High Performance Concrete by using Industrial Wastes

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***Abstract:-* India has seen the growth of industries manifold from the past couple of decades. As computer and other industries are growing, demand for iron and copper are also increasing as it has found a large application in these industries. Ground Granulated Blast furnace Slag (GGBS) and Copper Slags are the major by-products from a steel and copper industries respectively. If these slags are not disposed off properly, may cause environmental hazards to the area surrounding the industries. The phenomenon of widespread deterioration of concrete structures during the past two decades has become a matter of global concern, and therefore the durability of concrete structures has assumed great importance today. Considering the long term performance and stability of structures, in this study, the application of GGBS as cement and copper slag as fine aggregate has been started with expectation of large amount of consumption. This utilization of GGBS and copper slag helps in the disposal of waste products as well as a replacement for cement and the conventional fine aggregate, which are becoming scarce. This study presents an experimental investigation to assess the durability parameters of High Performance concrete with the industrial wastes. Durability parameters such as Water absorption and chloride penetration are to be studied. This study critically reviews the test results with 30% GGBS as cement and varying proportions of copper slag as fine aggregate and suggests maximum proportion of slag materials that can be used for the optimum performance.**

Key Words: GGBS, Copper slag, Water absorption and HPC

1.0 INTRODUCTION

In India, most of the construction activities are made with concrete, as it is easily available and the moulding can be done even by unskilled labour. Thus, concrete is becoming a very important material for every human. Concrete is being used for all major constructions, like Dams, Towers, Water tanks, Houses, Roadways, and Railway sleepers etc. Long- term performance of structures has become vital to the economies of all nations. Concrete has been the major instrument for providing stable and reliable Infrastructure. Deterioration, long term poor Performance, and inadequate resistance to hostile environment, Coupled with greater demands for more sophisticated architectural form, led to the accelerated research into the microstructure of cements and concretes and more elaborate codes and standards. As a result, new materials and composites have been developed and improved cements evolved. One major remarkable quality in the making of High performance concrete (HPC) is the virtual elimination of voids in the concrete matrix, which are mainly the cause of most of the ills that generate deterioration. Recently, composites are fastly replacing the conventional concrete. With many major developments in concrete industry, the waste material utilization in the manufacturing of concrete, being used as a replacement material for the ingredients, is also growing.

India has an enormous growth in the steel industries and Copper Industries. The Following are major by products in these industries Copper Slag - A by product of Copper refinery Ground Granulated Blast Furnace Slag (GGBS) - A by-product in the manufacture of iron in steel industry.

One such company producing slag is M/S.STERLITE INDUSTRIES (India) Ltd. In the process of manufacture of Copper granulated slag is generated as a by product for which the company is looking for prospective buyers. Current generation of copper is around 1, 20, 000 MT/Year which will go up in near future as the capacity is being expended. Ground Granulated Blast Furnace slag has been dried and ground to a fine powder. Iron ore, limestone, and coke are fed into the blast furnace where they reach a temperature of 1500^{o}C and the raw material reduced to molten iron and blast furnace slag. These are tapped off from the blast furnace and separated for processing. Molten iron is sent to the steel producing facility and slag (GGBS) is used to make concrete in combination with Portland cement. It is the Glassy granular material formed when molten blast furnace slag is rapidly chilled as by immersion in water.

NEED FOR THE STUDY

In India, the growth of industries has been observed from the past decade. As industries grow, their waste product generation increases. If these Slags are not disposed off

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properly, they may cause environmental hazards to the surrounding area. Considering the long term performance and stability of structures, in this study it is planned to replace some percentage of fine aggregate with Copper slag and some percentage of cement with GGBS to develop the High Performance Concrete.

OBJECTIVES

The objectives of this research work are to study

1. The properties of Industrial wastes and their suitability in High Performance Concrete.
2. To study the behaviour as well as Properties of concrete in fresh and hardened state.
3. To Study the effect of GGBS and Copper Slag on workability of Concrete.
4. To Study the durability characteristics of high performance concrete with industrial wastes.

