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# Sustainable production of fired clay bricks using waste foundry sand and silica fume

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**Abstract -** *The main objective of this study is to utilize waste foundry sand and a SCM (supplementary cementitious material) in sustainable brick production. One of the oldest building materials used in India is fired clay bricks. India is the second largest producer of bricks in the world, with about 240 billion bricks produced every year. The constant growth in economy and population, along with urbanization has resulted in increasing demand for buildings and infrastructure in our country. So, there will be high demand for primary building materials such as bricks. One of the major problems in clay brick production is the use of agricultural clay, which is of great significance to farmers. Disposal of industrial wastes which are hazardous to environment is also a major problem around the world. So, in this study, the behavior of bricks incorporating industrial wastes such as foundry sand & silica fume will be evaluated. Here in this study up to 50% replacement of clay in traditional fired clay bricks to industrial waste was investigated. It was found that bricks with 25% foundry sand and 15% silica fume by weight of clay had the best results. Also, the masonry application of proposed brick was evaluated and its behavior studied.*

***Key Words*: Clay bricks, industrial wastes, waste foundry sand, silica fume, compressive strength, masonry**

## 1.INTRODUCTION

The Indian economy is now growing at a fast pace. India has now become the fifth largest economy in the world. There is a constant growth in both economy and population hand by hand along with rapid urbanization. The overall urban population of the country has increased, there will a major need for infrastructure and housing. This will in turn increase the demand for construction materials such as bricks. As demand for fired clay bricks rises, along with it increases the demand for agricultural clay, leading to land degradation, which is a major problem in our country. So, in this study, industrial waste materials are added to bricks by replacing various amounts of clay for sustainable brick production.

## 2. LITERATURE SURVEY

Various studies are done by researchers on using industrial wastes in brick production. Some of them include:

S. Rubini et al (2019) [1] studied the performance of bricks with fractional restoration of foundry sand. The standard weight of the brick is 3.5 kg. Brick dimensions were 230 mm x 110 mm x 90 mm which were adopted. The foundry soil was separated by the percentage of 5%, 10%, 15%, 20%, 25%, and 30% of the total mass weight of the standard weight of the brick. The samples were cast in the brick chamber with a mixed ratio of catlinite material by hand mix method. Then dried up to 2–3 days & burnt in the kiln for a day and night. 25% FS specimen had the suitable compressive strength value of 4.86 MPa.

Nabil Hossiney et al (2018) [2] studied the use of foundry sand from the Belgian foundry industry in the manufacture of bricks. Mixes selected were 0%, 30%, 40% & 50% WFS. About 400 bricks were produced for each mix. Results indicated no change in appearance, Minimum compression resistance of 3.3 MPa & Maximum water absorption 21.61% for 50% Foundry sand. There was insignificant difference in apparent porosity, water-absorption & specific gravity, compared to commercial bricks.

M. Serhat Baspinar et.al. (2010) [3] studied the potential of using silica fume in fired clay brick production. 0%, 2.5%, 5% and 10% silica fume by weight of clay was added to original brick clay and fired at temperatures between 800 and 1100°C. authors concluded that although a decrease in the bulk density of the bricks was observed with silica fume addition, an increase in the strength values was observed for silica fume addition above 2.5%. A noticeable increase in the strength was also observed at higher firing temperatures.

## 3. EXPERIMENTAL INVESTIGATION

### 3.1 Materials Used

### 3.1.1 Foundry sand

Waste foundry sand (WFS) is a by-product of metal casting industries, used to create molds & cores. Most of the world's WFS is mainly generated by suppliers of automotive industries. Millions of tons of foundry sand go to the landfill annually. The waste foundry sand for this study was collected from the metal casting unit of Autokast Ltd, Kerala. Obtained foundry sand was tested for specific gravity and fineness modulus and was found to be 2.28 and fineness modulus 1.9 respectively.

### 3.1.2 Clay

Clay for fired clay brick production was from a local brick kiln nearby. Clay can be molded into different shapes, when wet with water and then dried and burned to produce various products such as bricks, clay tiles etc. physical characteristics such as Atterberg limits and particle size were found out along with specific gravity. The specific gravity of clay was found to be 2.31. Liquid limit (LL) and plastic limit (PL) values obtained were 45 and 29.54 respectively. Plasticity index value obtained was 15.46. within the limit as per IS 2117: 1991 [9]

### 3.1.3 Silica Fume

Silica fume (SF) is a by-product from the production of elemental silicon and ferro alloys containing silicon. The fume produced at the electric furnace condenses into fine particles and is recovered from the process exhaust gases by classification and filtration. It is very fine, non-crystalline and spherical in nature and is in submicron particle size. The specific gravity of silica fume was found using Le Chatlier's apparatus and was 2.

