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Experimental study on Strength and Durability characteristics of Ground Granulated blast furnace slag(GGBS) concrete Mix 50.

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ABSTRACT

The environment is being degraded due to the activities of human beings which are necessitated by the construction field (buildings, road, canals, dams, etc.), which is fast depleting the natural virgin sand lining the river bed. As a result there is urgent need to find an alternate material, which is considered to be a waste product to replace these materials because the disposal of the waste product such as GGBS. A twofold compensate on towards the conservation of environment takes place when a waste materials such as GGBS is used for construction purpose. Thus, it is imperative that more studies and experiments be conducted on such waste products which serve as viable replacement for natural materials. The current paper focus mainly on the experimental findings of strength and durability of M50 grade concrete with partial replacement of GGBS.

Key words: *Blast furnace slag, Concrete, Flexural strength, Durability.*

1. INTRODUCTION

Concrete, over years has proved to be one of the most indispensable materials for civil engineers, considering the quantity of concrete that goes into every construction. We are now at a time when the world has felt the need to live a greener and cleaner life. Having said that, the carbon footprint that goes during the production of cement is quite enormous, thereby making it a significant contributor of greenhouse gases.

The environment is being degraded due to the activities of human beings which are necessitated by the construction field (buildings, road, canals, dams, etc.), which is fast depleting the natural virgin sand lining the river bed. As a result there is urgent need to find an alternate material, which is considered to be a waste product to replace these materials because the disposal of the waste product such as GGBS. A twofold compensate on towards the conservation of environment takes place when a waste materials such as GGBS is used for construction purpose. Thus, it is imperative that more studies and experiments be conducted on such waste products which serve as viable replacement for natural materials.

1.1 Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag (GGBS) is the slag from iron delivering blast furnaces that is quickly extinguished in water and after that ground into a powder. Synthetically it is like, yet less responsive than, Portland concrete (Pc).

At the point when blended with water it will hydrate likewise to Portland bond. It is constantly utilized as a part of mix with Portland concrete, normally in the range 60% Pc and 40% ggbs to 30% Pc and 70% ggbs, contingent upon the application.

Another significant obstacle of broad utilization of GGBS solid lies in the little wellspring of supply of GGBS. As Hong Kong is not a noteworthy maker of steel, GGBS as a by-result of steel must be foreign made abroad and this acquaints higher material cost due with transportation and the supply of GGBS is shaky and flimsy

Following are the technical benefits, which GGBS imparts to concrete:

1. Widely used in mass concreting as it has low heat of hydration.
2. Increase in long term strength.
3. Considerable sustainability benefits.

Table 1.1: Chemical compositions of GBFS
(Source: JSW CEMENT LTD.)

Sl. No.	Chemical Composition	Mass (%)
1	SiO_2	30.2
2	Al_2O_3	19.6
3	CaO	35.2
4	MgO	9.26
5	SO_2	0.27
6	MnO	0.5
7	Fe_2O_3	0.6

1.2 Properties

Being a processed material, GGBS has some inherent properties, few of which are listed as under: (Source: Slag cement association)

Strength: The main hydration product of GGBS is same as Portland cement that is calcium-silica-hydrate, which is the major chemical compound providing strength to harden state.

With a similar substance of cementitious, comparative 28-day qualities to Portland bond will ordinarily be accomplished when utilizing something like 50 percent GGBS. At higher GGBS rates the cementitious substance may should be expanded to accomplish equal 28-day quality. GGBS solid additions quality more consistently than proportionate cement made with Portland bond

Early age temperature rise: Supplanting of Portland concrete with GGBS decreases temperature increment and avoids early-age warm breaking. The higher the rate of GGBS, the lower the rate at which warm creates and the littler the expansion in the most extreme temperature.

Colour: The delicate granulated round grain is white and generously lighter than Portland concrete. This is likewise observed as white cement is made with GGBS, particularly half additional speed percent and from that point.

1.3 Objectives

Having clearly identified the materials and their advantages as mentioned earlier, the objectives of this project were laid down based on criteria of adaptability and practicability. Following are the defined objectives:

1. To characterise the unconventional materials i.e. GGBS and to compare with conventional ingredients of concrete
2. To study the influence of GGBS on strength development and workability of concrete and compare the results with concrete of natural sand and cement respectively.
3. To assess the concrete produced using GGBS at different levels of replacement to the cement and to compare the results with conventional concrete mix along with durability test.
4. To conduct a cost comparison of concrete produced with or without GGBS in different proportions.
5. To make conclusion based on the present study and recommend the research areas.

