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Experimental Investigation of GGBS Incorporated Concrete in the Aspect of Compression and Flexural Strength with M-Sand as Fine Aggregate

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Abstract--- *To make concrete as Eco-friendly material and to reduce the carbon footprint on the environment, in this research work river sand is replaced fully with crushed sand (Manufactured Sand/M-Sand) and Ground Granulated Blast Furnace Slag (GGBS) which is replaced partially with cement. Ground Granulated Blast Furnace slag is an industrial waste material which is obtained from the manufacturing industries of iron. By replacing the GGBS partially the strength of concrete can be enhanced and the durability property of the concrete also enhanced with partial replacement GGBS in Ordinary Portland Cement, the alkali-silica reaction can be alleviated. This is achieved by limiting the cement content of the concrete mix and thereby limiting the sum of alkali content in the concrete mix. GGBS is replaced in cement from 40% to 70% with a constant increment of 5%. By experiment, the study on workability, compression strength and flexural strength of concrete is investigated.*

Keywords--- *Ground Granulated Blast Furnace Slag (GGBS), High Strength Concrete, Manufactured Sand, GGBS Concrete, GGBS Cement.*

I. INTRODUCTION

Concrete is a major part of the building, which plays a very important role in the environment. All the base material of concrete-like fine aggregate, binding material, coarse aggregate are major contributors to carbon emission. In the aspect of Eco-friendly material, in this experimental work usual fine aggregate river sand is fully replaced with Manufactured sand/M-Sand and in binding material cement, Ground Granulated Blast Furnace Slag (GGBD) is partially replaced from 40% to 70% with the increment of 5%. For this research work, we have used High strength concrete of grade M50 by using OPC grade 43. By replacing the river sand, rivers can be preserved and groundwater levels can be increased and depletion can be controlled. The Ground Granulated Blast Furnace Slag is the industrial waste material, which is formed in the manufacturing process of iron and by replacing the GGBS with cement, the durability of concrete can be increased. The alkali-silica reaction can be alleviated by replacing of GGBS with cement, removal of cement content by replacing the GGBS will decrease the alkali content in the concrete(1).

Objective

- To study the strength parameter of GGBS incorporated concrete
- To study the alternative materials which can be partially replaced in cement

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- To study about the Manufactured Sand/M-Sand replaced concrete strength
- To reduce the carbon footprint using ground granulated blast furnace slag
- To study the workability of GGBS incorporated concrete

II. MATERIAL PROPERTIES

For this research work, Cement of Grade OPC 43 is used as binding material, Crushed Stone Sand/Manufactured Sand is used as Fine aggregate, Crushed hard blue granite of ISS 20mm was used as coarse aggregate, portable water is used for the whole concrete work, CONPLAST SP430 was used as a super plasticizing chemical admixture. All the above-stated materials are tested to confirm that all the materials having the required properties.

Cement

Ordinary Portland cement of 43 grade was used for this research work. The physical properties and

Compressive strength of the cement were tested and test results are given in

Tables 1 and 2.

Table 1: Physical Properties of Concrete

Physical Properties	**Values**	**Requirement as per IS 8112-2013**
Specific Gravity	3.15	-
Fineness	270.80 m^2/kg	Minimum 225 m^2/kg
Initial Setting Time	41 minutes	Minimum 30 minutes
Final Setting Time	265 minutes	Maximum 600 minutes
Soundness (Le Chatelier Test)	1 mm	Maximum 10 mm

All the above test results are within the limit which is mentioned under IS 8112-2013, Ordinary Portland Cement, 43 Grade – Specification (2).

The grade of concrete is tested by casting the cement mortar cubes. A total of 9 numbers of cubes is cast for testing purposes. For every 3 days, 7 days and 28 days, 3 Cubes are tested for compression test and mean compressive strength is identified, test results are tabulated in Table 2.

Table 2: Compressive Strength of Cement

Age of Cement Mortar Cube	**Mean Compressive Strength, N/mm^2**	**Requirement as per IS 8112-2013**
3 Days	24.01	Minimum 23 N/mm^2
7 Days	34.35	Minimum 33 N/mm^2
28 Days	45.69	Minimum 43N/mm^2

The physical properties and compressive strength of Ordinary Portland Cement are identified by the testing procedure which is stipulated under IS 4031: Hydraulic Cement - Methods of Physical Tests

Fine Aggregate

Crushed stone sand/M-Sand was used as a fine aggregate in this research work. The specific gravity of crushed stone sand was 2.540. The sieve analysis test was conducted on crushed sandstone.

