Performance Study of Concrete using GGBS & Copper Slag as a Partial Replacement for Cement & Fine Aggregates

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***Abstract*— Conservation of natural resources and preservation of environment is necessary thing. Rapid growth of industrialization has resulted the generation of huge quantity of wastes, both in solid and liquid in industrial sectors. It's presumed that about 10-15% of wastes produced are hazardous and generation of hazardous wastes is increasing at the rate of 2-5% per year. These generated waste were dumped on land or discharged in to water bodies and thus becomes a large source of environment pollution and health hazards. This study presents the information about utilization of industrial wastes as a suitable material for construction purposes, by which cost of construction can be reduced and also a safe disposal of waste materials can be achieved. In the present study cement will be partially substituted by GGBS (10%, 20%, and 30%) and fine aggregates will be partially replaced by copper slag 20%. The strength parameters such as compressive strength, tensile strength will be confirmed for both 7 days and 28 days of curing period. Based on the test appropriate results will be derived.**

Keywords – GGBS, Copper slag, Compressive Strength, Split Tensile strength & Water Absorption.

I INTRODUCTION

Concrete is the best vital material for the construction of high rise buildings and many substructures. It is the widely used man-made building materials in the world. Somewhat more than a ton of concrete is created each year for every human being on the world. Infrastructure development in such regions, mainly in evolving countries resembling India, is more. Concrete is a combination of cement, fine aggregate, coarse aggregate, water and sand is the chief raw material used as fine aggregate in the manufacture of concrete. The normal sources of river sand are getting exhausted progressively. The response for the guard of the natural environment and the ban on mining in some zones is further creating the problem of availability of river sand. At present-day, the construction industry is afflicted with the insufficiency of this essential component material of concrete.

Basically, concrete is inexpensive, strong, and long-lasting. Although concrete technology crossways, the industry continue to rise to the stress of a changing market. The construction industry recognizes that substantial improvements are essential in production, product concert, energy efficiency and environmental performance. The industry wants to face and prevail over a number of institutional, competitive and technological challenges. One of the chief challenges with the environmental consciousness and shortage of space for land-filling is the waste by-products consumption as an alternative to discarding. All the way through the engineering sector, including the concrete production, the cost of environmental fulfillment is high. Use of industrial by-product such as foundry sand, fly ash, bottom ash and slag can answer in significant improvement largely in industry energy efficiency and environmental presentation.

1.0 Copper Slag

Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tonnes of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry. Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation.

Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for fine aggregates. For example, copper slag has a number of favorable mechanical properties for fine aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability. Copper slag also exhibits pozzolanic properties since it contains low CaO. Under activation with NaOH, it can exhibit cementations property and can be used as partial or full replacement for Portland cement. The utilization of copper slag for applications such as Portland cement replacement in concrete, or as raw material has the dual benefit of eliminating the cost of disposal and lowering the cost of the concrete. The use of copper slag in the concrete industry as a replacement for cement can have the benefit of reducing the costs of disposal and help in protecting the environment. Despite the fact that several studies have been reported on the effect of copper slag replacement on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

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1.1 Ground Granulated Blast-furnace Slag (GGBS)

Is a by-product from the blast-furnaces recycled to create iron. Blast furnaces are nourished with precise mixture of iron-ore, coke also limestone, and worked at a temperature of about 1,500°C. When iron-ore, coke and limestone melt in the blast furnace, two yields are formed—molten iron, and molten slag shown in fig 1.2. The molten slag is lighter and floats on the top of the liquefied iron. The molten slag contains frequently silicates and alumina from the unique iron ore, mutual with some oxides since the limestone. The procedure of refining the slag includes cooling of molten slag through pressured water jets. This quickly extinguishes the slag and customs granular particles generally not greater than 5 mm. The speedy cooling inhibits the formation of larger crystals, and the causing granular material comprises around 95% non-crystalline calcium-alumino silicates. The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill to a very fine powder, which is GGBS. Although normally designated as "GGBS" in the UK, it can similarly be mentioned to as "GGBS" or "Slag cement".

