Partial replacement of Cement by Ground Granulated Blast Furnace Slag

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Abstract: **Cement is major constituent material of the concrete which produced by natural raw material like lime and silica. Once situation may occurs there will be no lime on earth for production of cement. This situation leads to think all people working in construction industry to do research work on cement replacing material and use of it. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduces cost of concrete and help to reduce rate of cement consumption. This study report of characteristics strength of GGBS concrete will give assurance to encourage people working in the construction industry for the beneficial use of it. This research work focuses on strength characteristics of M20 grade concrete with partial replacement of cement by GGBS with 0%, 10%, 20%, 30%, 40% and 50% and compare with PCC.**

Index Terms*:* Cement, GGBS, Physical & Chemical properties, PCC

I. INTRODUCTION

Cement is a very important building material used in the construction industry. The hardened cement paste resembled the natural stone occurring at Portland in England. Hence it was named as Portland cement. Portland cement is used as a raw material all over the world. It developed from other types of hydraulic lime in England in the mid nineteenth century and generally obtained from clinkers, grinding the clinker and adding small amounts of other materials to it. Several types of portland cement are available with the most common being called Ordinary Portland Cement (OPC).Due to its ease for preparing and fabricating in all sorts of conceivable shapes. It is used as a binder in production of cement concrete due to its availability. The usage of Portland cement is prominent in all most all the civil engineering structures. Each year concrete industry uses about 1.6 billion tons of Portland cement to produce approximately 12 billion tons of concrete worldwide.

Disadvantages of Portland Cement

- Portland cement is caustic so it can cause chemical burns, the powder can cause irritation or with severe exposure causes lung cancer, and contains some toxic ingredients such as silica and chromium.
- Environmental concerns are the high energy consumption required to mine, manufacture and transport the cement and the related air pollution including the release of greenhouse gasses (carbon dioxide), dioxin, NOx, Sulphur dioxide and particulates.
- As the production of one ton of Portland cement generates approximately one ton of carbon dioxide consuming approximately one Giga Joule (GJ) of energy to produce one ton.
- About half of the carbon dioxide emission from Portland cement production is due to calcinations of lime stone and other half are due to the combustion of fossil fuel.

Alternative Binding Materials

- Fly Ash
- Ground Granulated Blast furnace Slag (GGBS)
- Silica Fumes
- Meta Kaolin.
- Rice Husk Ash (RHA)

II. GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground granulated blast-furnace slag is a non metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water tons form a glassy sand like granulated material. The granulated material when further ground to less than 45 micron will have specific surface of about 400-600m^2/kg. GGBS often blended with Portland cement as low cost filler, less liable to segregation during transport and handling, and remains workable for longer periods and also provides resistance to alkali-silica reaction. Since it contains aluminum oxide and silica oxide, it is suitable for making of the geo polymers.

III. MATERIALS AND PROPERTIES

This paper describes a procedure to achieve concrete mix using GGBS as a partial replacing material for cement. In addition, the test results for acceptance characteristics for concrete mix such as Workability characteristics (Slump flow), Mechanical

characteristics (Compressive strength, Split Tensile Strength & Flexure Strength) are presented. The materials used in the research are:

1.Cement (OPC 53 grade) Ordinary Portland Cement is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar & stucco. Ordinary Portland cement of 53 grade JSW Cement conforming to IS: 12269-1987 has been used and properties are presented in Table 1.

Table 1: Properties of Cement

Properties	Results	IS 12269:1987
Setting time *Initial	105 min	≥30 min
*Final	380 min	≤600 min
Standard Consistency	33%	≤ 40%
Specific Gravity	2.83	2.8 - 3.3
Fineness of Cement	3.45%	≤ 10%

2. Fine Aggregate In this investigation fine aggregate used is 4.75 mm down, manufactured sand has been used, obtained from the local market in Mysore is tested as per IS: 2386, presented in Table 2.