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Table 3: Sieve Analysis of Fine Aggregate

Sieve Size (mm)	Percentage of Passing, %	Percentage Passing Limits
4.75 mm	100.00	90-100
2.36 mm	93.47	75-100
1.18 mm	66.60	55-90
600 microns	49.14	35-59
300 microns	27.62	8-30
150 microns	7.58	0-10

From the sieve analysis, it is confirmed that the results of crushed stone sand/M-Sand, are within the limit which is specified under the IS 383-2016: Coarse and Fine Aggregate for Concrete Specification. The sampling for the test was done with the accordance with the IS 2430-1986: Methods of Sampling of Aggregate for Concrete. The testing method for sieve analysis is followed with the reference to the IS 2386-1963: Methods of Test for Aggregate for Concrete.

Coarse Aggregate

The graded aggregate of crushed hard blue granite of size 20 mm was used as a coarse aggregate. The specific gravity of the coarse aggregate was 2.674. The sieve analysis test was conducted on the coarse aggregate with the reference made in IS 2386-1963: Methods of Test for aggregate for Concrete and the sampling of material for the test was done with the accordance with IS 2430-1986: Method of sampling of aggregate for concrete.

Table 4: Sieve Analysis of Coarse Aggregate

Sieve Analysis (mm)	Percentage of Passing, %	Percentage of Passing Limits
40 mm	100	100
20 mm	97.33	90-100
10 mm	29.52	25-55
4.75 mm	1.25	0-10

Other Physical properties for coarse aggregate such as Water Absorption, Impact Test and Crushing Strength Tests were conducted by following the IS 383-2016: Coarse and Fine Aggregate for Concrete - Specification. The test results are tabulated in Table 5.

Table 5: Physical Properties of Coarse Aggregate

Physical Properties	Values	Limits as per IS 383-2016
Water Absorption	0.40 %	2% Max
Impact Value	17.50 %	30%
Crushing Value	21.50 %	30%

Water

Portable water was used for the preparation of concrete mix(3). The water used in this project work has a pH level of 6.8.

Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is one of the greenest materials which are available in the industry. GGBS is the waste material that is produced in the manufacturing of iron as a by-product. The ground

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granulated blast furnace slag is used for replacement in cement, before using it is needed to grind it well to make it as such fine material as cement. Further GGBS is tested to identify its physical properties. The specific gravity and fineness property of the GGBS is tested, the test was done with the accordance with the IS 12089. The test results are tabulated in Table 6.

Table 6: Physical Properties of GGBS

Physical Properties	Values	Limits as per IS 12089
Specific Gravity	2.89	
Fineness	320.00 m^2/kg	Minimum 300 m^2/kg

Ground Granulated Blast Furnace slag was used for replacement of cement, than any other material which is available as an industrial waste material because GGBS has relatively high calcium oxide content in it (4). The GGBS particles are finer than OPC particles, thus it would reduce the amount and rate of bleeding of the concrete (5). The Specific area of GGBS was 4500 cm2g-1(6). This GGBS material, which has high latent hydraulic properties (7). By incorporating GGBS in concrete, we can improve the mechanical property, workability and chemical resistance of concrete (8).

The GGBS is not only used for replacing cement but also used for replacing fine aggregate in concrete, which also shows the increased performance of concrete(9). Due to the fine pore structure of GGBS, GGBS incorporated concrete to have a better performance against corrosion (10). The bending and compressive strength also increased with the decrease of particle size of GGBS (11).

When comparing the GGBS incorporated concrete with the conventional concrete, the corrosion resistance of the GGBS incorporated concrete is improved (12). By using the GGBS in concrete, the freeze Thaw resistance of the concrete can be increased due to the fineness of GGBS; air pores in concrete are reduced (13). The production of cement will lead to environmental pollution and subsequently leads to depletion of raw materials (14), to avoid these situations, better materials like GGBS need to be incorporated in the production of cement.

Chemical Admixture

To impart additional workability, CONPLAST SP430 super plasticizing chemical admixture was used in concrete for workability. Based on trial and error methods, the optimum percentage of Super Plasticizer was found at 0.8% by weight of cement was used as given in Table 7. All the test results are with the standard limits (15).

Table 7: Properties of Chemical Admixture

Chemical Admixture	Properties
Specific Gravity	1.20
pH	6.73
Chlorine ion content	0.2%

Mix Design

Concrete mix design was done as per IS 10262-2009 for M50 grade of concrete. The quantities of ingredient materials and mix proportions as per design are mentioned in table 8.