**Fig -1**: Silica fume

**Fig -2**: Foundry sand

### 3.2 Brick manufacturing

The manufacturing of bricks was done in a local brick kiln. 5 mixes were selected, i.e., 5%, 10%, 15%, 20% and 25% SF incorporation by weight, while keeping 25% WFS constant [1]. The mixing was done manually using hand and was machine molded. 150 bricks were produced for the study with each having size 230 x 110 x 75 mm. The bricks were kept for drying in the sun for 15 days and was burned in kiln for 1 day at a temperature of about 1100°C

**Table -1:** Mix proportion

| Sl no. | Clay (kg) | WFS (%) | SF (%) | WFS (kg) | SF (kg) | Designation |
|---|---|---|---|---|---|---|
| 1 | 73.5 | 25 | 5 | 26.25 | 5.25 | S5 |
| 2 | 68.25 | 25 | 10 | 26.25 | 10.5 | S10 |
| 3 | 63 | 25 | 15 | 26.25 | 15.75 | S15 |
| 4 | 57.75 | 25 | 20 | 26.25 | 21 | S20 |
| 5 | 52.5 | 25 | 25 | 26.25 | 26.25 | S25 |

### 3.3 Testing of bricks

### 3.3.1 Compressive strength

The bricks were tested for compressive strength in accordance with IS 3495[4]. The bricks, after immersing in water for 24 hours were then filled with mortar (1:3) on the testing surface and were kept under damp jute bag for 24 hrs. later immersed in water for 3 days before testing. The dried specimens were then placed in the compression testing machine of capacity 2000 KN between two 3mm thick 3 ply plywood sheets. Results are tabulated in table 2.

**Fig -3**: Wire cut bricks

**Fig -4**: Finished bricks

### 3.3.2 Water Absorption

Tested to identify the amount of water absorbed by the brick specimen after it has been submerged in water for 1 day. It was found that all the bricks were having water absorption value within the limit (20%) as per IS 1077: 1992[5]. Results are tabulated in table 3.

**Table -2:** Compressive strength and bulk density

| Mix | Compressive Strength(N/mm²) | Bulk density |
|---|---|---|
| S5 | 7.5 | 1.82 |
| S10 | 9.37 | 1.83 |
| S15 | 12.11 | 1.79 |
| S20 | 9.84 | 1.87 |
| S25 | 9.51 | 1.82 |

**Table -3:** Water Absorption

| Mix | Initial Wt. (Kg) | Wt. after 24 hr. water immersion (Kg) | Water absorption (%) |
|---|---|---|---|
| S5 | 3.017 | 3.535 | 17.16 |
| S10 | 2.987 | 3.504 | 17.30 |
| S15 | 2.947 | 3.472 | 17.81 |
| S20 | 2.995 | 3.514 | 17.33 |
| S25 | 3.032 | 3.548 | 17.01 |

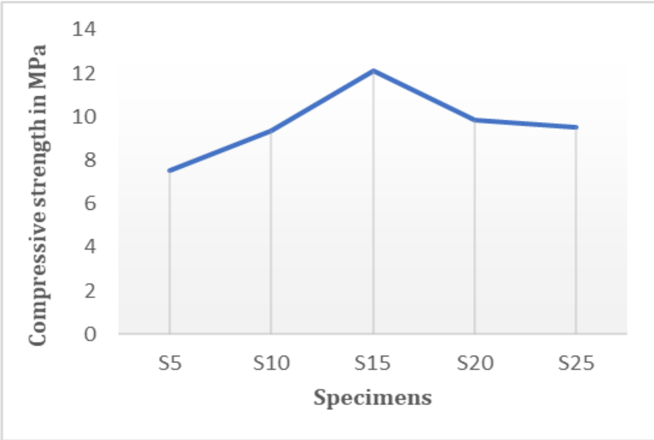


**Chart -1**: Compressive strength of bricks

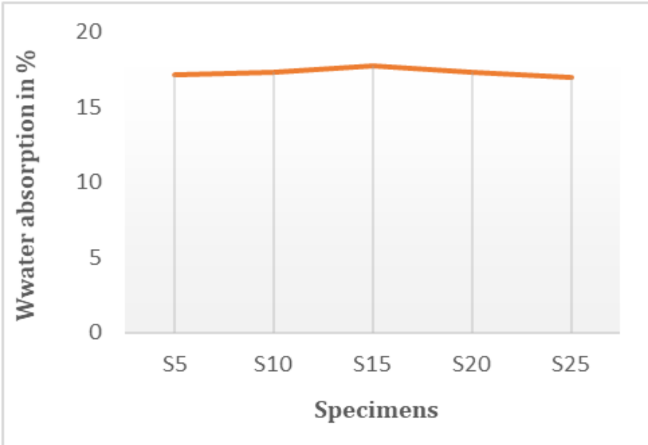


**Chart -2**: Water Absorption of bricks

### 3.3.3 Efflorescence

Determined as per IS 3495-3, efflorescence is the deposit of water-soluble salts formed on the surface of bricks. In this test, the bricks are kept upright in a flat dish with water filled to a height of 25mm. Water is filled twice and allowed to evaporate and then inspected for salt deposits. Slight efflorescence was found in all specimens.