1.2 Objectives and aim of present work

The main objective of present work is to utilize wastes and by-products generated from industries as an alternative material for cement and fine aggregates, so that burden on the raw materials used in the manufacture of cement industry will be reduced, the scarcity of the natural sand can be overcome up to some extent and also make concrete quite economical

1.2.1 Aim of present study

- This study attempts to compare the strength parameters like compressive strength & split tensile strength when cement is partial replaced by GGBS & fine aggregates partial replaced by Copper slag.
- To conclude the optimum strength obtained by using the alternative materials with different percentage of replacement in concrete.
- To conclude the strength of concrete when copper slag is blended with GGBS for mix proportion M30 grade concrete. As per IS 10262:2009.

II. EXPERIMENTAL DETAILS AND METHODOLOGY

2.1 Materials used

The strength of the concrete mainly depends upon the properties of the ingredients that are used in the concrete.

Ingredient Materials of Concrete:

- OPC 53 Grade Ultra-tech cement
- River Sand as Fine Aggregates
- Quarried and Crushed Stone as Coarse Aggregates
- Copper Slag as a replacement material for Fine Aggregate
- Ground Granulated Blast Furnace Slag (GGBS) as a replacement for Cement

The physical properties of the ingredient materials are obtained from the tests conducted in accordance with Indian Standards.

2.1.1 Cement

Ultra-tech Ordinary Portland cement of 53 grade conforming to IS 12600: 1989 was used in this project. Its physical properties were tested in accordance with B.I.S specification physical properties of cement as shown in table 1.

Table 1 - Physical Properties of Cement

Sl No	Particulars	Test Results found
1	Specific Gravity	3.10
2	Normal Consistency (%)	29.5
3	Initial Setting Time (min)	110
4	Final Setting Time (min)	270

2.1.2 Fine aggregates

The locally available river sand conforming to grading of Zone II of IS: 383 - 1970 was used as fine aggregate in this work.

2.1.3 Coarse Aggregates

The locally available crushed broken stone material has been used as coarse aggregate. Coarse aggregate of 20 mm nominal size are used in this project work.

2.1.4 GGBS

The properties of GGBS are tabulated in Table 2 as given by JSW Cement Ltd., Vijanagar Works in Mangalore.

Table 2 - Physical Properties of Cement

Sl No	Particulars	Test Results found
1	Specific Gravity	2.88
2	Colour	White & Grey
3	Fineness (m2/kg)	406
4	Moisture Content (%)	0.13

2.1.5 Copper Slag

Copper Slag was procured from Vivek Engineering's, Kavoor Mangalore. Its physical properties are tabulated in Table 3

Table 3 - Physical Properties of Copper

Sl No	Particulars	Test Results found
1	Specific Gravity	3.29
2	Particle shape	Irregular
3	Appearance	Black & glassy
4	Fineness modulus	3.75

2.2 Mix Proportion

Mix design of concrete is prepared as per IS 12600: 1989 as shown below

Table 4 - Mix Proportion for M30 Grade

Grade	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (ltr/m^3)
M30	385.93	710.72	1181.52	175

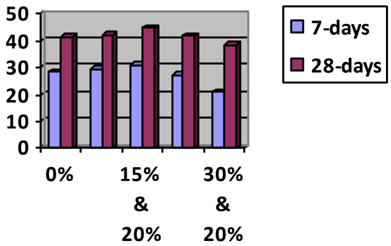
III. TESTS & RESULTS

3.1 Compressive Strength

The compressive strength of three cubes 150mm x 150mm x 150mm were tested for 7 & 28 days. 2000 KN capacity compression testing machine (CTM) was used to measure the compressive strength of concrete. As per IS: 516-1959, loading rate of 2.5 kn/s was applied. Compressive strength was measured for 7 & 28 days. The table below shows the compression strength for control mix trail.