1.4 Need for the Study

1. Conveying the overall effectiveness of GGBS and cement respectively.
2. To see scope for use of industrial by-product in the production of concrete in all possible aspects including practical ability, economic feasibility and ecological benefits.
3. Reasonably come out with an optimum combination of various ingredients which can produce green concrete from the point of sustainability and economy.
4. The reason for the venture is to highlight the utilization of non-regular materials for the readiness of solid, which highlights the points of interest.

2. SCOPE OF PRESENT WORK

Mix design of concrete M50 grade has made as per IS code regulations of conventional concrete, to reduce the water content a super plasticizer is used. Proportioning of concrete with substitute materials has made, GGBS replaced to cement by 20,

35, and 50%. The individual material properties have to been studied. The main fresh property- workability has to be tested by slump test and appropriate inferences were drawn. The mechanical properties such as compressive strength of concrete, split tensile strength, and modulus of elasticity of concrete mixes were determined. Compressive the strengths were determined at 3, 7 & 28, split tensile strength and modulus of elasticity was determined at 28 days. And due considerations were to be made, and results are presented in this report.

3. MATERIAL PROPERTIES AND MEHODLOGY

3.1 Material Properties

3.1.1 Introduction

The materials used in the making of concrete have equally diverse properties and behaviour. The properties of these materials were determined in the laboratory as per standard specifications, results of which given in table below,

3.1.2 Cement

Ordinary Portland Cement (OPC) of 53 grade is used. The properties are determined as per IS: 4031-1988 and the test results are presented in

Table 3.1: Properties of Cement

Sl. No.	Properties	Test Results	Requirements as per IS: 8112-1989
1	Standard Consistency, %	31.50	No standard value
2	Initial setting time, minutes	38	30 (minimum)
3	Final setting time, minutes	480	600 (maximum)
4	Specific gravity	3.1	No standard value
5	Fineness of Cement, %	5.3	10 (maximum)

Table 3.2: Properties of Coarse aggregate

Properties	**Coarse Aggregate**
Specific Gravity	2.63
Aggregate Crushing Value, %	27.89
Los Angeles Abrasion Test, %	27
Aggregate Impact value, %	24.99
Flakiness and Elongation index, %	27
Bulk Density (kg/m^3) Dry loose Dry compact	 1495 1658

3.1.5 Super Plasticizer

Conplast SP430 is a chloride free, superplasticising admixture in view of chose sulphonatednapthalene polymers. It is provided as a dark colored arrangement which immediately

Table 3.3: Properties of Conplast SP 430

(Source: FOSROC Chemicals (India) Ltd.)

Specific Gravity	1.20-1.25
Chloride Content	Nil
Solid content	40%
Recommended dosage	5ml to 20ml/kg of binder
Operating Temperature	10 to 40°C
Colour	Dark brown liquid

3.1.6 Ground Granulated Blast Furnace Slag (GGBS)

The GGBS was obtained from JSW Cements. The properties are determined as per IS: 12089-1987 and the test results are presented in Table 3.5.

Table 3.4: Properties of GGBS

Sl. No.	Properties	Test Results
1	Specific gravity	2.87
2	Standard Consistency, %	34%
3	Initial setting time, minutes	128
4	final setting time, minutes	277
5	Soundness, Lechatelier's value, mm	1.5

3.2 Experimental Work on Concrete

3.2.1 Introduction

Mix design of concrete was made as per IS code regulations of conventional concrete. On similar lines, proportioning of concrete with substitute materials was made. The individual material properties have been studied and as mentioned earlier. The main fresh property- workability was tested and appropriate inferences were drawn. Workability for designed concrete mix was measured in terms of slump as per IS guidelines. The compressive strength of concrete was determined by casting cubes of dimensions 100 x 100 x 100 mm. split tensile strength was carried out on cylindrical specimens of size 100mm dia. and 200mm length. also the flexural strength was determined by casting by rectangular prism of size 100 x 100 x 500 mm. modulus of elasticity of concrete mix determined by casting cylindrical specimens of size 150mm dia. and 300 mm length. Compressive the strengths were determined at 3, 14 and 28 days. Flexural strength, split tensile strength and modulus of elasticity was determined at 28 days.

3.2.2 Concrete Mix Design

M50 concrete mix is designed for this study as per IS: 10262-2009 with following design stipulations.

