggregate is 20 mm. It is governed by IS: 383-1970. Hooked end type of steel fibre is used for this present study. Aspect ratio (l/d) is 50, Diameter = 1 mm and Length = 50 mm. The specific gravity of hook ended steel fibre is 2.7. Hook ended steel fibre conforming to ASTM A820. Partially replace 1% steel fibre by the volume of cement. In Figure 2 steel fibre are shown. Super plasticizer or high range water reducing admixtures are an essential component for concrete. Conplast SP-430 was used as a super plasticizer with the standard specific gravity of 1.20. It is governed by IS: 9013-1999. Ordinary potable water was used. The pH value is not less than 8.0. Water conforming to as per IS: 456-2000.

Mix Proportions

By trial and error four mix proportions were done for conventional concrete and the details are given in Table 1 and the fourth mix was considered as the final mix for conventional concrete in this study. In this study four mixes for the replacement materials, i.e., CC, TM1, TM2 and TM3. The TM1 is CC plus 20% GGBS, TM2 is CC plus 1% Steel Fibre and the TM3 is CC plus 20% GGBS plus 1% Steel Fibre. The mix proportion for the replacement materials are given in Table 2.

Table 1: Detailed Mix Proportion of Conventional Concrete

Mix	I	I	III	IV
Ratio	1:1.36:2.66	1:1.69:3.39	1:1.87:3.66	02:03.8
Cement kg/m³	445.55	383.17	356.44	340.6
FA kg/m³	607.74	649.53	668.24	683.51
CA kg/m³	1189.45	1299.76	1307.85	1308.55
Water kg/m³	191.58	153.27	153.27	153.27
W/C	0.43	0.4	0.43	0.45
SP kg/m³	NIL	4.981	4.635	3.406
Slump mm	0	0	25	70

Table 2: Detailed Mix Proportion of Replacement Materials

Mix	Cement kg/m³	GGBS kg/m³	Steel Fibre kg/m³	Sp kg/m³	Slump mm
CC	340.6	-	-	3.406	70
TM1	272.48	68.12	-	2.724	52
TM2	337.19	-	3.41	3.371	67
TM3	269.07	68.12	3.41	2.69	58

Note: Mix Ratio = 1:2:3.84, FA = 683.51 kg/m³, CA = 1308.55 kg/m³, Water content = 153.27 kg/m³ and W/C = 0.45.

Properties of Concrete

Workability Test

The workability test is carried out by conducting the slump test as per IS 1199-1959 on three trial mixes with GGBS and steel fibre on ordinary concrete.

Compression Test

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 150 mm x 150 mm x 150 mm and cylinders of size 150 mm in diameter and 300 mm height.

The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm². The compressive strength can be determined using the formula given below in Equation 1.

$$f_{cu} = P_c/A \quad ...(1)$$

where,

f_{cu} = Compressive Strength of Specimen

P_c = Load in Compression

A = Area of Specimen

Flexure Test

The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100 mm x 100 mm x 500 mm the modulus of rupture can be determined by using the formula given below in Equation 2.

$$f_{cr} = (P_{max} \times l)/bh^2 \quad ...(2)$$

where,

f_{cr} = Flexural strength

P_{max} = maximum load in (N) kg.

b = width of the prism in mm

h = depth of the prism in mm

l = span of the prism in mm

The loading must be applied centrally and without subjecting the specimen to any torsional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

Elastic Modulus for Concrete

The Elastic Modulus for Concrete test is the most common test conducted on hardened concrete, partly because it is an easy test to perform. Concrete is not really an elastic material, i.e., it does not fully recover its original dimensions upon unloading. Hence, the elastic constants are necessarily considered for conventional design of reinforced concrete structures. The young's modulus of elasticity is a constant defined as the ratio, within the linear elastic range, of axial stress to axial strain under uniaxial loading. In the case of concrete under uniaxial compression, it has some validity in the very initial; portion of stress- strain curve, which is particularly linear, i.e., when the loading is of low intensity and of very short duration. If the loading is sustained for very long duration, inelastic creep effects come into play, even at relatively low stress levels. This test is normally conducted by using the cylinder specimens of size 150 mm x 300 mm.

Rapid Chloride Penetration Test

The test set up is called Rapid Chloride Penetration Test (RCPT) assembly. This is two-compartment cell assembly. Disk specimen is assembled between the two compartments cell assembly and checked for air and water tight. In the (ASTM C1202) test, a water-saturated, 50 mm thick, 100 mm diameter concrete specimen is subjected to a 60 V applied DC voltage for 6 hours using the RCPT apparatus. In one reservoir is a 3.0% NaCl solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as in Table 3 given below.

