AN EXPERIMENTAL STUDY ON CONCRETE USING FLY ASH, COPPER SLAG AND GGBFS

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ABSTRACT

The replacement of natural resources in the manufacture of cement and sand is the present issue in the present construction scenario. Fly-Ash, Copper slag and Ground Granulated Blast Furnace Slag (GGBFS) are industrial by-product materials produced from the process of manufacturing coal, copper and iron. Use of Fly-Ash, Copper slag and GGBS does not only reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product. current study with minimize the cost of cement and sand with concrete mix grade M20 by studying the mechanical behavior of this concrete mix by partial replacing with such as Fly-Ash, Copper slag and GGBS in concrete mix. In this study, partial replacement of Cement with Fly-Ash and Sand with Copper Slag and coarse aggregate with GGBFS considered. Experimental study is conducted to evaluate the workability and strength characteristics of hardened concrete, properties of concrete have been assessed by partially replacing cement with GGBS, and sand with Copper Slag. The cement has been replaced by Fly-Ash accordingly 10% and sand has been replaced by Copper slag accordingly 30% based on past research paper. Corse aggregate has been replaced by GGBFS accordingly (without Fly-Ash and Copper slag), 20%, 40%, 60%, 80% and 100% for M20 mix. Concrete mixtures were produced, tested and compared in terms of compressive, flexural and split tensile strength with the conventional concrete.

Keywords:-*Copper-slag,GGBFS,Workability, Compressive strength, Split tensile strength, Flexural strength*

I. INTRODUCTION

Concrete is the best vital material for the construction of high rise buildings and many substructures. In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, Fly-Ash, copper slag and GGBFS are few of the industrial by-products which comes out from blast furnace during metal extraction process. In many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction Industry. 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 Fly-Ash

Coal is a dominant commercial fuel in India, where Many mines are operated by Coal India and other subsidiaries. production of hard coal was 358.4 Mt.; while utilization was 407.33 Mt. India is the sixth largest electricity generating and consuming country in the world. Fly ash can be considered as the world's fifth largest raw material resource. An estimated 25% of fly ash in India is used for cement production, construction of roads and brick manufacture. The fly ash utilization for these purposes is expected to increase to nearly 32 Mt by 2009–2010. Currently, the energy sector in India generates over 130 Mt of FA annually and this amount will increase as annual coal consumption increases by 2.2%. The large-scale storage of wet fly ash in ponds takes up much valuable agricultural land approximately (113 million m^2) and may result in severe environmental degradation in the near future, which would be disastrous for India.

1.1 copper slag

Copper slag is by product of the manufacture of copper. Large amount of copper slag is generated as waste worldwide during the copper smelting process. River Sand is common form of fine aggregate used in the manufacturing of concrete. However, because of increased cost and large-scale depletion of sources alternatives for river sand are being considered. There have been many alternative materials with similar physical & chemical properties of Sand found (Lime stone waste, marble powder, furnace slag and welding slag, stone dust etc.) and research have been carried out to check the suitability of its use as partial replacement of sand. Copper Slag is an industrial by product abundantly available near copper producing industries having similar physical &chemical properties of Sand can be considered as an alternative to the river sand. This will help in resolving a major concern of industrial waste disposal along with decreased cost of construction.

1.2 GGBFS

Ground Granulated Blast Furnace Slag (GGBFS) is a by product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years. GGBFS cement can be added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water. The normal ratios of aggregates and water to cementations material in the mix remain unchanged. GGBFS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBFS vary from 30% to up to 85%. Typically, 40 to 50% is used in most instances.

1.3 Objectives and aim of present work

The work reported in this study, Fly-Ash, Copper slag & GGBS are used as a cement, sand & coarse aggregate as partial replacement of material in concrete mix. Optimal dosage range of this Fly-Ash and Copper slag constant according past research paper & GGBFS are chosen based on concrete mix studies. The ultimate focus of this work is to ascertain the performance of concrete mix containing Copper slag & GGBS and compare it with the controlled concrete mix.

