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An Experimental Investigation on the Strength Parameters of Double Blended Green Concrete with GGBS and Copper Slag

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***Abstract* - Cement is a very valuable commodity as it can be used to construct structurally sound buildings and infrastructure. However, in many developing countries cement is expensive due to the unavailability of local resources and to produce enough cement to meet the demand it must be imported. During manufacturing of 1 tonne of OPC, an equal amount of carbon-di-oxide are released into the atmosphere. Use of cement and aggregates may lead to active shortage in the future. Disposal and pollution problems can be reduced to greater extent by partially replacing the cement using GGBS and copper slag obtained from industries. This study investigates the use of GGBS as partial replacement of cement and copper slag as partial replacement of fine aggregate (each with a proportion of 30%, 50%, and 70%). To evaluate these replacements on the properties of the OPC mix, a number of laboratory tests were carried out. The destructive tests to be carried out (7, 14 and 28days) in this project are compressive strength (cube size:150mmx150mm), flexural strength (beam size 500mmx100mmx100mm), split tensile strength of concrete (100mm diameter and 200mm height cylinder) and the non-destructive tests such as Ultrasonic Pulse Velocity and durability tests such as Rapid Chloride Penetration test. Finally, the test results are compared with conventional concrete and the percentage savings in cost has been worked out.**

Keywords – GGBS, Copper slag, Blended concrete, M40 grade concrete

1. INTRODUCTION

Our country's infrastructure requirements are increasing day by day and concrete is considered as the main constituent. Ordinary cement Portland is recognized as a major building material around the world in terms of per capita consumption, it is the second most consumed material in the country. However, cement production has decreased limestone reserves in the world and requires high energy consumption. The rapid increase in construction activity causes a serious shortage of traditional building materials, resulting in a high cost. Researchers around the world are currently focusing on ways of using industrial or agricultural waste as a source of raw materials for the industry. These waste, not only of economic use, but also influence foreign currency revenue and environmental pollution. The iron ore and copper industries generate large amount of slags which are disposed and they get mixed with the land area thereby polluting it. The extraction obtained from iron is GGBS and that from copper is copper slag. The GGBS has a phenomenal amount of Calcium Oxide present in it which helps in the improvement of strength on the whole. The presence of silica content in copper slag helps as a best replacement for fine aggregate. Keeping the socio-economic needs of our society in mind the concrete of tomorrow must not only be economic but also be durable meeting the specific standards. Therefore, in this project an attempt has been made to utilize GGBS and copper slag as partial replacement of cement and fine aggregate in certain proportions thereby getting an idea about the strengths they induce in concrete. After 28th day tests on certain proportions an optimum percentage is chosen in each of GGBS and copper slag and these both are blended in concrete to produce a double blended green concrete which will be an economically friendly concrete for which destructive, non-destructive tests are to be carried and cost can be analyzed.

2. REVIEW OF LITERATURES

2.1 P. Vignesh and K. Vivek published a journal on, "An experimental investigation on strength parameters of flyash based geopolymer concrete" in International Research Journal of Engineering and Technology (IRJET), volume 2, Issue 2: In this paper an attempt was made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Sodium silicate and sodium hydroxide solutions were used as alkaline solution in all 5 different proportions and found that the maximum compressive and split tensile strength was achieved when % of flyash was 70 and GGBS was 30. On the contrary flexural strength decreased with increase in percentage of flyash. The optimum replacement level of flyash by GGBS in Geopolymer concrete will absorb water less than the nominal concrete. It achieves a compressive strength of 70% in a short period of 4 hours after setting.

2.2 Arvind Nakum et.al., in their research titled, "High strength concrete incorporating ground granulated blast furnace slag and steel fibres" focused to improve the structural strength of concrete thereby reducing the quantity of steel. The experimental work done was reviewed which mainly deals with mechanical and durability properties of high strength concrete reinforced with metallic (steel) fibres based upon normal curing. They carried out the work by replacing cement with GGBS from 10 to 50% with an addition of 1% steel fibre for M40 grade concrete and performed compressive, split tensile and flexural strengths and durability tests and found that upto 40% replacement by ggbs there was a drastic improvement in strength after which it decreased.