Table 3: Recommended Values from ASTM C1202

Charge Passed (Coulombs)	Chloride ion Penetrability
>4000	High
2001-4000	Moderate
1001-2000	Low
100-1000	Very Low
<100	Negligible

The resistance to chloride penetration is one of the simplest measurements to determine the durability of concrete. Separate specimens of similar size were cut from the same cylinder for conducting RCPT test and the test duration was 6 hours, so that the coefficient of chloride penetration is compared for each mix. The RCPT test was conducted on saturated and surface dry specimens.

Calculation

The calculation for the RCPT test is done by using the Equation 3 given below.

$$Q = 900[I_0 + 2I_{30} + 2I_{60} + ... + 2I_{330} + 2I_{360}] \quad ...(3)$$

where,

Q = Charge passed (coulombs)

I_0 = Current (Amperes) immediately after voltage is applied.

I_t = Current (Amperes) at t min voltage is applied.

Sulphate Attack

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water and those which are not immersed in sulphate water. The concrete cubes of 150 mm size after 28days of water curing and dried for three days were immersed in 5% Na_2SO_4 and 5% $MgSO_4$ added water for 30 days. The concentration of sulphate water of 7 was maintained throughout the period. After 30 days immersion period, the concrete cubes were removed from the sulphate waters and after wiping out the water and girt from the surface of cubes tested for compressive strength following the procedure prescribed in IS: 516-1959.

Acid Attack

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for three days. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 30 days after 28 days of curing. Hydrochloric acid (HCl) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were placed. The pH was maintained throughout the period of 30 days. After 30 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive Strength on immersing concrete cubes in acid water.

Water Absorption Test

The water absorption values for various mixtures of concrete were determined on 150 mm x 150 mm x 150 mm cubes as per ASTM C 642. The specimens were taken out of curing tank at 28 days to record the water saturated weight (Ws). The drying was carried out in an oven at a temperature of 105 °C. The drying process was continued until the difference between two successive measurements agreed close. Oven-dried specimens were weighed after they cooled to room temperature (Wd). Using these weights, saturated water absorption (SWS) was calculated. The formula used to find water absorption value of concrete specimens is given in equation.

$$SWA = [(Ws - Wd)/Wd] \times 100 \quad ...(4)$$

where,

SWA – Saturated Water Absorption in percentages

W_s = Weight of the specimen at fully saturated condition in kg

W_d = Weight of oven dried specimens in kg.

RESULTS AND DISCUSSION

Compression test Results

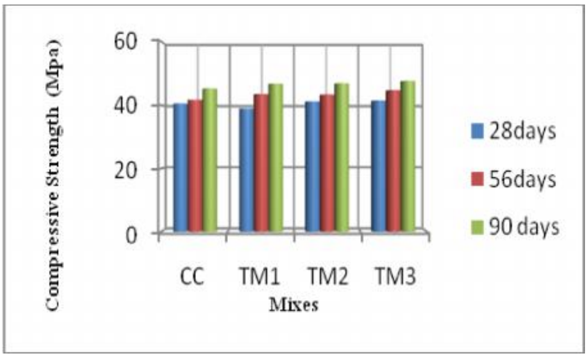
The results of compressive strength for M30 grade on concrete by the average of three cubes. The specimens are separated by three trial mixes with

GGBS and steel fibre. The Table 4 gives the variation of compressive strength at 28 days, 56 days and 90 days curing.

Table 4: Comparison of Compression Test

Mix	Average Compressive Strength (Mpa)		
	28 days	56 days	90 days
CC	40.52	41.7	45.24
TM1	38.97	43.46	46.72
TM2	41.17	43.33	46.84
TM3	41.43	44.7	47.58

Figure 1: Comparison of Compression Test at 28 days, 56 days and 90 days



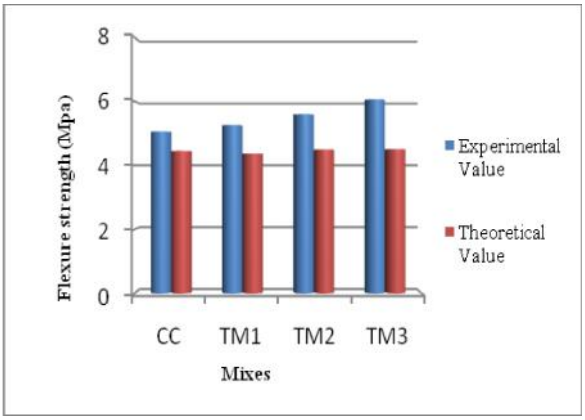
Flexure Test Results

The results of flexure strength for M30 grade on concrete on prism. The specimens are separated by three trial mixes with GGBS and steel fibre. The Table 5 gives the variation of flexure strength @ 28 days curing.