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Table 8: Details of Concrete Mix Proportions

Cement	Fine aggregate	Coarse Aggregate	Water
450 kg/m^3	621 kg/m^3	1235 kg/m^3	165 kg/m^3
1	1.38	2.74	0.33

Specimen Preparation

To compare the properties of Ground Granulated Blast Furnace Slag (GGBS) incorporated concrete with conventional concrete, all types of concrete are cast and cured for testing purposes. For Compression testing cubes are cast with the dimensions of 150mm X 150mm X 150mm and flexural testing, beams are cast with the dimensions of 150mm X 150mm X 700mm (16). For compression tests, 7 days, 14 days and 28 days aged concrete specimens are prepared. For flexural test 7 days and 28 days, aged concrete specimens are prepared.

Table 9: Details of Specimens

Types of Concrete	Cube (150mm X 150mm X 150mm)	Beam (150mm X 150mm X 700mm)
Conventional Concrete	9	6
40% of Replacement of Cement by GGBS	9	6
45% of Replacement of Cement by GGBS	9	6
50% of Replacement of Cement by GGBS	9	6
55% of Replacement of Cement by GGBS	9	6
60% of Replacement of Cement by GGBS	9	6
65% of Replacement of Cement by GGBS	9	6
70% of Replacement of Cement by GGBS	9	6

III. RESULTS & DISCUSSIONS

Workability of Concrete

The workability of the concrete is the important property of the concrete, some material will reduce the workability of the concrete and some may increase it. So to find the workability of the concrete slump cone test is conducted on all various mixes of concrete. All the test results are tabulated as follows.

Table 10: Result of Slump Cone Test on Concrete

Types of Concrete	Slump Value (mm)
Conventional Concrete	110
40%GGBS + 60%OPC	135
45%GGBS + 55%OPC	160
50%GGBS + 50%OPC	170
55%GGBS + 45%OPC	175
60%GGBS + 40%OPC	180
65%GGBS + 35%OPC	182
70%GGBS + 30%OPC	185

From the above test results, it is found that incorporating Ground Granulated Blast Furnace Slag (GGBS) in concrete will increase the workability of the concrete. The workability of the concrete is increased than the conventional concrete in all GGBS incorporated concrete. At most 68% of workability was increased when 70% GGBS were replaced with cement and 23% of workability was increased when 40% GGBS were replaced with

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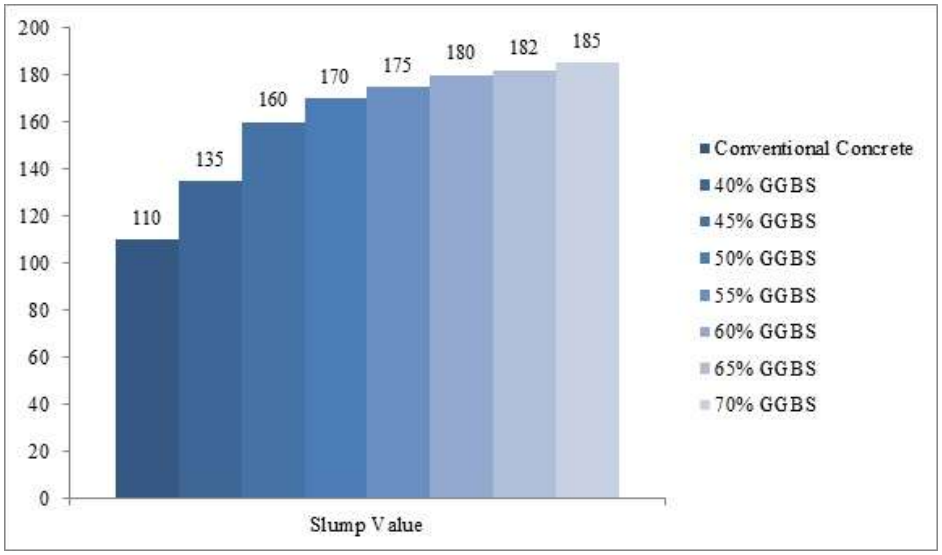
cement. The following graph will illustrate the increased workability when the GGBS incorporated concrete.



Graph 1: Comparison of Slump Value

Compressive Strength

The compression test was conducted for various ages of concrete (7 Days, 14 Days & 28Days), for every age three numbers of the specimen are tested to identify the mean value of the concrete.

All the test results are tabulated as follows. For compression test, 150mm X 150mm X 150mm cubes are used for testing (17).