2.3 Ishwar Chandra Takur et.al., in their journal, "Properties of concrete incorporated with GGBS" published in IJERT volume 5 Issue 8 have utilized GGBS in M30 grade concrete where the mechanical properties such as compressive, split tensile and flexural strength and physical properties such as dry and moist density, water absorption were analyzed. Here GGBS was partially replaced from 10% to 70%. The maximum compressive strength and flexural strength was achieved at 50%, split tensile strength with 60% replacement of GGBS in proportion to cement. It was also found that dry and moist density, water absorption decreased with increase in % of GGBS. The authors finally concluded that there was 40% savings in concrete production upon utilizing GGBS.

2.4 M.V. Patil in his research titled," A study on properties and effects of copper slag in concrete" studied the strength characteristics of M30 grade concrete upon partial replacement of copper slag as fine aggregate in proportions ranging from 0 to 100%. He found that there was an increase in compressive strength when copper slag was replaced by 20% after which there was a decrease and the reason was mainly due to the presence of voids made by the finer particles of copper slag. The split tensile strength and flexural strength increased in the proportion of 20%. The modulus of elasticity of concrete decreased with increase in percentage of copper slag.

2.5 Tamilselvi et.al., in their journal titled, "Experimental study on concrete using copper slag as replacement Material of Fine Aggregate" studied the strength properties and conducted non destructive tests on M40 grade concrete by replacing copper slag in proportions of 0,20,40,60,80 and 100%. It was found that upon 40% replacement of copper slag as a substitute to fine aggregate the compressive, split tensile and flexural strength increased after which there was a gradual decrease. The non-destructive tests rebound hammer and ultrasonic pulse velocity showed a maximum result on 40% replacement thereby proving the concrete to be of excellent quality.

3. STUDY OF MATERIALS

The materials used in this project are cement, GGBS, fine aggregate, Copperslag, coarse aggregate and water. The tests were conducted conforming to IS.

3.1 Ground Granulated Blast Furnace Slag (GGBS): It is obtained by rapidly chilling the molten iron slag from the furnace to produce a glassy product. CaO present in this mainly contributes to the compressive strength. The specific gravity was found to be 2.74.

3.2 Copper Slag: It is a by-product of copper which has similar properties as that of fine aggregate because of the presence of silica content. The specific gravity was found to be 2.60.

Fig. 1: GGBS

Fig. 2: Copper slag

Table1: Comparison of Properties of Cement and GGBS

Properties	Cement (%)	GGBS (%)
CaO	61.96	40
Al_2O_3	5.36	10
MgO	1.334	8
SiO_2	20.69	35

Table 2: Comparison of Properties of FA and Copper slag

Properties	FA (%)	CopperSlag(%)
Fe_2O_3	61.96	55
SiO_2	5.36	35
Al_2O_3	1.334	3.01

4. CASTING OF CONCRETE CUBES

The mix design of 1:1.46:2.42 was arrived for M_{40} grade and the raw materials were casted in certain proportions. Cubes, cylinders and prisms were casted with 30%, 50% and 70% of GGBS for partial replacement of cement and the same proportion of copper slag for partial replacement of fine aggregate. The mixing was done using mechanical mixers and the same were compacted using mechanical vibrators. Normal curing was adopted and the hardened properties were tested on 7^{th}, 14th and 28^{th} days. The following replacements were adopted:

Table 3: Designation of Concrete

Design Mix	Proportions
M0	100% OPC
M1	30% ggbs and 70% cement
M2	50% ggbs and 50%cement
M3	70% ggbs and 30% cement
M4	30% copper slag and 70% fine aggregate
M5	50% copper slag and 50% fine aggregate
M6	70% copper slag and 30% fine aggregate

5. TEST RESULTS

5.1 Strength Test: Compressive, Split tensile and Flexural strength tests were conducted on the casted cubes on 7^{th},14^{th} and 28^{th} day of curing both for conventional and partially replaced concrete. The materials responded well for lower percentages of replacements and gave satisfactory results for higher percentages.