Table 3.5: Concrete mix design

Unit of batch	Water (Litters)	Cement (Kgs)	FA (Kgs)	CA (Kgs)
Per Cubic meter of concrete	168	440	668	1139
Ratio of ingredients	0.37	1	1.52	2.6

Concrete Mix Proportions

Ordinary Portland cement, GGBS, coarse aggregate and water are the materials used. The proportions considered for M50 concrete is presented in Table 3.7 for w/c 0.37, fifteen concrete mixtures with different replacement levels were cast. i.e., 0%, 20%, 35% and 50% of cement by GGBS. All experiments were done at room temperature.

3.2.3 Compression Test

Its most needed test for all concrete samples to determine how the concrete will act under this loading condition. The cubes which is casted of standard size are taken out after 28 days of curing and kept for drying. The area of cube is noted and kept in machine such a manner that the top face is perpendicular to compaction done. Load at failure is noted down and the compressive strength of sample was figured by the accompanying equation:

3.2.4 Tensile Test

Tensile strength is an essential property of concrete since solid structures are profoundly helpless against pliable splitting because of different sorts of impacts and connected stacking itself. Because of trouble in applying uniaxial pressure to a solid example, the elasticity of the solid is dictated by indirect test techniques.

1. Split Tensile Test
2. Flexure Test

1) Split Tensile Test

Tensile test is done to decide the tensile characteristic of concrete in a roundabout way. This test could be performed as per IS: 5816-1970. A standard test specimen is 300 mm in tall and 100mm in dia. is set on a level plane between the stacking surfaces of pressure testing machine as shown in fig 3.11.As the load is applied the cylindrical samples starts to split along its

longitudinal axis. The load at failure is noted down and the tensile strength is calculated, which can be figured from the equation as,

2) Flexural Test

The specimen of size 100×100×500 mm was casted for to determine flexural strength test. Two point load method is used to test the beam specimen with an effective span of 400 mm as per the IS 516-1959

4. RESULTS AND DISCUSSIONS

4.1 Workability

The workability of fresh concrete is a very important factor of consideration in any construction. In this project, the workability of every mix was measured in terms of slump. The result presented in Table 4.1 and is graphically represented in Figure 4.1.

Table 4.1: Variation of slump and at different levels of cement replacement with GGBS.

Cement replacement in % with GGBFS			
0%	**20%**	**35%**	**50%**
100	130	140	145

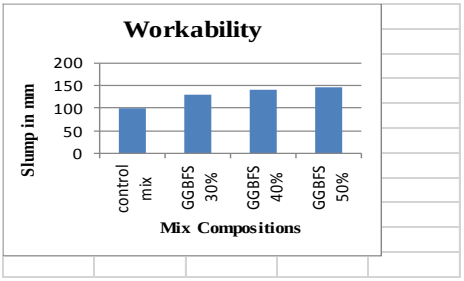

Fig. 4.1: Variation in slump by partial replacement of cement by GGBFS

Typical concrete mix design for M50 grade of concrete was made as per IS: 10262-2009 using GGBFS taking the appropriate material properties. For workability slump test was conducted and the results obtained are shown in Table 4.1. The designed slump (100mm) was achieved in case of concrete with natural sand and cement.

When GGBS is replaced to cement there is marginal increase in workability, the increase in workability is about 30, 40, 45% as shown in figure 4.1 this might be due to lower water demand and fineness of slag. In the mix with GGBS workability has not much affected, there is increase in workability for all combinations then the control mix. This decrease or increase in workability can be compensated by adding proper dosage of suitable chemical admixtures.

4.2 Density Test

Table 4.2: Variation density at different combinations of partial replacement of cement with GGBS

Combination	**Density kg/m^3**
	28thday
Control Mix	2413
GGBS 20%	2410
GGBS 35%	2413
GGBS 50%	2414
GGBS 0%	2413
GGBS 0%	2413
GGBS 0%	2413
GGBS 20%	2411

GGBS 20%	2314
GGBS 20%	2313
GGBS 35%	2413
GGBS 35%	2413
GGBS 35%	2420
GGBS 50%	2418
GGBS 50%	2418
GGBS 50%	2416

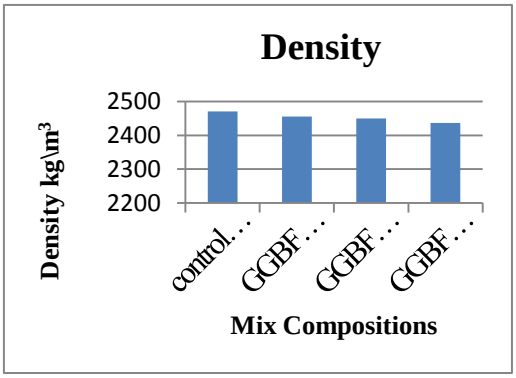

Fig. 4.2: Variation of Density at different combinations of partial replacement of cement by GGBFS

