Experimental Study on Hollow Concrete Block Using Copper Slag and GGBS (Ground Granulated Blast Furnace Slag)

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Abstract- *"Hollow concrete block" have become a regular or frequent choice today in construction activities as these blocks offer various benefits simplicities in their use as building elements strength as compared to the conventional blocks. These blocks are used for both load bearing and non-load bearing wall. The study covered in the present paper is an attempt to ascertain the technical feasibility of utilizing an industrial waste material for manufacturing of the construction building material i.e. solid masonry concrete blocks. In present work, experimental studies for hollow blocks using copper slag; which is by-product of copper extraction by smelting used as the partial replacement of fine aggregate in different percentage and GGBS which is by product of iron manufacturing is used as the partial replacement of cement. The M-15 grade is chosen for the work. The study reported in this paper is a development of hollow concrete block using copper slag and GGBS. The dimension of hollow concrete block is 390mm × 190mm × 190mm. copper slag is used as various percentages of 0%, 20%, 40%, 60% and GGBS of 0%, 5%, 10%, 15%, 20%, 25% and 30%. Tests conducted on the hardened concrete include Compressive strength, Water absorption, Bulk density and Thermal conductivity.*

Keywords- Hollow concrete block, Copper slag, GGBS, Masonry, Compressive strength, Thermal conductivity

I. INTRODUCTION

Concrete blocks, whether of normal weight or lightweight, are widely used in the construction of claddings, load and non-load bearing walls. In many countries, the price of most conventional building materials is increasing and in some countries there is a general paucity of natural materials that are suitable for construction. In recent years, there has been an increase in the consumption of raw materials in the construction industry at a rate far exceeding their replacement. This justifies the need for a concentrated research effort towards seeking alternative building materials, which can be used as a partial or full replacement of either cement or aggregates, which are considered the main ingredients used in the manufacturing of blocks. Therefore, the use of waste, recycled and by-product materials in the manufacturing of masonry blocks could provide a viable solution to the problem. This can yield the dual benefits of reducing the costs of disposal and minimizing environmental pollution problems that arise from the manufacturing of such materials.

Copper slag is an industrial by-product obtained during the matte smelting and refining of copper. When one ton of copper is produced, 2.2-3 tons of copper slag is generated. Copper slag is widely used for sandblasting, railroad ballast, cement and concrete industries. Several researches have investigated the possible use of copper slag as fine aggregate and coarse aggregate in normal concrete and its effect on different mechanical properties of concrete. Silicon oxide is the major component of sand and it is also found to be in huge amount in copper slag as well. Thus, the common component of sand and copper slag makes their properties quite similar to each other.

The production of concrete is not an environmentally friendly process as it contributes to the emission of greenhouse gases. The biggest contributor to greenhouse gases is carbon dioxide (CO_2), which accounts for 82% of the total greenhouse gases. The cement industry alone, contributes to approximately 5-7 % of the global manmade greenhouse gas emissions. The high emission of CO_2 from the industry is mainly due to the process of calcination and fuel combustion, which amounts up to 50 and 40% of the total emission in the cement industry, respectively. The use of common supplementary materials such as fly ash and ground granulated blast furnace slag (GGBS) as partial cement replacement significantly reduces the CO_2 emission. The blast furnace slag is a by-product of the iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500˚C to 1600˚C. The molten slag has a composition of about 30% to 40% SiO2 and about 40% CaO, which is close to the chemical composition of cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then waterquenched rapidly, resulting in the formation of a glassy granulate. This glassy granulated is dried and then ground to the required size, which is known as ground granulated blast furnace slag (GGBS).

II. MATERIALS

2.1 Cement

The cement used in this project is an ordinary Portland cement 53 grade manufacturing by Hathi Cement Company. The specific gravity and fineness modulus of cement is 3.15 and 6% respectively.

2.2 Fine aggregate

In addition with the copper slag, river sand is used as a fine aggregate, having the specific gravity and fineness modulus as 2.36 and 2.53 respectively.

2.3 Coarse aggregate

10 mm nominal size gravel has been used for this study with the specific gravity as 2.68 and fineness modulus as 6.09.

2.4 Copper slag

As detailed earlier, existing studies reported the supreme quality of the copper slag and its impact in concrete, hence this study considers copper slag as one of the partial replacement for fine aggregate. The copper slag used for this study was collected from one copper industry situated in Gozaria, Mehsana, Gujarat. The physical and chemical properties of copper slag are shown in following table.