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Table 4: Compressive Strength results

Design Mix	Compressive Strength (N/mm^2)		
	7[th]day	14[th]day	28[th]day
M0	31.27	41.32	50.36
M1	44.72	47.25	63.7
M2	32.89	39.1	53.92
M3	27.26	30.37	37.63
M4	32.15	45.92	54.37
M5	35.25	50.37	58.96
M6	37.63	54.84	67.85

Table 5: Split Tensile Strength results

Design Mix	Split Tensile Strength (N/mm^2)		
	7[th]day	14[th]day	28[th]day
M0	1.563	2.149	3.07
M1	2.236	2.457	3.33
M2	1.644	2.03	3.12
M3	1.362	1.579	2.7
M4	1.61	2.38	2.83
M5	1.762	2.62	3.065
M6	1.88	2.85	3.528

Table 6: Flexural Strength results

Design Mix	Flexural Strength (N/mm^2)		
	7[th]day	14[th]day	28[th]day
M0	2.189	4.12	6.10
M1	3.13	4.23	6.4
M2	2.301	3.93	6.12
M3	1.91	2.82	5.25
M4	2.25	3.44	4.07
M5	2.47	3.78	4.422
M6	2.63	4.113	5.089

From the above results, it can be found that M1 and M6 mixes gave higher results when compared with M0. Thus, these two proportions are considered for making the blended concrete.

5.2 Blended concrete: The blended concrete gets its name by mixing two materials in some proportions as a replacement of nominal mix materials. Here from the 28[th] day test results 30% of GGBS and 70% of copper slag were added as a replacement to cement and fine aggregate and the properties were studied.

5.2.1 Strength test: The blended concrete responded well for the strength test and it can be seen from below table:

Table 7: Comparison of OPC with Blended concrete

Type of mix	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Flexural strength (N/mm^2)
100%OPC	50.36	3.07	6.10
Blended concrete	64.5	3.24	6.02

5.2.2 Ultrasonic Pulse Velocity test: This test is mainly conducted to assess the strength and quality of concrete by passing the pulses into the concrete structure at a certain velocity. Higher velocity indicates good quality and continuity of the material, while slower velocity may indicate the presence of cracks or voids.

Table 8: Comparison of UPV values

Types of mixes %	M0	M1	M6	Blended concrete
UPV(m/s)	4740	4340	4450	4570

The above table shows that the blended concrete responded well with respect to OPC when comparing with other mixes proving the concrete to be of good quality.

5.2.3 Durability test: Here, rapid chloride permeability was performed to determine the chloride permeability by measuring the number of coulombs able to pass through a sample.

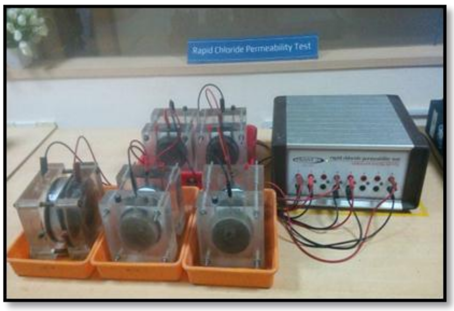

Fig.3: RCPT Test setup

Table 9: Comparison of RCPT values On 28[th] day

Types of mixes %	M0	M1	M6	Blended concrete
Chloride ion penetration values(coulombs)	2927	625	545	1743

5. COST ANALYSIS

Cost is the major factor which influences every project, whether to be implemented or not. So, the cost of using GGBS and Copper slag in concrete is analyzed and the approximate cost is estimated. The price of materials is of market rates.

Cement = Rs. 400/ bag
Sand = Rs. 840/m^3
Coarse aggregate = Rs. 700/ m^3
GGBS = Rs. 4/kg
Copper slag = Rs. 0.20/kg

While working out the cost there was about 16.30% reduction when adopting blended concrete than OPC.

6. CONCLUSIONS

Based on the Experimental investigation on concrete using GGBS and copper slag, the following can be concluded.

- From the of 7, 14 and 28 day results of compressive strength, there is increase in strength when 30% of GGBS is added in replacement of cement and decrease in strength with further addition of GGBS whereas during the addition of 70% of copper slag in place of fine aggregate the strength increases where there is a mediocre strength for lower % replacements.
- There is an increase in split tensile strength when 70% of copper slag is replaced.
- The flexural strength gets increased on addition of 30% of GGBS in place of cement and on further addition the strength gets decreased.
- When comparing OPC with double blended concrete there is a drastic increase in compressive and split tensile strength by 13.5% and 5.24% whereas the flexural strength slightly decreased by 1.3%.
- The UPV test proved the OPC to be of excellent quality and moreover the bended concrete matched the properties of OPC to a nominal extent.
- In RCPT test OPC responded well compared to other mixes and the blended concrete showed phenomenal improvement.
- The cost is very much effective when double blended concrete is added i.e. there is an overall reduction in cost of about 16.30%. By this we could suggest that if blended concrete is preferred an environment friendly concrete can be produced.

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