Both conventional and GGBS incorporated concrete are tested for various ages of concrete-like 7 Days, 14 Days and 28 Days and strength comparisons are made for all ages of concrete.

Fig. 1: Compression Testing

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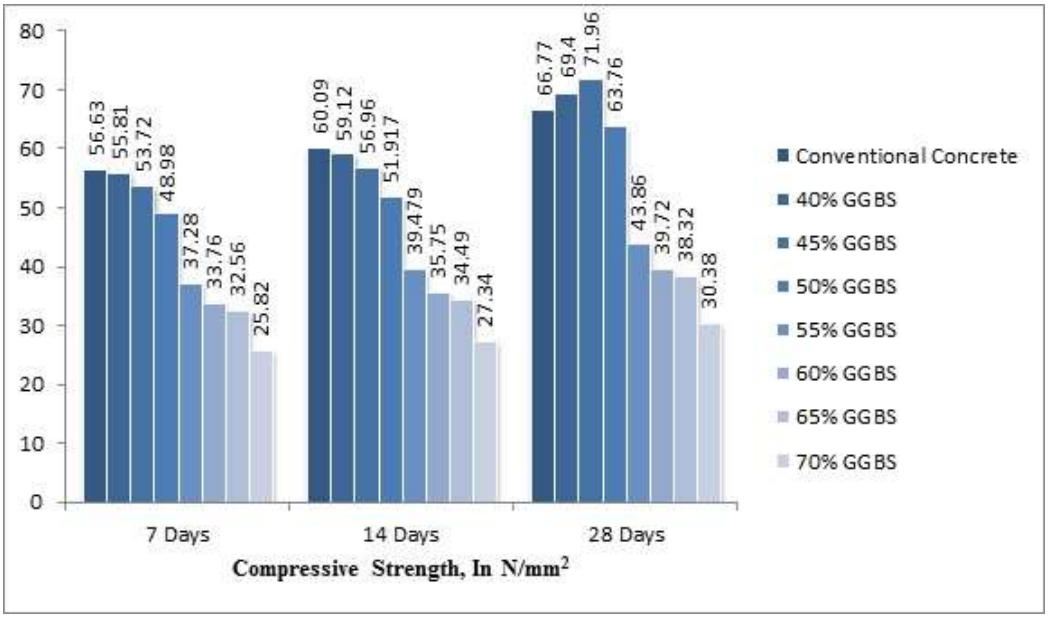
Table 11: Compression Test Results

Concrete Type	Compressive Strength @ Various age of Concrete		
	7 Days, N/mm^2	14 Days, N/mm^2	28 Days, N/mm^2
Conventional Concrete	56.69	60.09	66.77
40% GGBS + 60% OPC	55.81	59.12	69.40
45% GGBS + 55% OPC	53.72	56.96	71.96
50% GGBS + 50% OPC	48.98	51.92	63.76
55% GGBS + 45% OPC	37.28	39.47	43.86
60% GGBS + 40% OPC	33.76	35.75	39.72
65% GGBS + 35% OPC	32.56	34.49	38.32
70% GGBS + 30% OPC	25.82	27.34	30.38

In 7 days concrete will achieve 65% of its total strength when comparing all the 7 days results in most types of concrete reached the estimated strength of the concrete expect the 70% GGBS Incorporated concrete which falls below the estimated strength. In 14 days, concrete will achieve 90% of its total strength, when comparing the 14 days results, conventional concrete, 40%,45%,50% - GGBS incorporated concrete are achieved the estimated strength and other various percentages of GGBS incorporated concrete are failed. In 28 days concrete will attain 99% of estimated strength and as like 14 days results, Conventional concrete, 40%, 45%, 50% -GGBS incorporated concrete are achieved the estimated strength and remaining concrete are failed to achieve the estimated strength.



Graph 2: Comparison of Compressive Strength

From the above graph, it is concluded that GGBS incorporated concrete attains full strength at the age of 28days only; the growth of strength takes much time than the conventional concrete. When results are compared with the 7 days and 14 days' strength, conventional concrete's strength is grown fast than the GGBS incorporated concrete. But in 28 days result in 40%,45%- GGBS incorporated concrete's performance was increased than 7 Days and 14 Days and also achieved higher strength than the conventional concrete with increased workability. When compared with the conventional concrete the strength of 40% GGBS incorporated concrete was increased by about 4% and 45%

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GGBS incorporated concrete was increased by about 7.8%. When comparing with the grade of concrete 50% GGBS incorporated concrete also performed well against the conventional concrete, which is achieved 63.76 N/mm2. All other GGBS incorporated concrete are failed to achieve the target strength of the concrete.