Table 5: Variation of Flexure Test

Mix	Flexure Strength (Mpa)	
	Experimental Value	Theoretical Value
CC	5.06	4.45
TM1	5.26	4.36
TM2	5.6	4.49
TM3	6.06	4.5

Figure 2: Variation of Flexure Test Results



Elastic Modulus of Concrete Results

The results of Elastic Modulus of Concrete for M30 grade on concrete on cylinder. The specimens are separated by three trial mixes with GGBS and steel fibre. The Table 6 gives the variation of flexure strength @ 28 days curing.

Table 6: Variation of @ Elastic Modulus of Concrete 28 days

Mix	Elastic Modulus of Concrete (Gpa)	
	Experimental Value	Theoretical Value
CC	33.85	31.82
TM1	34.57	31.21
TM2	34.87	32.08
TM3	35.69	32.18

Figure 3: Variation of Elastic Modulus of Concrete @ 28 days

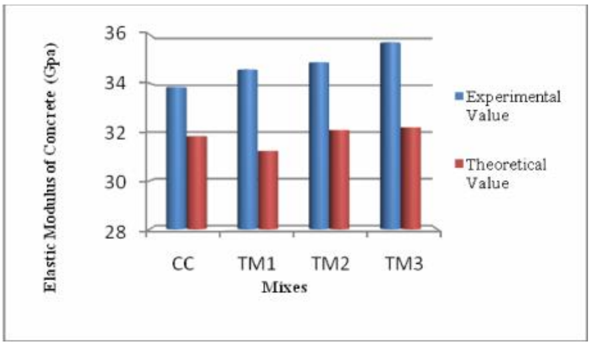
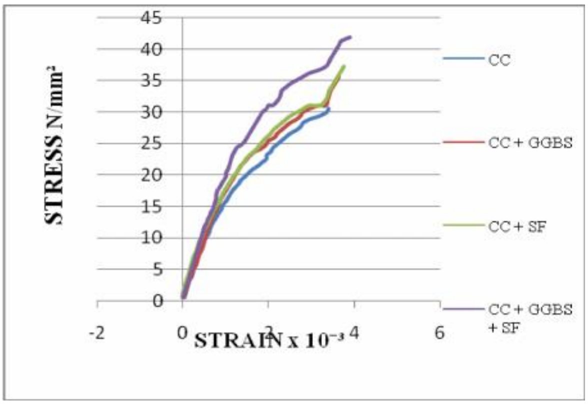


Figure 4: Stress Strain Curve for Various Mixes



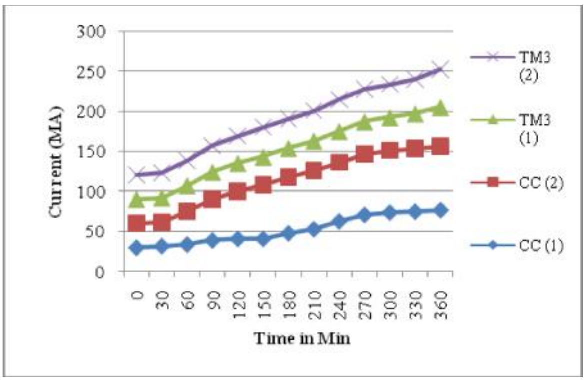
Rapid Chloride Penetration Test Results

The results of RCPT for M30 grade on CC AND TM3 concrete on cylinder. The Table 7 gives the test results for RCPT test.

Table 7: Variation of RCPT Test Results

S. No.	Mix	Cumulative Current in (MA)	Charge Passed in Coulombs	Remarks
1	CC	753	1355.4	Low
		883	1589.4	Low
2	TM3	531	955.8	Very Low
		532	957.6	Very Low

Figure 5: Variation of RCPT Test Results for 6 hours



Sulphate Attack Results

The results of sulphate attack on CC AND TM3 concrete are given in the Table 8.

Table 8: Sulphate Attack Results

Mix	Initial Weight (gm)	Weight After Sulphate Attack (gm)	Loss in Weight (%)	Average Loss in Compressive Strength (%)
CC	8547	8515	0.37	18.31
	8586	8556	0.34	
	8602	8578	0.27	
TM3	8672	8651	0.24	7.94
	8716	8698	0.2	
	8643	8618	0.28	