Table 2: Properties of Fine Aggregate

Properties	Values
Specific gravity	2.61
Bulk density	1460
Fineness modulus	3.68
Water Absorption	0.60
Classification zone	Zone-2

3. Coarse Aggregate Coarse aggregate crushed granite of 12.5 mm maximum size and retained on IS 4.75 sieve has been used, obtained from the local market in Mysore, are tested as per IS: 2386, presented in Table 3.

Table 3: Properties of Coarse Aggregates

Properties	Values
Water absorption	1.7%
Specific gravity	2.8
Fineness Modulus	4.49
Bulk density	1620 kg/m^3
Crushing value	26%
Impact value	20%

4. GGBS It is a by-product obtained during the manufacturing of iron from the blast-furnace. It is a non-metallic material, essentially consists of silicates and aluminates of calcium and other bases typically used in Geo polymers. The chemical composition & physical properties is presented in Table 4 & Table 5 respectively.

Table 4 Chemical Composition of GGBS

Binder	Chemical composition of GGBS (%)							
GGBS	Al_2O_3	Fe_2O_3	SiO_2	MgO	MnO	S	Chlorides	CaO
	13.26	0.63	37.20	8.70	0.33	2.20	0.004	37.30

Table 5 Physical Composition of GGBS

Binder	Physical properties of GGBS (%)		
GGBS	**Color**	**Specific Gravity**	**Fineness (m^2/kg)**
	Half White	2.86	3.70

IV. METHODOLOGY

Experimental investigation is carried out to study the properties of concrete by partially replacing cement with certain percentage of GGBS, for mix design for M-20 grade (IS 10262 – 2009).

Experimental Procedure

a) Collection of materials from various sources.

b) Basic tests on materials used.

c) Mixing the materials in definite proportions as per obtained mix proportions & testing for Workability.

d) Replacement of materials

i. Replacing a part of cement by GGBS in various percentages.

ii. Casting the test specimen.

e) Testing the specimen for Compressive strength, Flexural strength & Split Tensile strength.

V. EXPERIMENTAL TESTS

1. Tests conducted for Fresh Properties

a. Slump Cone Test Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

2. Tests conducted for Mechanical Properties

a. Compressive Strength Test To calculate compressive strength, cubes are casted of 150mm*150mm*150mm size for the required mix design. The sample is placed on the compressive testing machine properly and then applies the load gradually until the first crack will get appear. Note the load value corresponding to sample failure.

b. Flexural Test To calculate Flexural strength, beams are casted of 100mm*100mm*500mm size for the required mix design. The sample is placed on the testing machine properly and then applies the load gradually until the first crack will get appear. Note the load value corresponding to sample failure.

c Split Tensile Test To calculate split tensile strength, cylinder are casted of 150mm*300mm size for the required mix design. The sample is placed on the testing machine properly and then applies the load gradually until the first crack will get appear. Note the load value corresponding to sample failure.