The density concrete with natural sand and OPC was found to be 2413 kg\m^{3}at 440 kg/m³ of cement. GGBS when used as a replacement to cement at 20, 35 an 50% with the variation of density at different levels of replacement.it is seen that the density deceased with increase in GGBS content, it is possible since the specific gravity of GGBS is lower than that of cement., it is due to rough finish and large surface area hence binding is more. When GGBS is replaced for cement there is marginal decrease in density for all percentage of variation as shown in fig 4.2, this might be due to dense partial packing.

Table 4.3: Variation of Compressive strength at different combinations of partial Replacement of cement with GGBFS

Combination	Compressive strength MPa		
	3thday	7thday	28thday
Control Mix	52.00	49.50	51.60
GGBFS 20%	49.33	49.60	53.75
GGBFS 35%	50.17	52.52	56.77
GGBFS 50%	48.12	49.24	54.16
GGBFS 0%	53.75	48.76	55.19
GGBFS 0%	55.70	49.71	57.36
GGBFS 0%	50.12	46.77	53.81
GGBFS 20%	51.90	50.36	54.28
GGBFS 20%	55.01	52.78	58.57
GGBFS 20%	50.38	46.21	56.39
GGBFS 35%	55.45	56.36	61.30
GGBFS 35%	56.98	58.41	64.95
GGBFS 35%	54.37	52.27	63.71
GGBFS 50%	53.80	54.10	60.51
GGBFS 50%	55.14	56.34	61.97
GGBFS 50%	51.06	50.18	58.20

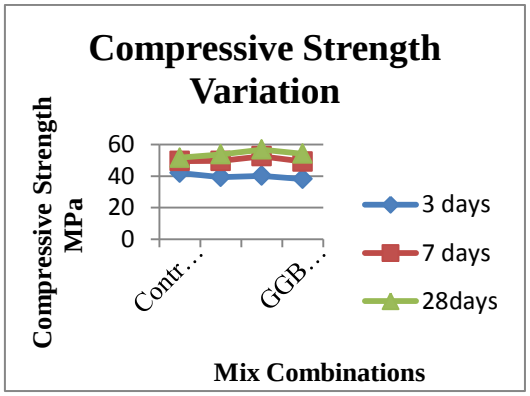

Fig. 4.3: Compressive strength variation

4.3.2 Shear Strength

Table 4.4: Variation of Shear strength at different combinations of partial Replacement of cement with GGBFS

% of GGBS	Load at Failure (kN)	Shear Strength	Average in(Mpa)
0	95	3.8	4.0
	95	3.8	
	110	4.4	
20%	100	4.2	4.6
	120	4.8	
	118	4.7	
35%	120	4.8	4.9
	128	5	
	125	4.9	
50%	118	4.7	4.6
	115	4.6	
	110	4.4	

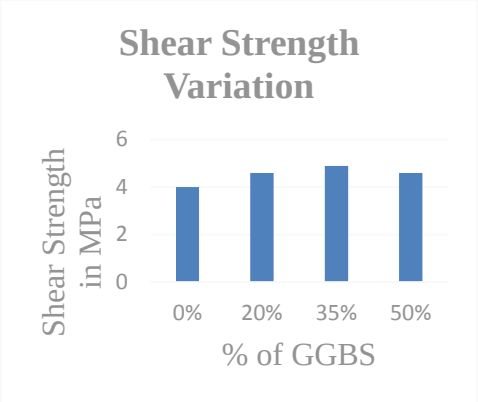

Fig 4.4: Variation of Shear strength

4.3.3 Split Tensile Strength

The split tensile strength result presented in Table 4.5 and is graphically represented in Figure 4.5, From the results it can be seen that GGBS 35% replacement has higher tensile property,

Table 4.5: Variation of Split tensile strength at different combinations of partial replacement of cement with GGBS

Combination	Split tensile strength MPa
	28thday
Control Mix	3.18
GGBS 20%	3.29
GGBS 35%	3.39
GGBS 50%	3.16
GGBS 0%	3.22
GGBS 0%	3.28
GGBS 0%	3.16
GGBS 20%	3.24
GGBS 20%	3.35
GGBS 20%	3.27
GGBS 35%	3.46
GGBS 35%	3.57
GGBS 35%	3.51
GGBS 50%	3.42
GGBS 50%	3.49
GGBS 50%	3.38