### 3.3.4 Bulk density

The bulk density of the bricks was found as per procedure described in ASTM C20 [8]. It is the ratio of dry weight of the brick to its volume.

### 3.3.5 Soundness

In this test, two bricks are struck one another. Bricks are sound if they make a clear metallic ringing sound without breaking. S20 and S25 specimens were sound than others.

### 3.4 Mix Optimization

From the results obtained from the above tests conducted, WFS and SF incorporated bricks can be classified as class II bricks as per IS 1077: 1992. Among the different mix proportions considered, S15 specimen with WFS 25% and SF 15% by weight can be adopted as the best specimen with water absorption value of 17.81% and compressive strength of 12.1 N/mm².

### 3.5 Masonry Specimens

Masonry prisms are prepared and tested for compressive strength as per IS 1905-1987 [6] and wall panels as per BS EN 1052-1: 1999 [7]. As per appendix B of IS 1905-1987, the assembled masonry specimen should at least be 40cm high and should have a height to thickness (h/t) ratio of at least two but not more than five. So, as per the dimensions of the brick and code provision, 3 specimens of average dimensions 230 x 230 x 500mm "Fig.6" and average h/t ratio 2.15 were prepared and tested for compressive strength after 28 days curing.

**Fig -5**: Masonry Prisms

In this study, the prisms were casted with 10mm thick cement mortar of mix proportion 1: 6, which was selected as per the provisions of IS 2250: 1981 [10].

The prisms were tested by placing between plywood sheets of 4mm thickness in universal testing machine (UTM) of 1000 kN capacity. Compressive strength values obtained by the test is multiplied by a correction factor specified in table 12 of IS 1905-1987 to get the actual compressive strength values. 850 x 230 x 340mm masonry wall panels with 10mm thickness mortar joints were tested for compressive strength. The specimens were tested in UTM after curing for 28 days as specified in BS EN 1052-1: 1999. An I section beam was placed on top to transfer the compressive load from the machine as uniformly distributed load.

## 4 RESULTS AND DISCUSSION

### 4.1 Compressive strength of masonry prism

The obtained values of compressive strength of prisms were multiplied with a correction factor of 0.752 obtained from table 12 of IS 1905-187 to get the actual compressive strength of the masonry. The average value of compressive strength obtained was 2.387 N/mm$^2$. Basic compressive stresses of the masonry were also found out. Average value of basic compressive stress obtained as per prism test was 0.717Mpa and as per table 8 of IS 1905-1987 [7] was 0.91 MPa for bricks of compressive strength 12.11 MPa and 1:6 mortar proportion.

**Table -4:** Compressive strength of masonry prism

| Sl No. | Compressive strength (MPa) | Compressive strength after applying correction factor: 0.752 | Average value (MPa) |
|---|---|---|---|
| 1 | 3.742 | 2.813 | 2.87 |
| 2 | 3.818 | 2.87 | |
| 3 | 3.894 | 2.928 | |

### 4.2 Compressive strength of wall panels

The compressive strength of wall panels was found out as per the procedure laid down in BS EN 1052-1: 1999 and was compared with the compressive strength values specified in table 2 of BS 5628-1:1992 [11] for specific mortar proportions and compressive strength of brick unit. Results are tabulated below.

**Table -5:** Compressive strength of wall panels

| Sl No. | Compressive strength (MPa) | Average value (MPa) |
|---|---|---|
| 1 | 2.551 | 2.55 |
| 2 | 2.53 | |
| 3 | 2.573 | |

Average value of compressive strength obtained by experimental testing is 2.55 N/mm$^2$ and as per table 2 of BS 5628-1:1992 for mortar proportion1:6 and brick unit of compressive strength 12.11Mpa was 3.87 N/mm$^2$.

**Fig -6**: Failure of masonry specimens

## 5. CONCLUSIONS

It was found that, among the 5 mixes selected, it was found that specimen S15 with 25% WFS and 15% SF can be effective with a compressive strength value of 12.11 N/mm$^2$. These bricks can be classified as class I bricks as per IS 1077: 1992 and can be used for superior work, load bearing structures. Experimental investigation of compressive strength of masonry specimens using S15 bricks were done and found that the average compressive strength of masonry prism as 2.87N/mm$^2$.

Basic compressive stress obtained is 0.717 MPa, which was lesser compared to value specified by IS 1905-1987 (0.91Mpa). Compressive strength of wall panels was found to be 2.55 MPa which is less than specified in BS 5628-1:1992 (3.87Mpa). finally, it was able to produce silica fume and waste foundry sand incorporated bricks by local condition and with minimum processes without any effect on the physical appearance.

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