Table 1 Physical properties of copper slag

S. No	Property	Values
1	Specific gravity	2.98
2	Fineness modulus	3.56
3	Color	Bright black
4	Bulk density	1900 kg/m^3

Fig.1 Copper slag

Table 2 Chemical properties of copper slag

Component	Chemical composition (%)
Sio2	83.05
Al_2O_3	6.090
Fe_2O_3	2.27
CaO	1.05
MgO	0.33
Na_2O	1.849
K_2O	3.46
Loss of ignition	1.90

2.5 GGBS

The blast furnace slag is a by-product of the iron manufacturing industry. The use of ground granulated blast furnace slag (GGBS) as partial cement replacement significantly reduces the CO_2 emission. The GGBS used for this study was collected from Arhum Enterprise, Ahmedabad. The physical and chemical properties of GGBS are shown in following table:

Table 3 Physical properties of GGBS

S. No	Property	Values
1	Specific gravity	2.9
2	Fineness modulus	3.36
3	Color	Off white
4	Bulk density	1200-1300 kg/m^3

Fig.2 GGBS

Table 4 Chemical composition of GGBS

Component	Chemical composition (%)
Sio2	83.05
Al_2O_3	6.090
Fe_2O_3	2.27
CaO	1.05
MgO	0.33
Na_2O	1.849
K_2O	3.46
Loss of ignition	1.90

III. EXPERIMENTAL STUDY

3.1 Mix design

This work involves seven trial mixes and one control mix. M-15 grade was chosen for the work. The mix design was calculated as per IS: 10262-2009. The W/C ratio is 0.55. The variable investigated in this study was the replacement of sand by copper slag at 40% and cement by GGBS at 0%, 5%, 10%, 15%, 20%, 25% and 30%.

Table 5 Samples with different mix proportions

Mix no.	Combinations	% of copper slag	% of GGBS
1	Control mix	0	0
2	C40G0	40	0
3	C40G5	40	5
4	C40G10	40	10
5	C40G15	40	15
6	C40G20	40	20
7	C40G25	40	25
8	C40G30	40	30

Table 6 Mix proportions

Water	Cement	Fine aggregate	Coarse aggregate (Grit)
208 (liter)	378.18(Kg)	1128.10 (Kg)	712.51(Kg)
0.55	1	2.99	1.89

3.2 Blocks production

For preparing hollow concrete blocks, two methods are used either hydraulic press or machine press. Mixing of concrete is done either by hand or by machine. The molds for the blocks are pre-oiled. The block's size is 390×190×190 mm with two slots each measuring 115×130×190 mm. The thickness of face cell and web are 30 mm and 20 mm respectively.

Fig. 3 Hollow concrete block

3.3 Testing the properties of the blocks

After 28 days from the date of casting, the blocks are removed from the curing tank. They are dried, weighed and subjected to the following tests. (1) Compression test, (2) Bulk density, (3) Water absorption, (4) Masonry prism test, (5) Thermal conductivity

IV. TEST AND DISCUSSION

4.1 Compressive strength of hollow concrete block

Compressive strength tests of the blocks is carried out as per IS: 2185 (Part-1) 2005. The compressive strength of block is measured at 28 days. Average of four blocks is taken. Results show that the maximum strength is achieved of 12.34 N/mm^2 for mix of 40% of copper slag and 15% of GGBS.

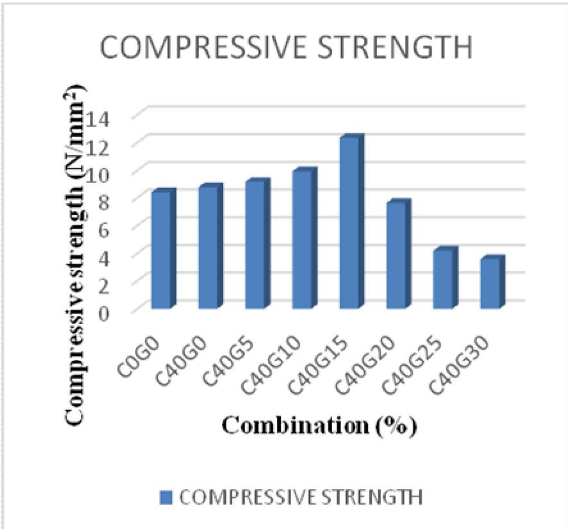

Fig. 4 Compressive strength of the blocks at 28 days

Table 7 Summary of results

Mix	Compressive strength (N/mm^2)	Bulk density (kg/m^3)	Water absorption (%)
Control mix	8.39	1342.43	2.53
C40G0	8.76	1080.33	2.91
C40G5	9.17	1116.55	2.79
C40G10	9.94	1162.72	2.68
C40G15	12.34	1193.97	2.49
C40G20	7.63	1215.99	2.33
C40G25	4.21	1249.37	2.16
C40G30	3.6	1272.81	2.06

4.2 Bulk density of hollow concrete block

Bulk density of the blocks is carried out as per IS: 2185 (Part-1) 2005. As per IS code, the bulk density must be greater than 1100 kg/m^3 and less than 1500 kg/m^3. The combination C40G15 gives the bulk density of 1193.97 kg/m^3, which satisfies codal requirement.

