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A Study On Influence Of Steel Slag In Concrete Hollow Blocks.

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ABSTRACT

Concrete hollow blocks have an important place in the modern building industry as they are cost-effective and a greater alternative to the burnt clay bricks. The main advantages of hollow concrete blocks are good durability, fire resistance, good thermal and sound insulation, minimal dead load, easy installation and relatively higher speed of construction. While hollow blocks are usually made of conventional concrete an attempt has been made to manufacture slag concrete hollow blocks in which the fine aggregate used is replaced in varying percentages with EOF slag. EOF slag is obtained as a by-product during the manufacturing of steel which is generated in voluminous amounts and is hazardous in nature. Three grades of concrete and five varying percentages of replacement of fine aggregates with the EOF slag 0%, 25%, 50%, 75% and 100%. In total, 15 slag hollow blocks were cast and tested. The results show that the optimum percentage of replacement of fine aggregates was 25%. In order to study the chemical relation between the slag and the cement, EDAX and SEM were conducted.

Keywords: Aggregates, Compressive strength, Concrete, Hollow blocks, Steel slag

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INTRODUCTION

This is the right time to look into the future because due to the elevated public awareness of energy and ecological issues, the rapid industrial growth cannot be speculated. Therefore in the future, the engineers while selecting the materials, they are expected not only to consider the engineering properties and cost but also the environmental friendliness of the chosen materials [1].

The world steel industry produces about 780Mt of crude steel and an average of about 400kg of solid by-products are generated by the steel industry. The total steel production in India is about 25 million tonnes and the waste generated annually is around 8 million tonnes [2]. The steel industry involves a complicated process from raw material processing to casting and rolling of steel which involves not only a tremendous amount of raw materials and energy but also generates huge amounts of by-products and wastes. The type of by-product that is extensively generated is slag. Experts and related research studies have been conducted on the use of slag in concrete in different ways. All the related research focused on the use of slag as an effective replacement for natural aggregates with the view of reducing the use of natural resources [7].

Usually, three types of slag namely blast furnace slag, convertor slag and the electric arc furnace slag are produced. In addition to this, there is another type of slag called the Energy Optimization Furnace (EOF) slag. The EOF slag used in this experimental investigation is a type of slag produced as a by-product from the Energy Optimization Furnace used to manufacture steel. The influence of replacement of fine aggregates with this slag in manufacturing the hollow concrete blocks was taken as the main objective of this study. The EOF slag was replaced with five varying percentages of natural fine aggregates 0%, 25%, 50%, 75% and 100%. Three grades of concrete in each percentage were used to manufacture the hollow blocks.

EXPERIMENTAL PROGRAM

Materials

The natural fine aggregate and EOF Slag aggregate are sieved and graded according to IS 383 [8] in order to use them for the appropriate mix design. The cement, coarse aggregates, fine aggregates and water used for the preparation of hollow blocks complied with IS 10262 [9]. The chemical constituents of EOF slag are given in Table 1and the physical properties of EOF slag are given in Table 2.

Table 1: Chemical constituents of EOF slag

Constituents	%
LOI	3.70
CaO	36.96
FeO	28.93
SiO_2	13.81
MgO	7.46
Al_2O_3	2.53
MnO	3.00
P_2O_5	1.58
TiO_2	0.60

Na_2O	0.057
K_2O	0.032

Table 2: Physical properties of EOF slag

Designation	Properties
Colour	Light to dark brown
Shape	Highly angular
Surface texture	Rough
Specific gravity	2.93

Variables in the study

The experiment was carried out using three different mixes of concrete, **1: 2: 4 , 1: 2.5 : 3.5** and **1: 3: 3** where the sand was replaced with EOF steel slag in varying percentages which is given in Table 3.

Table 3: % of slag replacement

% of fine aggregates	0	25	50	75	100
Corresponding % of slag replacement	100	75	50	25	25

Preparation of hollow blocks

The hollow blocks were prepared as per the code IS 2185 [10]. The size of the slag hollow blocks prepared was 400 x 150 x 200 mm. The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, are calculated. The quantities of cement, coarse aggregates, natural fine aggregates, slag and water for each batch is determined by weight, to an accuracy of 0·1 percent of the total weight of the batch. The slag concrete hollow blocks were moulded and prepared by a manually operated machine moulder as shown in Fig. 1. The specimens were cured at a relatively humid condition at a temperature of 27± 2°C for a period of 28 days.