METHODOLOGY

The Methodology for this thesis is given in the form of flow chart. Flow chart is given in Fig 1.For any successful investigation, numerous tests have to be performed and the trend of results should be carefully before arriving at the final conclusion. To realize the results from the tests experimental set up and testing procedures are required.

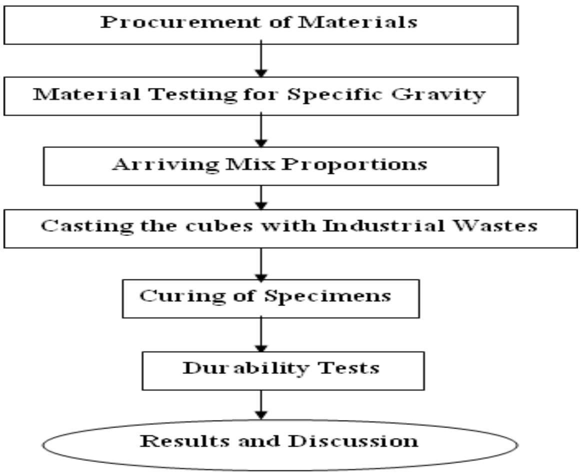

Figure 1 Methodology Flow chart

MATERIAL CHARACTERISTICS

a. Ordinary Portland Cement 53 Grade with Specific Gravity of 3.16
b. Locally available sand with fineness modulus of 2.86 and Specific gravity of 2.61
c. Locally available Coarse aggregate with fineness modulus of 5.27 and Specific gravity
c. Ground Granulated Blast furnace Slag with specific gravity of 2.94
d. Copper Slag in granular form with fineness modulus of 3.22 and Specific gravity of
e. Water confirming to the requirements of water of Concreting and curing.

S.No	Grade	Water	Cement	FA	CA
1	M30	0.370 166.5 lit/m^3	1 450.0 Kg/m^3	1.18 531.82 kg/m^3	2.88 1296.89 kg/m^3

CORRECTION IN MIX DESIGN FOR THE REPLACEMENT OF CEMENT WITH GGBS

Based on the above changes reviewed from the literature, the conventional IS method of concrete mix design was modified by making corrections in the compressive strength and water content

Corrections on Target mean strength
The target mean strength for the concrete incorporating slag is to be calculated using the formula
$F\ ck = (f\ ck + tS)C$

Where,

$f\,ck$ =Characteristic compressive strength at 28 days, MPa
S = Standard deviation, Mpa (5 MPa for M30)

C = Multiplication constant which is obtained from the strength percentage reduction values.

Calculation of Multiplication constant
As the proportion of slag increases, the compressive strength decreases. So the target mean strength of concrete incorporating slag was multiplied by the constant C to achieve the strength of the conventional concrete. The constant C is the value of the percentage reduction in strength between the conventional concrete and the concrete incorporating slag. The generalized curve relating the proportion of slag and the multiplication constant is obtained using the software SPSS (Statistical package for the social sciences).The constant C was obtained from the equation relating the percentage reduction and proportion of slag. The multiplication constant which is to be used as a strength

correction factor has been obtained and it is tabulated in Table 2.

Table 2 Multiplication constant for various grades and various % of GGBS replacement

S.No	Concrete grade and GGBS replacement	Multiplication constant (C)
1	M30 – 15S	1.05
2	M30 – 30S	1.10
3	M30 – 45S	1.13

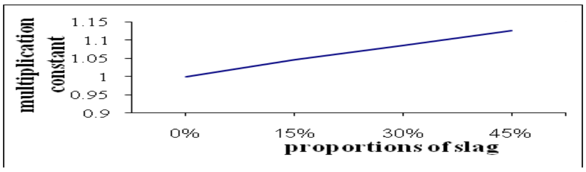

Figure 2 Generalized curve for multiplication constant

Correction on Selection of Water content

The lower relative density of GGBS causes an increase in paste volume. Compared to Portland cement, GGBS occupies about 9% more solid volume for the same mass. Thus the increase in paste volume improves the workability. When slag is added to the concrete mix initially, slag particles don't react since the heat of hydration is very low. So only remaining cement particles react with water and there is always more free

water. As the proportion of slag increases, the water needed for the concrete incorporating slag to maintain the same slump value as that of conventional concrete is less. Hence water content of the mix incorporating slag is reduced so that the constant slump value is maintained. The water content of the concrete incorporating slag is reduced in order to achieve the slump value 64 mm for M30. This water correction was applied in the mix design. The water content of the concrete incorporating slag is reduced at a percentage of 3.49%, 7.79% and 11.02% for M30 for the GGBS replacement level of 15%, 30% and 45% respectively. Thus the overall water reduction percentage varies from 3% to 12%.