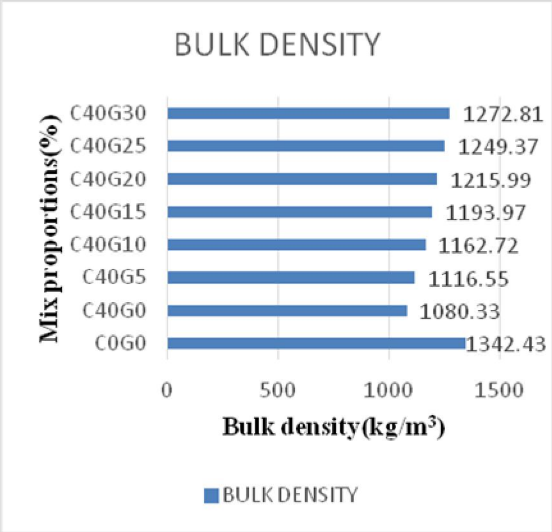

Fig. 5 Bulk density of the blocks

4.3 Water absorption of hollow concrete block

Water absorption of the hollow blocks is carried out as per IS: 2185 (Part-1) 2005. As per IS code, the maximum water absorption is 10% by mass. The combination C40G15 give the 2.49% of water absorption.

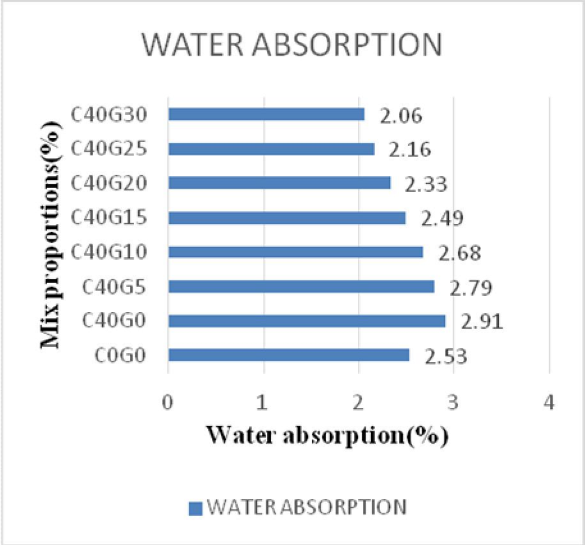

Fig. 6 Water absorption of hollow blocks

4.4 Masonry prism test

Strength of individual block specimen is not enough. A block has to perform well together with mortar joint in masonry because bond between the masonry unit and mortar is important for the masonry to resist stresses due to different types of loads. For this purpose, testing on blocks prisms need to carry out. The block prisms were built in accordance with IS: 1905-1987 of size 390 mm × 190 mm × 190mm for compression testing having height to width ratio is 3.03. The prisms were prepared for the following two combinations: (1) Control mix and (2) C40G15.

Fig. 7 Prism of hollow concrete block

Table 8 Prism compressive strength

Compressive strength of prism N/mm²			Average compressive strength of prism N/mm²
Conventional concrete block	Prism 1	4.25	4.24
	Prism 2	4.18	
	Prism 3	4.29	
Block made using copper slag 40% and GGBS 15%	Prism 1	4.04	4.11
	Prism 2	4.08	
	Prism 3	4.21	

4.5 Thermal conductivity

The Thermal conductivity of the concrete blocks was measured using a guarded hot plate method as per IS: 3346-1980.

Table 9 Thermal conductivity

Block type	Thermal conductivity
Conventional block	1.2
C40G15	0.72

Fig. 8 guarded hot plate for measuring the thermal conductivity

V. CONCLUSION

- Based on the experimental studies, the following conclusions can be drawn with respect to compressive strength, bulk density, water absorption, masonry prism test and thermal conductivity of concrete.
- Chemical analysis of copper slag and GGBS indicates good content of silica, alumina and calcium oxide, which supports the concept of replacement of sand and cement by copper slag and GGBS respectively.
- The compressive strength increases with the increase in % of GGBS.
- As compared to conventional concrete block, the compressive strength for the combination of C40G15 increases by 47%.
- As the percentage of GGBS increase, the value of bulk density increases.
- Increase in the percentage of GGBS, results in the reduction of water absorption.

- The strength of the block made using the combination C40G15 reduces by 3.06% as compared to the conventional block in case of masonry prism test.
- C40G15 has lower thermal conductivity compared to conventional hollow concrete block.

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