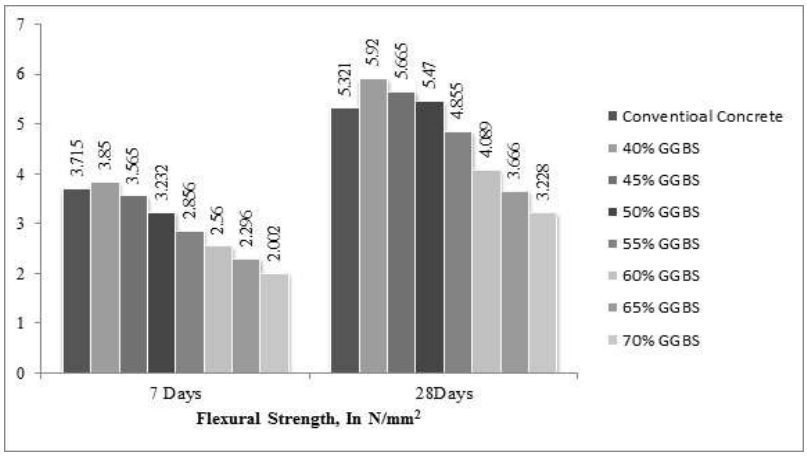
Flexural Strength

To identify the flexural strength of the concrete 150mm X 150mm X 700mm beam is cast for all variety of concrete. For this test, concrete is cast for testing at 7 Days and 28 Days. The test was carried with the criteria which are mentioned under IS 516-1959: Methods of Tests for Strength of Concrete. All the test results are tabulated in table no 12.

Fig. 2: Flexural Testing

Table 12: Flexural Test Results

Concrete Type	Flexural Strength @ Various age of Concrete	
	7 Days, N/mm^2	28 Days, N/mm^2
Conventional Concrete	3.175	5.321
40% GGBS + 60% OPC	3.850	5.920
45% GGBS + 55% OPC	3.565	5.655
50% GGBS + 50% OPC	3.232	5.470
55% GGBS + 45% OPC	2.856	4.855
60% GGBS + 40% OPC	2.560	4.086
65% GGBS + 35% OPC	2.296	3.666
70% GGBS + 30% OPC	2.002	3.228



Graph 3: Comparison of Flexural Strength

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From this test, it is very clear, that from both 7 Days and 28 Days results, that the performance of 40% GGBS incorporated concrete was found to be good and its performance was increased than the conventional concrete. At most 21% flexural strength was increased at 7 Days testing and 11.25% flexural strength was increased at 28 Days testing. The performance of 40%, 45%, 50% - GGBS incorporated concrete has higher flexural strength than the conventional concrete.

When comparing with compression test results it is found that the optimum results are obtained in 45% GGBS incorporated concrete, where both compression and flexural results are found to be satisfactory. When only flexural considered, 40% GGBS incorporated concrete is results were found to be satisfactory.

IV. CONCLUSION

The performance of GGBS incorporated concrete was found to be good when GGBS is replaced by about 40%, 45%, and 50% of cement weight. And other replacements are not satisfactory when comparing the results with the conventional concrete. By increasing the incorporation percentage of GGBS, workability of the concrete are by considering the workability, compression and flexural strength of the GGBS incorporated concrete, 45% GGBS incorporated concrete achieved optimum performance.

- Overall performance by the means of workability, concerning the percentage GGBS incorporation, is increased, workability also increased.
- In 40%,45%,50%,55%,60%,65%,70%- GGBS Incorporated concrete will have increased workability about 23%,45%,54.5%,59%,63.6%,65.4%,68.2%.
- In 40% & 45%, GGBS incorporated concrete achieved higher compression strength than the conventional concrete
- In 40%,45%,50% GGBS incorporated concrete achieved required compressive strength
- In 45% GGBS incorporated concrete compressive strength was increased by about 7.8% when compared with conventional concrete.
- The performance of 40&,45%,50% GGBS incorporated concrete was found to be good with increased flexural strength than the conventional concrete.
- When considering the compressive strength, better performance was found in 45% GGBS incorporated concrete when only flexural strength is considered, 40% GGBS incorporated concrete results were found to be satisfactory.
- The optimum performance was found in 45% GGBS incorporated concrete, with the consideration of workability, Compression strength, and Flexural Strength.
- In 40%,50%,55% - GGBS incorporated performance is found to be good in general and all other GGBS replacements are failed to perform.

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