1.3.1 Aim of present study

- This study attempts to compare the strength parameters like compressive strength & split tensile strength when cement is partial replaced by Fly-Ash & fine aggregates partial replaced by Copper slag & coarse aggregates partial replaced by GGBFS.
- To design and proportion the concrete mix for M25 grade concrete, as per the recommendation of IS:10262:2009.
- To check the variation of Compressive Strength, Split Tensile Strength, Flexural Strength, Shear Test, Pull out and Water Absorption results.
- Environmental friendly disposal of waste copper and steel slag.

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
- Crushed Stone as Coarse Aggregates
- Copper Slag as a replacement material for Fine Aggregate
- Ground Granulated Blast Furnace Slag (GGBFS) as a replacement for Coarse Aggregate.

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

Sr No	Particulars	Test Results found
1	Specific Gravity	3.15
2	Normal Consistency (%)	29.5
3	Initial Setting Time (min)	110
4	Final Setting Time (min)	270

2.1.2 Fine aggregates

The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. It conforms to IS 383 1970 comes under zone II.

2.1.3 Coarse Aggregate

The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work.

2.1.4 Fly-Ash

Class- F fly ash use. The fly ash was collected from Pravin Block Morbi, Gujarat.

2.1.5 Copper Slag

Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag used in this work was brought from Mark International, Rajkot, India

Table 2: - Physical Properties of Copper Slag

Sl No	Particulars	Test Results found
1	Specific Gravity	3.3
2	Particle shape	Irregular
3	Appearance	Black & glassy

2.1.6 GGBFS

GGBFS is a waste industrial by-product from the blast furnaces used to make iron. GGBFS used in this work was brought from GIDC area, Rajkot, Gujarat

Table 3: - Physical Properties of GGBFS

Sl No	Particulars	Test Results found
1	Specific Gravity	2.71
2	Particle shape	Irregular
3	Appearance	Black
4	Impact Value	8.3%

2.2 MIX DESIGN

The mix proportion chosen for this study is M20 grade with water-cement ratio of 0.5. In this test Cubes of standard size 150x150x150mm and Cylinders of standard diameter 150mm and height 300mm and Prisms of size

500x100x100mm were casted and cured for 7, and 28 days and tested as per code IS: 516-1959. The mix proportion chosen for this study is given in Table 4.

Table 4: - M-20 Mix Design

Grade	Water (ltr/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
M20	191	382	623.22	1190.10

II. TESTS AND RESULTS

2.1 Slump Test

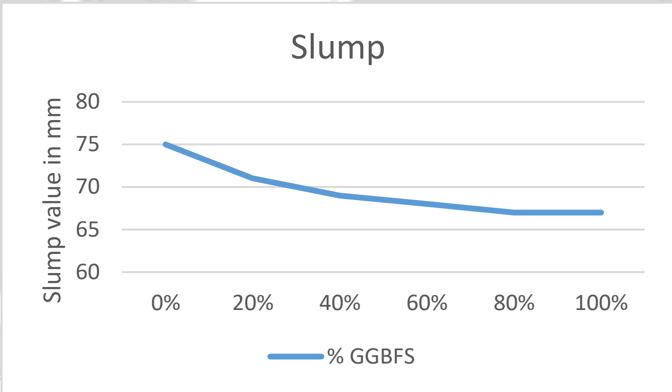
IS: 1199-1959 Method of sampling and analysis of concrete.

Table 5: - Slump Test Results

	% GGBFS	Slump
10% F.A & 30% C. S	0	75
	20	71
	40	69
	60	68
	80	67
	100	67

It was noted that the slump value decreased with the percentage of GGBFS increases in concrete.