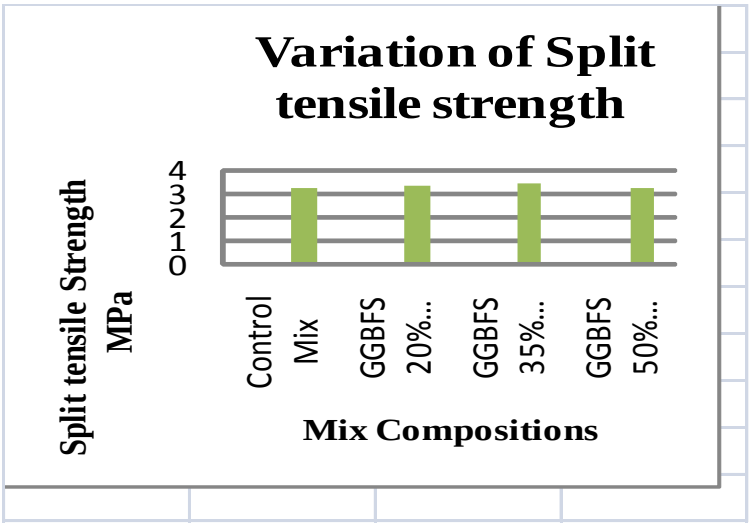

Fig. 4.5: Variation of Split tensile strength at different combinations by partial replacement of cement with GGBS

4.3.4 Flexural Strength

The flexural strength results presented in Table 4.6 and are graphically represented in Figure 4.6. From the table it can be seen similar trends as seen in compression and split tensile strength, GGBFS 40% and GBF Slag sand 50% has more flexural property then other replacement percentages, in combined mixes mix with 35% GGBFS and 50% GBF Slag sand got more flexural strength.

Table 4.6: Variation of Flexural strength at different combinations of partial replacement of cement with GGBFS

Combination	Flexural strength MPa
	28^{th}day
Control Mix	4.6
GGBS 20%	4.33
GGBS 35%	4.67
GGBS 50%	4.47
GGBS 0%	5.4
GGBS 0%	5.6
GGBS 0%	5.4
GGBS 20%	5.2
GGBS 20%	5.53
GGBS 20%	4.97
GGBS 35%	5.28
GGBS 35%	5.44
GGBS 35%	4.86
GGBS 50%	4.55
GGBS 50%	5.28
GGBS 50%	4.89

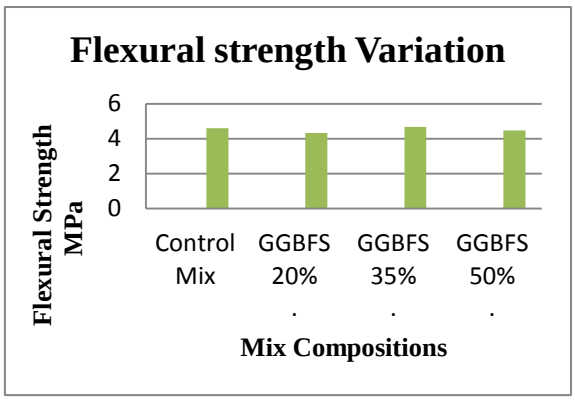

Fig. 4.6: Variation of Flexural strength at different combinations of partial replacement of cement by GGBS

5. MIX PROPORTIONS

a) Cement = 440 kg/m^3
b) Fine Aggregate = 668 kg/m^3
c) Coarse Aggregate = 1139 kg/m^3
d) Water = 168 kg/m^3
e) W / C Ratio = 0.37
f) Chemical admixture = 3.3 kg/m^3

Mix proportion: 1: 1.52: 2.6: 0.37

6.CONCLUSIONS

In this review, an attempt was made to build up the appropriateness of utilization of GGBS as a substitution to bond. Considering the realities and results expressed before, the accompanying conclusions were drawn.

- The quality of GGBFS cement is lower in early ages, yet increment in last stages, there is increment in compressive quality of around 13% contrasted with control blend at 28 days for 35% substitution. Likewise flexural and split elastic esteem expanded by 7% and 2% separately at 35% substitution, subsequently half substitution can be worried as ideal substitution level.
- The concrete with 35% GGBS has higher quality contrasted with different blends, henceforth it is considered has ideal blend, with economy savvy it has 15% lessening in cost.

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