Figure 6: Variation of Sulphate Attack Results

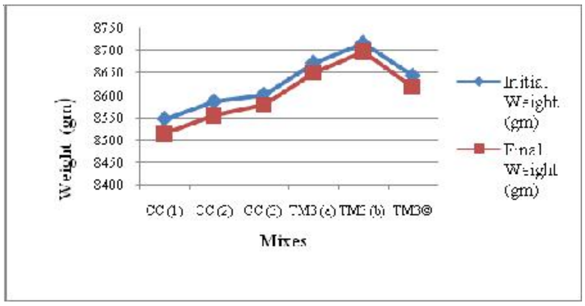
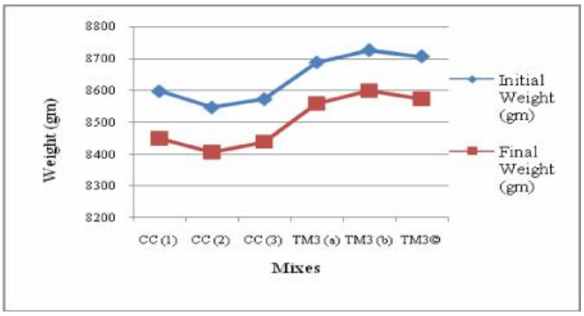


Table 9: Acid Attack Results

Mix	Initial Weight (gm)	Weight After Acid Attack (gm)	Loss in Weight (%)	Average Loss in Compressive Strength (%)
CC	8597	8448	1.7	21.15
	8546	8405	1.64	
	8572	8438	1.56	
TM3	8688	8558	1.49	10.45
	8726	8598	1.46	
	8707	8572	1.55	

Figure 7: Variation of Acid Attack Results



Acid Attack Results

The results of acid attack on concrete on cubes are shown below. The specimens are separated by one trial mix with GGBS and steel fibre. The Table 9 gives the test results.

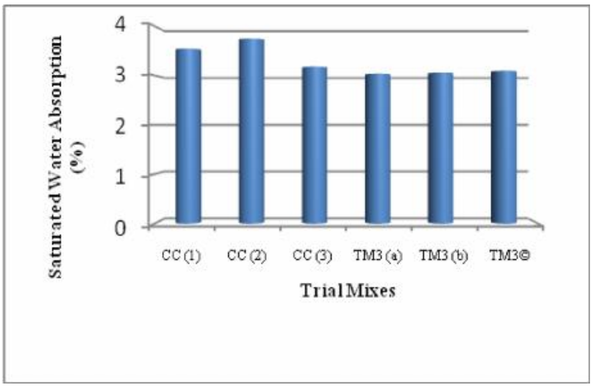
Water Absorption Test Results

Water absorption test results of cc and tm[3] concrete given in Table 10.

Table 10: Water Absorption Test Results

Mix	Saturated Weight (gm)	Dried Weight (gm)	Saturated Water Absorption %	Average Loss in Compressive Strength (%)
CC	8552	8260	3.535	34.94
	8209	7913	3.74	
	8381	8123	3.176	
TM3	8556	8304	3.034	13.56
	8700	8442	3.056	
	8628	8369	3.094	

Figure 8: Variation of Water Absorption Test Results



CONCLUSION

The study on the effect of steel fibre with GGBS can still be a promising work as there is always a need to overcome the problem of weakness of concrete.

The following conclusions are made from the present research.

- Marginal increase is observed in the workability, when adding GGBS and steel fibre in ordinary concrete.
- Super plasticizer is required for workable mix because of the addition of GGBS and Steel fibre.
- The compressive strength of the specimen is reached 95-100% at 28th day curing because of the addition of GGBS and steel fibre.
- The marginal increase of 1-7% in compressive strength at 28 days, 8-18% in compressive strength at 56 days and 25-66% in compressive strength at 90 days after attaining the full strength due to the addition of the combination of 20% GGBS and1% steel fibre in the ordinary concrete.
- The TM1 shows better increase in compressive strength from 28 days to 56 days because GGBS is pozzalonic material its early age strength is low and gives good result in later stage.
- The TM3 gives better increase in compressive strength when comparing the other two mixes in 28 days, 56 days and 90 days.
- There is a marginal increase of flexural strength around 25-66% after attaining the full strength due to the addition of the combination of 20% GGBS and 1% steel fibre in the ordinary concrete.
- The elastic modulus of concrete shows better increase in strength upto 15-28% after attaining the full strength of concrete.
- The RCPT test shows that the CC has low chloride permeability and the TM3 has very low chloride permeability.
- The sulphate attack shows that the loss in weight of about 0.2-0.37% and the loss in

compressive strength of about 7-18%. The acid attack shows that the loss in weight of about 1.4-1.7% and the loss in compressive strength of about 10-21%.

- The durability test results of TM3 shows very low loss in weight and compressive strength when compared to CC.
- The water absorption test shows that the saturated water absorption is from 3-3.5% and the loss in compression test in from 13-34.94%.
- From all the above mechanical and durability results the TM3 shows better result when compared to other mixes.

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