Chart 1: - Slump Vs % Replacement



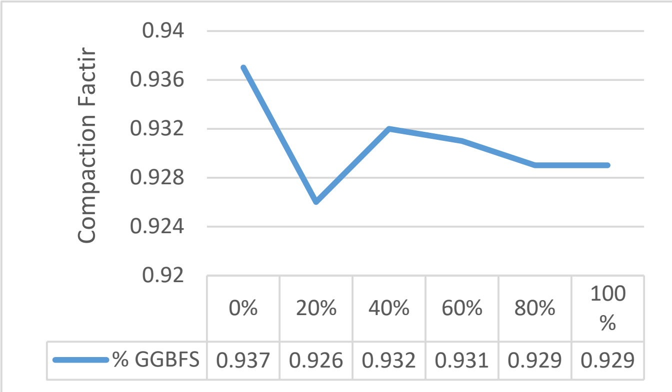
2.1 Compaction Factor Test

IS: 5515-1983Method of sampling and analysis of concrete.

Table 6: - Compaction Factor Results

	% GGBFS	Value
10% F.A & 30% C. S	0	.937
	20	.926
	40	.932
	60	.931
	80	.929
	100	.929

Chart 2: - Compaction Vs % Replacement



2.2 Compressive Strength

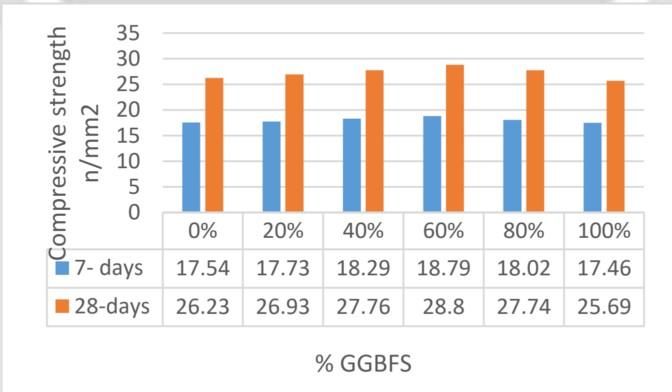
The compressive strength of three cubes 150mm x 150mm x 150mm were tested for 7 & 28 days. 2000 KN capacity compression testing machine (CTM) was used to measure the compressive strength of concrete. As per IS: 516-1959, loading rate of 2.0 kn/s was applied. Compressive strength was measured for 7 & 28 days.

Table 7: - Compressive Strength

	% GGBFS	7 DAYS	28 DAYS
10% F.A & 30% C. S	0	17.54	26.23
	20	17.73	26.93
	40	18.29	27.76
	60	18.79	28.80
	80	18.02	27.74
	100	17.46	25.69

The compressive strength of concrete for the partial replacement copper slag and Cement and GGBFS increased in the order of 0%, 2.66%, 5.83%, 9.79%, 5.75% for 0% GGBFS, 20%GGBS, 40%GGBFS,60%GGBFS 80%GGBS, proportions and decreased by 2.05% for 100%GGBFS proportions replacements respectively.

Chart 3: - Compressive Strength Vs % Replacement



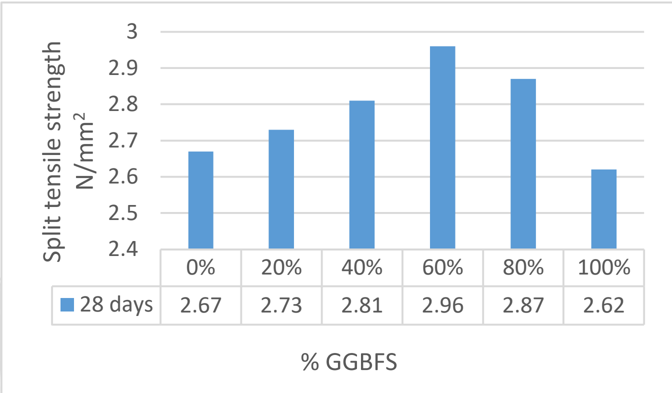
2.3 Split Tensile Strength

This test was carried out on a compression testing machine (CTM) of capacity 2000KN. As per IS: 516-1959 loading rate of 2.0kn/s was applied. Cylinder specimens (size 150 mm dia X 300 mm long) were used for this testing. Tensile strength was measured at 28 days.

