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STUDY ON STRENGTH AND DURABILITY PROPERTIES OF STEEL SLAG BRICKS

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Abstract:

The present study focuses on utilizing steel slag a waste material from the manufacturing of steel into cost effective building bricks and hence recycle the waste without any environmental problem to the surrounding environment. The investigation was carried out to evaluate the strength, durability and structural properties of steel slag building bricks. The results were compared with those of conventional clay bricks. The strength and durability properties of cement composites containing waste steel slag, sand have been studied in detail and the optimum mix proportions were obtained. The steel slag bricks have been tested for their compressive strength, water absorption, and prism test. The performance of the steel slag bricks is better when compared with that of conventional clay bricks.

Key Words: Steel Slag Bricks, Compressive Strength, Water Absorption, Prism Test & Cost Analysis

1. Introduction:

The utilization of industrial waste or secondary materials in the production of cement and brick has been encouraged in the construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of waste materials causes environmental and health problems (1). Therefore, recycling of waste materials is a great potential in brick industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. The use of steel slag in the Brick industry can have the benefit of reducing the costs of disposal and help in protecting the environment (2). Despite the fact that several studies have been reported on the effect of steel slag replacement on the properties of brick, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of steel slag in brick. Steel slag is obtained from Agni steel slag Private Limited, Ingur, Tamil Nadu, India and its specific gravity in fine form was found to be 2.95. The chemical composition of slag is usually expressed in terms of simple oxides calculated from elemental analysis determined by x-ray fluorescence. This slag is currently being used for many purposes. It is a glassy granular material with high specific gravity particle sizes. The size of the particle is of the order of sand and can be used as a fine aggregate in brick. To reduce the accumulation of steel slag and also to provide an alternative material for sand and cement, an approach has been done to investigate the use of steel slag in brick for the partial replacement of sand and cement.

2. Collection of Materials:

To attain these goals, materials were collected from various sources. Material collection is the basic and important step in any project.

2.1 Steel Slag:

Steel slag is obtained from Agni steel slag Private Limited, Ingur, Tamil Nadu, India and its specific gravity in fine form was found to be 2.95. In the study, steel is the main constituent material.

Table 1: Physical Properties of steel slag

Constituent	Composition %
CaO	Nil
SiO_2	11
FeO	76
MnO	5
MgO	Nil
Al_2O_3	1
P_2O_5	Nil
S	Nil
Metallic	6

2.2 Cement:

53 grade cement and sand were collected and the properties were studied as per BIS standard. The cement is obtained by burning at very high temperature of mixture of calcareous and argillaceous materials (3). The mixture of ingredients should be intimate and they should be in correct proportion. A small quantity of gypsum is added to the clinker and it is then pulverized into very fine powder, which turns into cement. In this study, 53 grade Portland Pozzolona Cement was used for the entire work. The physical properties of cement are furnished in Table 2.

Table 2: Physical Properties of Cement

S.No	Characteristics	Values
1	Standard consistency	53
2	Fineness of cement as retained on 90 micron sieve	3%
3	Initial setting time	30 minutes
4	Specific gravity	3.15
5	7 days compressive strength	37Mpa

2.3 Sand

The sand particle consists of small grains of silica (SiO2). It is formed by the decomposition of sand stones due to various effects of weather. According to the natural resources from which the sand is obtained, it is termed as Pit sand, River sand and Sea sand. Properties of fine aggregate shown in table 3

Table 3: Properties of fine aggregate

Properties	River Sand
Specific gravity	2.6
Sieve analysis	Zone-II
Fineness modulus	2.52

2.4 Preparation of Test Specimens:

The brick moulds are filled with the matrix and pressed under compression with force of 10 kN/mm^2 hydraulically. Then the bricks were taken out from mould. The size of the steel slag bricks was 230mm X 110mm X 70mm. Within 15days, i.e. after hearing the metallic sound when strikeout the brick surface, the specimen was ready for testing.