Figure 1: Preparation of slag concrete hollow blocks

Compressive strength test on hollow blocks

The hollow blocks were tested for their compressive strength using the standard Universal Testing Machine equipped with a plate setup. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq m/min until the resistance of the specimen to the Increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the crack patterns were noted. Fig.2 shows the compressive strength test of slag hollow blocks.

Figure 2: Testing of slag hollow blocks

RESULTS AND DISCUSSION

In total 45 specimens were tested for three mix proportions and five percentages of replacement of fine aggregates with the steel slag and the test results are shown in Table 4. The graph (Fig. 3) shows the variation of compressive strength with the various percentages of replacement of slag for natural fine aggregates.

Table 4: Compressive strength

Slag	Concrete mix ratios	Average compressive strength N/mm^2
0 %	1:2:4	8.03
	1:2.5:3.5	7.23
	1:3:3	6.70
25 %	1:2:4	8.38
	1:2.5:3.5	7.62
	1:3:3	6.98
50 %	1:2:4	7.39
	1:2.5:3.5	6.16
	1:3:3	5.02
75 %	1:2:4	6.82
	1:2.5:3.5	5.36
	1:3:3	4.49
100 %	1:2:4	6.52
	1:2.5:3.5	4.46
	1:3:3	3.76

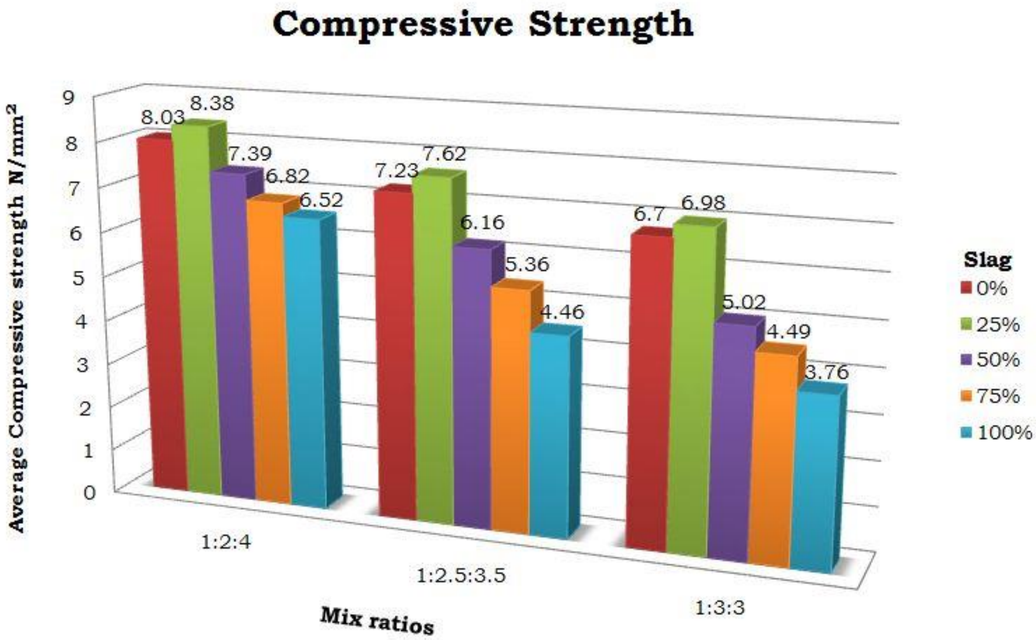

Figure 3: Compressive strength of slag hollow blocks

From the graph, it can be seen that the compressive strength the compressive strength of the hollow blocks is maximum for 25% of replacement of sand for all the three mix ratio which indicates that the maximum compressive strength of these blocks can be obtained with a specific proportion of the ingredients. Beyond 25% the graph shows a steady declination irrespective of the mix ratios. This can be attributed to the fact that there is a possibility of lower binding action between the slag aggregate and cement binder. Also, the declination in compressive strength at higher percentages of replacement can be due to the volumetric expansion caused by the calcium oxide present in the slag which hydrates into calcium hydroxide. This weakens the blocks and develops cracks under the applied loads.