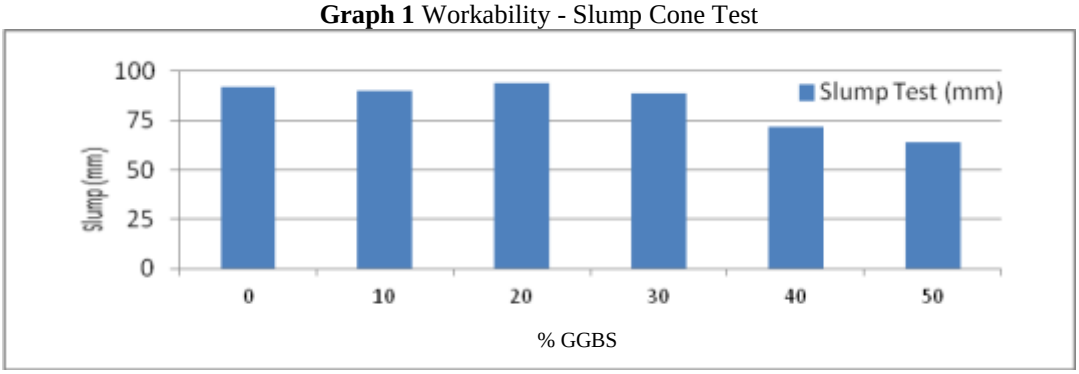
VI. RESULTS

1. Tests conducted for Fresh Properties
   a. Slump Cone Test

Table 6 Workability - Slump Cone Test

Sl. No	% GGBS	Slump Test (mm)
1	0	92
2	10	90
3	20	94
4	30	89
5	40	72
6	50	64

Graph 1 Workability - Slump Cone Test



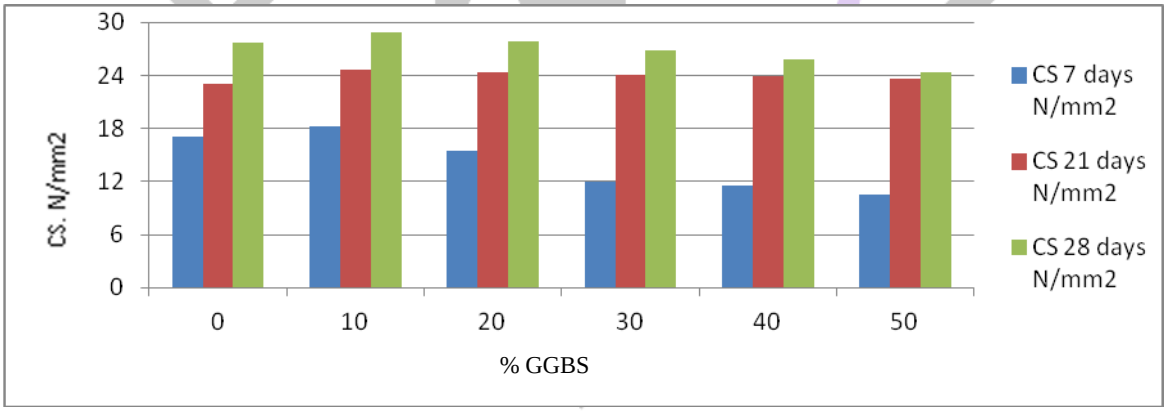
2. Tests conducted for Mechanical Properties

a. Compressive Strength Test

Table 7 Compressive Strength

Sl. No	% GGBS	Compressive Strength 7 days N/mm^2	Compressive Strength 21 days N/mm^2	Compressive Strength 28 days N/mm^2
1	0	17	23	27.70
2	10	18.30	24.70	28.80
3	20	15.40	24.40	27.90
4	30	11.90	24.10	26.80
5	40	11.60	23.90	25.80
6	50	10.50	23.60	24.40