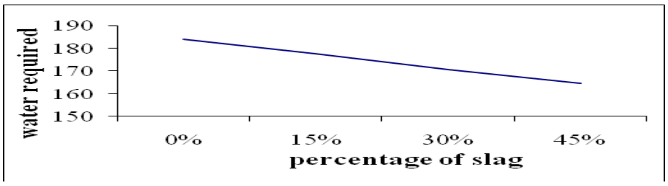

Fig 3 Generalized curve for water content

Mix design for M30 grade concrete with 30% GGBS replacement levels was followed as per IS method and the ingredients are obtained as follows.

Table 3 Mix Proportions for M30 grade concrete with 30% of GGBS replacement

S.No	Grade	GGBS Replacement with Cement	Water	Cement	FA	CA
1	M30	30%	0.35	1	1.23	3.05
			153.53 lit/m^3	438.66 Kg/m^3	538.08 kg/m^3	1337.32 kg/m^3

Correction in mix design for the replacement of sand with copper slag

The difference in Specific gravity of fine aggregate and copper slag is considered in the mix design since the copper slag have a higher density than the fine aggregate. Based on difference between the specific gravity of fine aggregate and copper slag mix proportions has been arrived for various replacement levels.

Table 4 Mix Proportions for M30 grade concrete with GGBS and copper slag replacement

S.N	Cement-GGBS replacement	FA-Copper slag replacement	Water lit/m^3	Cement Kg/m^3	GGBS Kg/m^3	FA Kg/m^3	Copper Slag Kg/m^3	CA Kg/m^3
1	70 – 30%	80 – 20%	153.53	307.06	131.60	455.52	113.88	1337.32
2	70 – 30%	60 – 40%	153.53	307.06	131.60	363.74	242.48	1337.32
3	70 – 30%	40 – 60%	153.53	307.06	131.60	258.89	388.89	1337.32
4	70 – 30%	20 – 80%	153.53	307.06	131.60	138.83	555.31	1337.32
5	70 – 30%	0 – 100 %	153.53	307.06	131.60	0	748.39	1337.32

Schedule of test specimens

From the earlier experimental investigations, it has been observed that the optimum replacement of GGBS to cement without compromising the compressive strength is 30%. With this, it is planned to replace the fine aggregate by Copper Slag at various replacement levels. The details of test specimens to be cast are given in Table 5.

Table 5 Schedule of test specimens

S. No	Cement – GGBS Proportion	Fine aggregate – Copper Slag proportion	No of Cubes/Cylinders		
			Compressive Strength	Water absorption	RCPT
1	100 – 0%	100 – 0%	3	3	3
2	70 – 30%	100 – 0%	3	3	3
3	70 – 30%	80 – 20%	3	3	3
4	70 – 30%	60 – 40%	3	3	3
5	70 – 30%	40 – 60%	3	3	3
6	70 – 30%	20 – 80%	3	3	3
7	70 – 30%	0 – 100%	3	3	3

TESTS ON CONCRETE SPECIMENS

Compressive Strength Test

Totally 21 cubes of 150 mm are to be cast, 3 specimens for each percentage replacement. The cubes are to be cast by hand compaction as per IS 516-1959. The specimens are to be kept in water for curing of 28 days. After curing, they have to be tested in wet condition by wiping water and grit present on the surface. The load should be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load is applied to the specimen will be recorded and the appearance of the concrete for any unusual features in the type of failure to be noted. Average of three values to be taken as the representative of the batch.

Water absorption Test

This method is used to find the water absorption of hardened concrete based on ASTM C642-81.