Table 5 - Compression Strength of 7 & 28 days

% of GGBS & Copper slag replacement	7-days (N/mm^2)	28-days (N/mm2)
0%	28.48	41.18
10% & 20%	29.58	42.05
15% & 20%	30.81	44.58
20% & 20%	27.40	41.62
30% & 20%	20.88	38.51



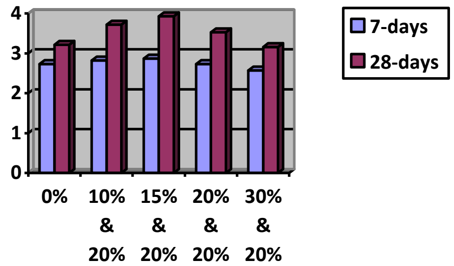
Graph 1: Comparison of compressive strength for 7 & 28 – days

3.2 Split Tensile Strength

This test was carried out on a universal testing machine (UTM) of capacity 1000KN. As per IS: 516-1959 loading rate of 2.5kn/s was applied. Cylinder specimens (size 150 mm dia X 300 mm long) were used for this testing. Tensile strength was measured at 7 & 28 days.

Table 6 – Split tensile Strength of 7 & 28 days

% of GGBS & Copper slag replacement	7-days (N/mm2)	28-days (N/mm2)
0%	2.73	3.21
10% & 20%	2.82	3.72
15% & 20%	2.87	3.93
20% & 20%	2.73	3.53
30% & 20%	2.57	3.16



Graph 2: Comparison of split tensile strength for 7 & 28 – days

3.3 Water Absorption Test

The concrete cube specimen of size 150mm x 150mm were casted for conventional concrete and for optimal mix (0% & 15% GGBS 20% CS) and after 28-days of water curing, the specimens were removed from curing tank and allowed to dry for 2 hours after that specimen is weighted(w1). Then the specimen is kept in hot oven for 24 hours and again weight of concrete cube specimen was taken (w2). Then the water absorption is calculated by formula = [(W1-W2)/W2] x 100

Table 7: W.A for 0% Conventional concrete

SPECIMEN	W1	W2	W.A	AVG., W.A
CUBE 1	8.523	8.490	0.38	0.39
CUBE 2	8.630	8.595	0.40	

Table 8: W.A for Optimal mix (15% GGBS & 20% CS)

SPECIMEN	W1	W2	W.A	AVG., W.A
CUBE 1	8.598	8.578	0.23	0.25
CUBE 2	8.721	8.696	0.28	

Hence water absorption for optimal mix (0.25) is less when compared with conventional concrete (0.39).

IV RESULTS AND DISCUSSION

The main aim of the study is to obtain the suitability of GGBS as a partial replacement of OPC in concrete and copper slag as partial replacement for fine aggregates. From compression test & split tensile test results of 28-days it is observed that there is gradual increase in its strength. OPC can be partial replaced by GGBS by 15% and copper slag is replaced by 20%. It is observed from studies and from journals that is due to development of C_2S (Di-calcium Silicate) hardens slowly and contributes largely to strength increase in concrete by GGBS. Addition of copper slag increases the density of concrete thereby increasing self-weight. High toughness of copper slag attributes to increase compressive strength.

V CONCLUSION

1. The compressive strength of concrete with partial replacement of sand by copper slag by 20% & cement by GGBS can be replaced by 15% has achieved 44.58 higher strength for 28-days when compared with control mix.
2. The split tensile strength of concrete with partial replacement of sand by copper slag by 15% & cement by GGBS can be replaced by 15% has achieved 3.93 higher strength for 28-days when compared with control mix.
3. The compressive strength of concrete for partial replacement of fine aggregate with copper slag by 20%& cement with GGBS by 15%has increased by 8.25% when compared with conventional concrete.
4. The split tensile strength of concrete for partial replacement of fine aggregate with copper slag by 20% & cement with GGBS by 15% has increased by 22.4% when compared with conventional concrete.
5. Water absorption for optimal mix (0.25) is less when compared with conventional concrete (0.39)

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IS Codes:

[13] IS 12600 : 1989

[14] IS : 383 - 1970