Graph 2 Compressive Strength



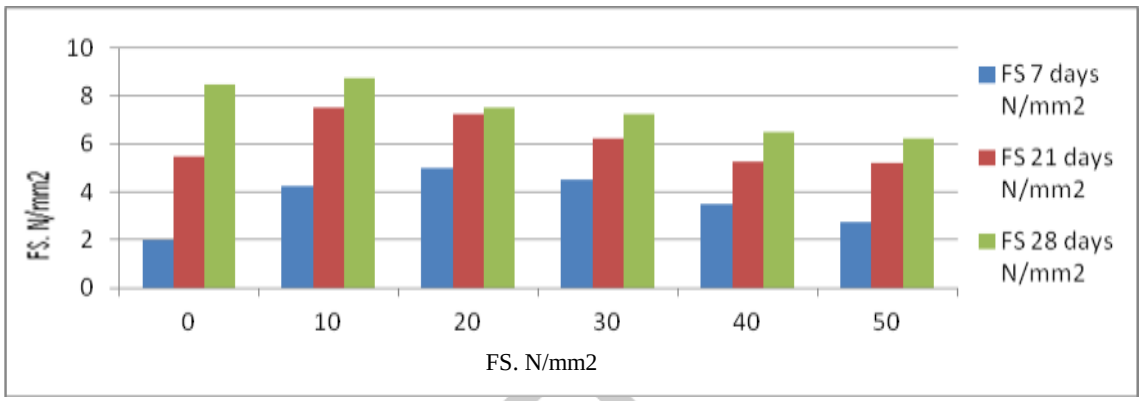
b. Flexural Strength Test

Table 8 Flexural Strength

Sl. No	% GGBS	Flexural Strength 7 days N/mm^2	Flexural Strength 21 days N/mm^2	Flexural Strength 28 days N/mm^2
1	0	2	5.50	8.50
2	10	4.25	7.50	8.75
3	20	5	7.25	7.50
4	30	4.50	6.25	7.25

5	40	3.50	5.25	6.50
6	50	2.75	5.20	6.25

Graph 3 Flexural Strength

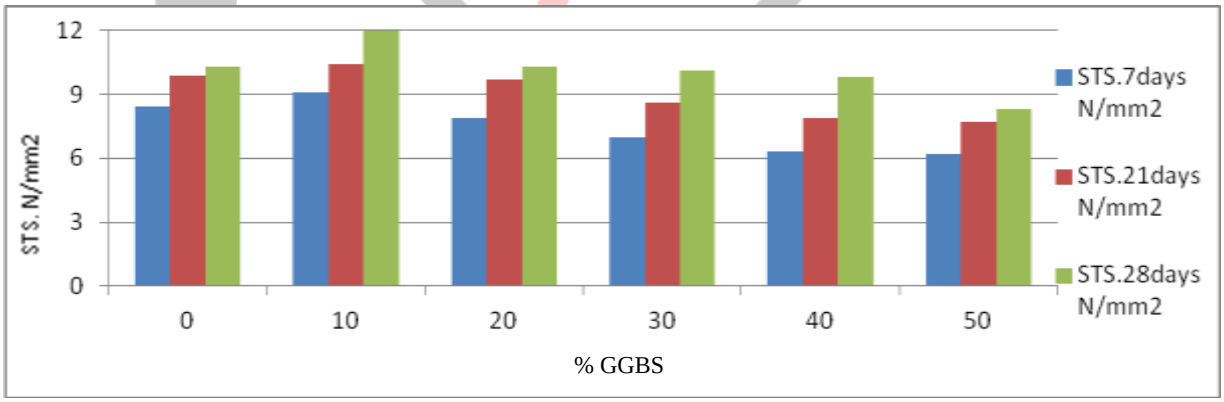


c. Split Tensile Strength Test

Table 9 Split Tensile Strength

Sl. No	% GGBS	Split Tensile Strength 7 days N/mm^2	Split Tensile Strength 21 days N/mm^2	Split Tensile Strength 28 days N/mm^2
1	0	8.40	9.90	10.30
2	10	9.10	10.40	12.10
3	20	7.90	9.70	10.30
4	30	7.00	8.60	10.10
5	40	6.30	7.90	9.80
6	50	6.20	7.70	8.30

Graph 4 Split Tensile Strength



VII. CONCLUSIONS

- The partial replacement of cement with GGBS in concrete mixes has shown enhanced performance in terms of strength and durability. This is due to the presence of reactive silica in GGBS which offers good compatibility.
- The compressive strength of concrete increased when cement is replaced by GGBS for M20 grade of concrete. At 10% replacement of cement by GGBS the concrete attained maximum compressive strength for M20 grade of concrete.
- Workability of concrete increases with the increase in GGBS replacement level.

- Use of GGBS in the concrete generates less heat while mixing with the water as against cement. It also helps to reduce the heat of hydration resulting less shrinkage and temperature cracks in the concrete.
- The split tensile & flexural strength of concrete is increased when cement is replaced with GGBS. The split tensile & flexural strength is maximum at 10% of replacement.
- The compressive strength for cubes, cylinder and beams at 28 days with 50% of GGBS shows less when compare to 0%. Hence we can conclude that we can replace cement with 10% of GGBS in future to attain maximum strength without adding any chemical admixtures.

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