3. Experimental Investigation of Steel Slag Bricks:

Steel slag is the major constituent of the mix proportions. From literature support, steel slag with cement, with and without sand are used as ingredients of the mix with various proportions (4). From these materials, 4 mix proportions were used and studied in terms of compressive strength and percentage of water absorption as per IS 3495(Part 1to4)1992 recommendation and their results are compared with Conventional bricks. Table 4 shows the details of mix proportions used in the study.

Table 4: Details of Mix Proportions

Designation	Mix Proportions	No of Bricks
A1	1:0:1	6
A2	1:0.5:3	6
A3	1:0:6	6
A4	1:3:6	6

All the proportions were taken on a weight basis steel slag was taken from Agni steel plant In this project, 53 grade Portland Pozzolona cement has been used. The properties of all the ingredients were as per BIS specification.

3.1 Quality of Materials:

The quantity of materials for all the mix proportions are shown in table 5

Table 5: Details of Amount of Materials.

S.No	Designation	Mix Proportions	Quantity of the materials(kg)		
			Cement	Sand	Steel Slag
1	A1	1:0:1	16	0	16
2	A2	1:0.5:3	2	4	12
3	A3	1:0:6	3	0	18
4	A4	1:3:6	2	6	12

3.2 Casting of Steel Slag Bricks:

All the dry mixes were mixed uniformly. Then, these dry mixes were sprinkled over the required amount of steel slag and mixed uniformly manually. After mixing, the mixes were placed in the mould for 30 minutes. From this process, two moulds were used at a time to make the process very fast. In this study, the bricks were molded manually by hand i.e. hand molding and these bricks were ground moulded bricks. Figure1 shows the mixing of steel slag moulding of bricks and demoulding of dry bricks respectively.

Figure 1: Casting the Steel Slag Brick

4. Compressive Strength of Steel Slag Bricks:

Compression test is the main and important test for bricks. This test was carried out by a Compressive Testing Machine (CTM) of 100 tonne capacity. This test was carried out on the 28th day from the date of casting of brick. While testing the brick, great care has been taken, because steel slag bricks never failed, it just compressed. Even though the steel slag brick failed at the higher load, the structure of the brick did not collapse. Only the outer faces cracked and peeled out. The compressive strength of brick A1 is 75% higher than the conventional clay brick, whereas, the strength of brick A2 is 67% higher than conventional bricks. Moreover the compressive strength is 22% higher than conventional clay bricks in case of A3. And for A4 brick compression strength is 31% higher than clay bricks (5). The compressive strength results are shown graphical in figure 2