Table 8: - Split Tensile Strength

	% GGBFS	28 DAYS
10% F.A & 30% C. S	0	0.00
	20	2.67
	40	2.73
	60	2.96
	80	2.87
	100	2.62

Chart 4: - Split Tensile Strength Vs % Replacement



The split tensile strength of concrete for the partial replacement copper slag and Cement and GGBFS increased in the order of 0%, 2.24%, 5.23%, 10.86%, 7.49% for 0% GGBFS, 0%GGBS, 40%GGBFS, 60% GGBFS & 80%GGBS, proportions and decreased by 1.87% for 100%GGBFS proportions replacements respectively.

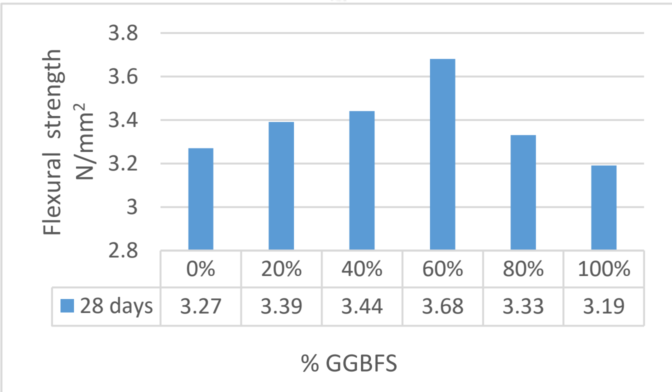
2.4 Flexural Strength

This test was carried out on a universal testing machine (UTM) of capacity 1000KN. As per IS: 516-1959 loading rate of 2.0kn/s was applied. Beam specimens (size 500 mm x 100mm x 100mm) were used for this testing. Flexural strength was measured at 28 days.

Table 9: - Flexural Strength

	% GGBFS	28 DAYS
10% F.A & 30% C. S	0	3.27
	20	3.39
	40	3.44
	60	3.68
	80	3.33
	100	3.19

Chart 5: - Flexural Strength Vs % Replacement



The flexural strength of concrete for the partial replacement copper slag and Cement and GGBFS increased in the order of 0%, 3.66%, 5.19%, 12.53%, 1.83% for 0% GGBFS,20%GGBS, 40%GGBFS, 60% GGBFS & 80%GGBS, proportions and decrease by 2.44% for 100%GGBFS proportions replacements respectively.

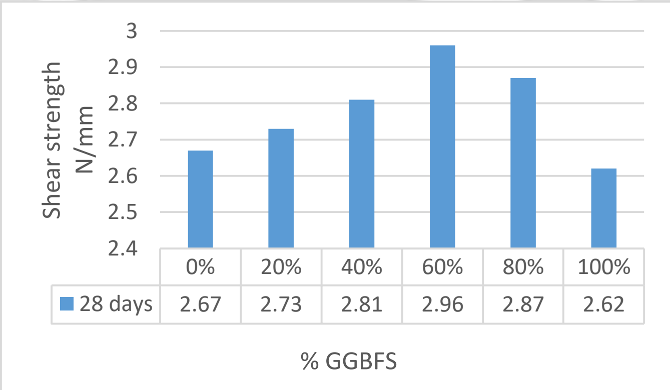
2.5 Shear Test

This test was carried out on a universal testing machine (UTM) of capacity 1000KN. Shear is defining to be action of two equal and oppositely directed forces whose lines of action are in planes very closer together.