Procedure as per ASTM C642-81

After 28 days curing the specimens are to be taken out from curing tank. Specimens are dried in an oven at 105^{O}C for 24 hrs. The dry specimens are cooled to room temperature (25^{O}C) weighed accurately and noted as dry weight. Dry specimens are to be immersed in a water container. Weight of the specimen at predetermined intervals to be taken after wiping the surface with dry cloth. This process is to be continued not less then 48 hrs or up to constant weight are to be obtained in two successive observations.

$$\% \text{ Absorption} = \times 100 \; \frac{\text{Saturated weight} - \text{Dry weight}}{\text{Dry weight}}$$

Rapid Chloride Penetration Test

AASHTO T277: Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (Rapid Chloride Permeability Test). In the AASHTO T277 (ASTM C1202) test, a water-saturated, 50-mm thick, 100-mm diameter concrete specimen is subjected to a
60 V applied DC voltage for 6 hours using the apparatus shown in Figure 4. In one reservoir is a 3.0 % NaCl solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as Table 6.

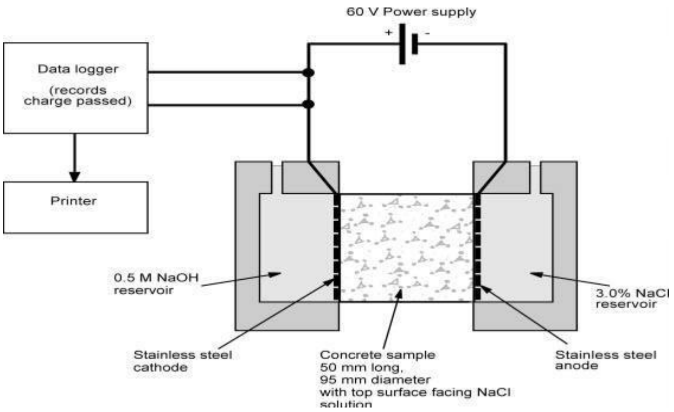

Fig. 4 ASHTO T277 (ASTM C1202) test setup

Table 6 Rapid chloride penetration test (RCPT) ratings

(per ASTM C1202)

S.No	ıarge Passed (colombs)	Chloride Ion Penetrability
1	> 4,000	High
2	2,000-4,000	Moderate
3	1,000-2,000	Low
4	100-1,000	Very Low
5	< 100	Negligible

RESULTS AND DISCUSSIONS

Slump test

The Slump test was conducted on fresh concrete for various percentage of replacement of fine aggregate with Copper slag and their results are tabulated below.

Table 7 Slump Values

S.No	Cement-GGBS replacement	FA-Copper slag replacement	Slump Value in mm
1	100 – 0%	100 – 0%	60
2	70 – 30%	100 – 0%	60
3	70 – 30%	80 – 20%	65
4	70 – 30%	60 – 40%	70
5	70 – 30%	40 – 60%	75
6	70 – 30%	20 – 80%	80
7	70 – 30%	0 – 100%	85

Compressive strength test

Table 8 Compressive strength test results

S.No	% Re placement of copper slag	28 days	
		ad in kN	Compressive Strength N/mm^2
1	Control mix	807.06	35.86
2	0	915.4	40.67
2	20	1034.08	45.95
3	40	1125.89	50.00
4	60	1163.60	51.71
5	80	1266.29	56.27
6	100	1439.68	63.98

Water absorption test

Table 9 Water absorption test results

S. No	6 Re placement of copper slag	% Decrease in Water absorption (compared with 1.548%)
1	20	20.755
2	40	46.144
3	60	66.552
4	80	74.700
5	100	76.188

CONCLUSION

Based on the above results

1. It is observed that there is no change in the slump value when GGBS alone present in the mix. But the addition of copper slag increasing the slump value depending upon the percentage of its replacement.
2. The compressive strength for 30% replacement of GGBS with cement and 100 % replacement of fine aggregate with copper slag increases by 57.31% for 28 days.
3. Water absorption for 30% replacement of GGBS with cement and 100 % replacement of fine aggregate with copper slag decreases by 76.188% for 28 days.

Further rapid chloride penetration test have to carried out on the casted cylinders and the results will be compared with conventional concrete.

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