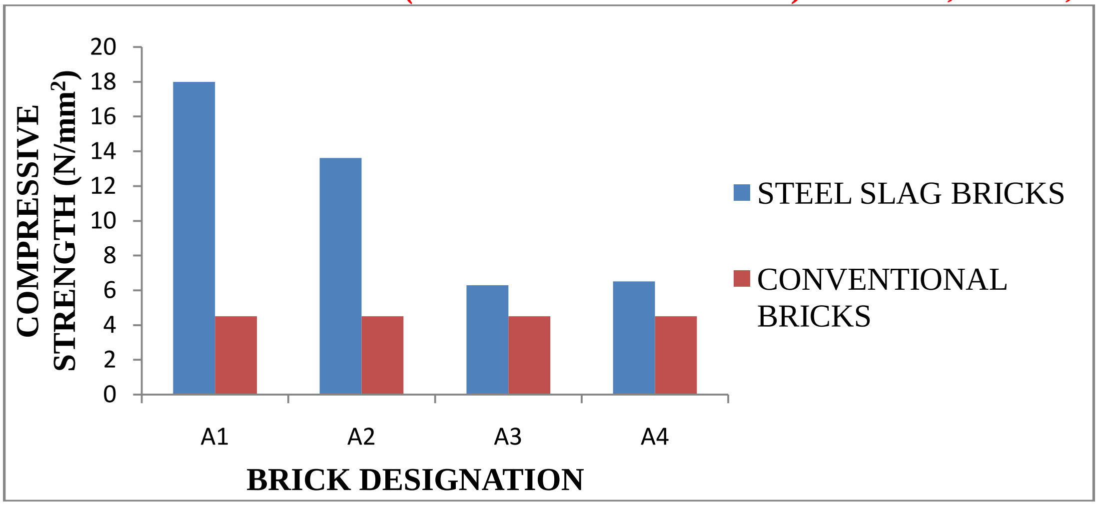

Figure 2: Compressive strength of different types of steel slag bricks and comparison of conventional bricks

5. Water Absorption:

5.1 Procedure:

Immerse the dried specimens completely in clean water at a temperature of 27+2°C for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (M_2). Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:

$$\text{Water absorption} = \frac{M_2 - M_1}{M_1} \times 100$$

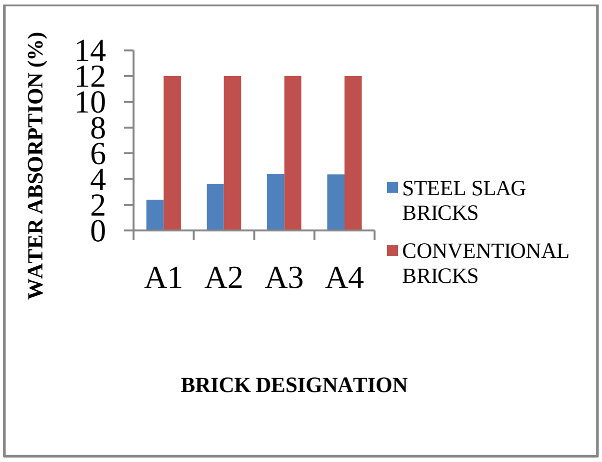

Figure 3: Water absorption of different types of steel slag bricks and comparison of conventional bricks

The Water absorption of brick A1 is 75% lower than the conventional clay brick, whereas, the strength of brick A2 is 67% lower than conventional bricks. Moreover the Water absorption is 22% lower than conventional clay bricks in case of A3. And for A4 brick is 31% Water absorption higher than clay bricks.

6. Steel Slag Prisms:

After casting the steel slag bricks, the prism was built with 1:3 cement sand mortar. First, two bricks were laid down and joints were filled with cement-sand mortar with 10 mm thickness. Over the cement sand mortar layer, another two bricks were laid opposite the base course, i.e. stretcher and header courses laid alternatively over the bricks. After casting the prism, the top and bottom faces are plastered with 10 mm thickness of 1:3 cement sand mortar(6). For the curing purpose, water was applied over the plastering surface by spraying. With the breadth of the prism considered as 'L', the height of the prism should reach '2L'.

Figure 4: Test setup of steel slag brick prism

7. Load vs Deflection:

From the load vs deflection behavior steel slag brick prism, the prism was subjected to vertical axial load by 100 tonne capacity universal testing machine. The loading rate was 10 mm per minute. The four number of dial gauges (having 50mm maximum and least count of 0.01mm) were fitted with four sides of prism. The value of longitudinal deformation was recorded automatically by a digital UTM and lateral deformations with corresponding load values were recorded. Based on the values, stress versus strain and lateral deformation graphs were plotted (7). From the load versus deflection curve, it is clear that first crack load occur at 33.5kN and ultimate load at 140kN; in the case of steel slag brick and 23kN &85 kN respectively for clay brick. The curve linear up to the first crack load. The first crack load increase up to 31% when compared to conventional clay bricks, ultimate load increase upto 39% when compared to conventional clay brick.