Table 10: - Shear Strength

	% GGBFS	28 DAYS
10% F.A & 30% C. S	0	1.23
	20	1.26
	40	1.33
	60	1.38
	80	1.32
	100	1.19

Chart 6: - Shear Strength Vs % Replacement



The flexural strength of concrete for the partial replacement copper slag and Cement and GGBFS increased in the order of 0%, 2.43%, 8.13%,10.21%, 7.34% for 0% GGBFS,20%GGBS, 40%GGBFS, 60% GGBFS & 80%GGBS, proportions and decrease by 3.25% for 100%GGBFS proportions replacements respectively

2.6 Pull Out Test

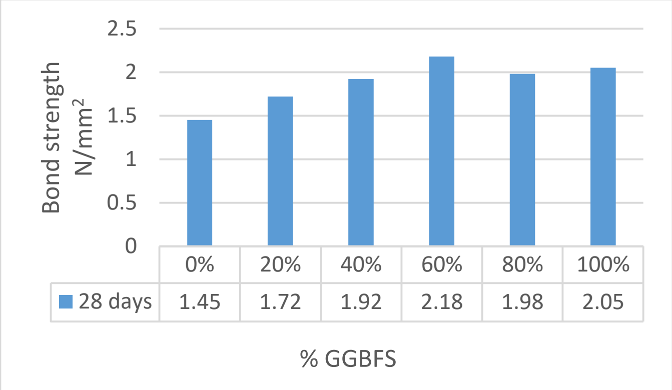
Pull Out Test consider accordingly IS: IS 2770-1 (1967). The moulds shall be of size suitable for casting concrete cubes of dimensions specified and shall conform to the requirements of compression test specimens specified in IS: 516.1959.

Table 11: - Pull Out Strength

	% GGBFS	28 DAYS
10% F.A & 30% C. S	0	1.45
	20	1.72
	40	1.92
	60	2.18
	80	1.98
	100	2.05

The bond strength of concrete for the partial replacement copper slag and Cement and bond strength are in order of 1.45%, 1.72%, 1.92%, 2.18%, 1.98%, 2.05%for 0% GGBFS,20%GGBS, 40%GGBFS, 60% GGBFS, 80%GGBS, & 100%GGBFS proportions replacements respectively.

Chart 7: - Bond Strength Vs % Replacement



2.7 Water Absorption Test

The concrete cube specimen of size 150mm x 150mm were casted for conventional concrete and for optimal mix 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 12: - % Water Absorption

	% GGBFS	28 DAYS
10% F.A & 30% C. S	0	4.36
	20	3.67
	40	3.33
	60	2.03
	80	2.27
	100	2.08

III. CONCLUSIONS

1. The compressive strength was increased by 2.66% to 9.79% for 20% to 60% replacement of GGBFS aggregate.

2. The split tensile strength was increased by 2.245 to 10.86% for 20% to 60% replacement of GGBFS aggregate.

3. The flexural strength was increased by 3.66% to 12.53% for 20% to 60% replacement of GGBFS aggregate.

4. The shear strength was increased by 2.43% to 10.21% for 20% to 60% replacement of GGBFS aggregate.

5. The pull-out bond strength achieves 2.18 at 60% replacement of GGBFS aggregate.

6. The water absorption range is 2.03% to 4.36%.

ACKNOWLEDGMENT

I express most sincere thanks to my beloved guide Prof. Y.V.AKBARI Department of Civil Engineering, Rajkot, Gujarat. whose valuable guidance and direction were mainly responsible for this thesis work. I am also grateful to our beloved principle Dr. D.D VYAS, whose co-operation during the thesis work. I would also thank all the Teaching Staff of the department for their valuable suggestions and support. Finally, I would like extend my heart fully thanks to my family, my friends and Well-wishers who have supported me for this thesis work.

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IS Codes:

IS 10262-2009: - “CONCRETE MIX PROPORTIONING”
IS 456-2000: - “PLAIN AND REINFORCED CONCRETE”
IS: IS 2770-1 (1967): - “Pull Out Reinforced”