In the construction of residential buildings where burnt clay bricks plays a significant role, the slag hollow blocks can be utilized as a component for constructing walls. Slag hollow blocks comply with the conditions for environmentally friendly products as it is made with the industrial by-products and the manufacturing of these blocks are totally energy conservative.

Microstructure Analysis

Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Analysis (EDAX) analyses were conducted on slag hollow block samples. The sample was selected from the fractured surface of a hollow block after the compressive strength test. From the SEM images (Fig. 4) a dense structure and uniform hydration products can be seen in the slag hollow blocks. No interfacial transition zone is found which indicates that there is a strong interaction between the aggregates and the paste which plays a major role in providing the compressive strength in the concrete. Additionally, a close grained integrated structure can be observed which improves the other mechanical properties of the slag concrete.

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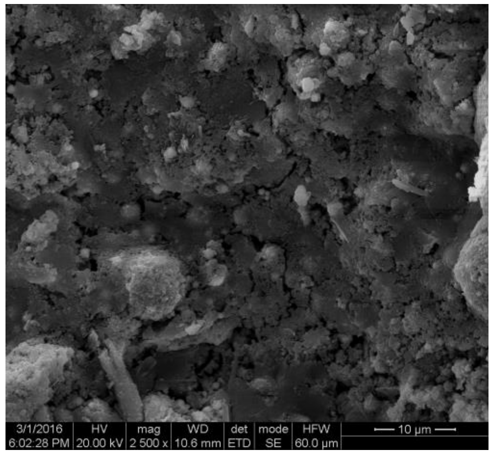

Figure 4: Scanning Electron Microscope image of slag concrete

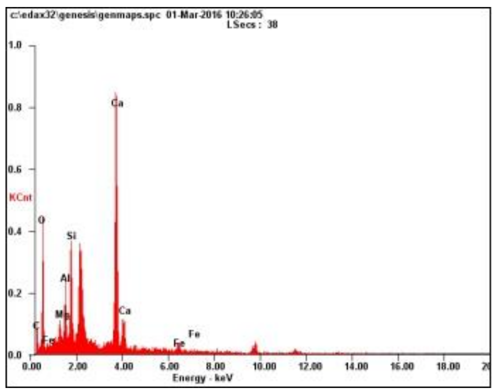

Figure 5: Energy Dispersive X-Ray Analysis image of slag concrete

The EDAX result of the slag concrete hollow block sample is shown in Fig. 5. The activation of slag is shown in the following equation:

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$$

The reaction products in the slag hollow block sample showed amounts of Ca, Si, Mg, Al and otherelements. The four major chemical components of the slag are the Ca, Mg, Si and Al, in which the ratios of these are believed to make the slag hydraulically active or inactive. Therefore the strength of the slag can be increased with the increase in CaO/SiO_2 ratio. For this reason, the ratio $(CaO+MgO+Al_2O_3)/SiO_2$ is most likely to be used to assess the slag reactivity.

CONCLUSION

This study evaluated the use of EOF steel slag as a replacement for natural fine aggregates in varying percentages. The following conclusions were made:

- The slag hollow blocks have sufficient strength and have potential as a replacement for conventional hollow concrete blocks and hollow burnt clay bricks.
- The hollow blocks with slag content 25% shows the maximum compressive strength making it optimum for use in the construction industry.
- The increase in compressive strength of the hollow blocks at higher percentages of replacement was found to be substantially lower.

- The slag has more pronounced binder action at lower percentages of replacement.
- Upon analysing the microstructure, it can be concluded that slag has good binding action and enhances the strength of concrete when used in specific proportions.

Therefore, the utilization of wastes in making concrete will help to mitigate the problem of disposal and health issues. It is essential to create awareness among the professionals and the users to employ the use these waste materials to conserve the natural resources and protect the environment and also to conserve energy.

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