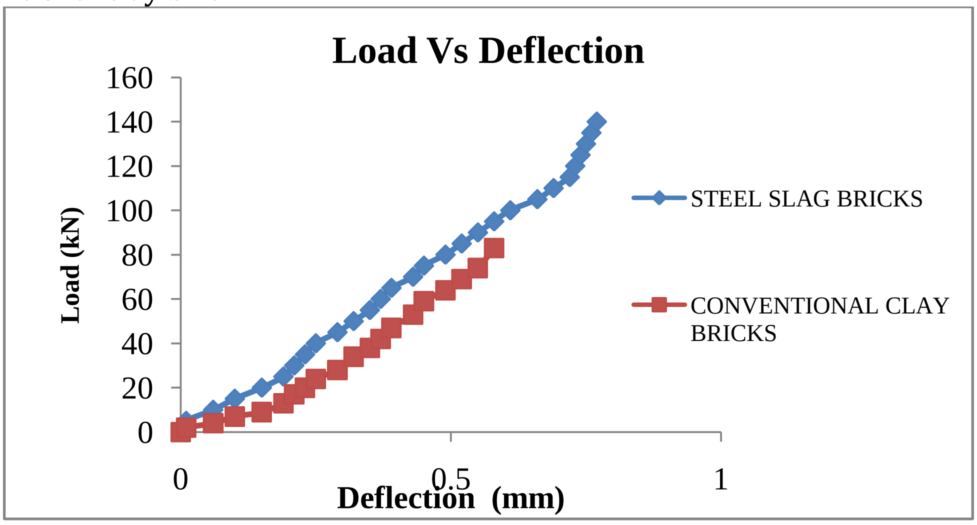

Figure 5: load deflection of steel slag bricks and comparison of conventional bricks.

8. Energy Absorption:

Energy Absorption = Area under the load deflection curve up to 25 % maximum load (after reaching the maximum load)

Table 6: Details of energy absorption of conventional and steel slag bricks

S.No	Energy Absorption of Conventional Brick (kN mm)	Energy Absorption of Steel Slag brick (kN mm)
1.	27.77	71.87

The energy absorption of steel slag brick is 71.87 kN mm and the energy absorption of steel slag brick is 61% higher than the conventional clay brick.

9. Field Tests:

The following field tests help in ascertaining the good quality bricks:
(i) Uniformity in size, (ii) uniformity in color (iii) structure (iv) hardness test (v) sound test (vi) strength test and (vii) Efflorescence Test (8). All the field tests were performed for A1, A2, A3 and A4 steeI slag bricks and their performance were in comparable with the conventional bricks.

10. Cost Analysis:

Steel slag building bricks were compared with conventional bricks, which are available in market. The rates of the conventional clay bricks and flyash bricks were Rs 5.00/- and Rs.5.50/- per 1 brick respectively. The average cost of steel slag bricks is Rs 4.50/- per brick which seems to be lesser than the cost of conventional bricks.

Table 7: Cost of steel slag bricks

S.No	Designation	Cost of Bricks(Rs)
1	A1	10.13
2	A2	5.39
3	A3	3.80
4	A4	3.53

11. Conclusion:

Experimental investigations were carried out to study the effect of steel slag on the properties such as compressive strength, percentage of water absorption and energy absorption with various proportions.

The following conclusions were drawn from the study

- ✓ The compressive strength of brick A1 is 75% higher than the conventional clay brick
- ✓ The water absorption of brick A1 is 80% lower than the conventional clay brick
- ✓ The energy absorption of steel slag brick is 71.87 kN mm and the energy absorption of steel slag brick is 61% higher than the conventional clay brick.
- ✓ The rates of the conventional clay bricks was Rs 5.00/- per brick and cost of A1 brick is Rs 10.13/-. Even though the cost of A1 brick is higher when compared to other bricks that can be used for construction due to their light compressive strength.

It is evidently concluded that the steel slag building bricks can be used for the construction of non-load bearing walls, partition walls, in filled walls etc.

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