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Experimental Study on Utilization of Steel Mill Scale in Fly Ash Brick

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ABSTRACT: In the present scenario, Burnt clay bricks are being used extensively almost throughout India and are perhaps the most important building construction material. The total clay taken out from the agricultural fields per day was over 300 million tonnes for 10,000 Crore bricks. At this juncture in order to mitigate this impact, A local steel manufacturing company generates quantities reaching almost 7000 tonnes per year. This paper investigates the potential for recycling the steel mill scale in the fly ash brick at various proportions such as 10%, 20%, 30%, 40%, 50% by weight of the Quarry sand and comparing the experimental test results according with IS codal provisions.

KEYWORDS: Compressive strength, Durability, Water absorption, Efflorescence Density, Compressive load on wall panel, Triplet Prism test

I. INTRODUCTION

Nowadays availability of natural resources for construction is poor. Scarcity of construction materials leads to High price of materials. In order to reduce the usage of natural resources and save the environment alternate materials can be used in construction materials and other purposes. Initially Clay bricks were used for wall construction. Clay usage become more which leads them to buy clay for brick manufacturing from agriculture lands and other farms.

Consumption of clays beyond the availability leads to destroying the natural resources and shrinkage of agriculture land and valuable cultivation land. A Survey says that more than 12 hectares lands were consumed for clay soil every year and also the total clay taken out from the agricultural fields per day was over 300 million tonnes for 10,000 Crores bricks. Because of this human activity valuable fertility lands were spoiling and the land become unusable.

II. AIM OF THE STUDY

The basic aim of this project is to evaluate the strength of Fly ash bricks with Steel Mill Scale .The following tests are to be carried out check the quality of Fly ash bricks.

- Compressive strength.
- Durability
- Water absorption
- Efflorescence
- Density
- Compressive load on wall panel
- Triplet Prism test

Scope of the Study

Bricks will always be the necessity of building materials and in future soil for the making of bricks would not be available in plenty as the use of land is rapidly increasing, at that time fly ash will fulfill the necessity of clay bricks as these bricks are made by the industrial wastes. Use of fly ash bricks with steel mill scale waste would be more efficient.

Literature Review

ObadaKayali 2010 studied that the properties of Fly ash and clay made bricks and concluded that the mechanical properties of fly ash bricks have exceeded to those of standard load bearing clay bricks. Compressive strength was 24% better than good quality clay bricks and tensile strength was nearly three times the value for standard clay bricks. The bond strength of the fly ash bricks is 44% higher than the normal clay bricks. The density of fly ash bricks is 28% less than that of standard clay brick. The reduction in a weight of bricks results in a great deal of savings in terms of raw

materials and transportation costs. Fly ash brick can easily soak up mercury from normal air which is in contact with it and thus makes it cleaner for berating. There is also a process named carbonation in which fly ash absorbs carbon dioxide from normal atmosphere due to which carbon sequestration occurs and the amount of carbon gets reduced in atmospheric air which helps in minimizing global warming.

Sunil Kumar 2013 has presented an extensive review in reported work on fly ash bricks. He investigated the flexural strength, water absorption test, density, porosity and stability of these solid bricks and hollow blocks. He witnessed that these bricks and blocks have enough strength for their usage in low rate housing growth. Tests were conducted to determine the compressive strength and hardening effects and to analyze the effects of curing with time. The compacts treated in hot water shows better strength and hardening effects as compared to normal water cured compacts. Initially the strength of these blocks and bricks increases with higher rate and then at a comparatively lower rate. There is a direct relationship between FA and water absorption. As the content of FA increases water absorption also increases. And on the other hand water absorption decreases with increase in density of the FA compacts. These FA bricks and blocks with proper phosfogypsum extent have improved resistance to robust sulfate environment.

Ball MC & Carroll RA 2013 has shown that the various bricks manufacturing methods and understands the reason behind the strengthening effects of these autoclaved FA bricks. The FA bricks becomes hard mainly due to the formation of calcium silicate hydrate and calcium aluminate silicate hydrate. The hydrothermal reaction takes place between silica, alumina and water when the compacts are allowed to cure under the steam bath normally at 110°C - 180°C. The presence of Tobermorite phase also helps in enhancing the hardenability of the Fly ash bricks.

Cultrone G, Sebastian E, and Elert K 2009 investigated that the permeability of FA bricks and co-relates its effects on various chemical and mineralogical configuration of Fly ash particles. FA bricks also depend on the temperature of firing resulting in to more vitrified dense structure and phenomenal change in shape and size

Giuseppe 2010 studied that the porosity of the brick depends directly on the mineralogical composition of the raw material and the firing temperature, but generally, bricks fired at high temperatures are more vitreous and undergo the greatest changes in size and porosity.

Nutan.C.Patel 2013 In this paper, Experiments have been carried out by several materials like fly ash, lime, sand, kheda dust, glass fibre for the manufacturing of the brick. The fly ash of 'F' category was used as a raw material for making fly ash bricks. The combination of fly ash brick have different % of Glass Fibre adding like 0.2%, 0.4%, 0.6%, 0.8%, 1.0%. In the testing of the fly ash brick there are main two types of the testing was carried out. Compressive strength test, water absorption after 7, 14, 21 days. With changing (increasing) in the % of Glass Fibre of compressive strength of Fibre fly ash brick was increase and water absorption was decrease. In the experimental work, 1% of Fibre addition in the brick gives maximum strength as 5.86N/mm² after 21 days. If we increase the compressive strength of brick, water absorption gets decreased as 12.32% after 21 days.

Prashant.G. Sonawane 2013 In this research work, an attempt was made to find out the possibility of using pond ash in burnt clay bricks. The part of clay is replaced by pond ash in different compositions and are the bricks are made in conventional method at a brick manufacturing plant. It is burnt normally and tested in laboratory. The result shows that the % of clay-pond ash brick in which exceeds 20%, the dimensions exceeding tolerance limit. It was observed that the bricks are tends to swelling when the % of pond ash was increasing. The % of WA increase with increase in % of pond ash in brick. When is immersed in cold water for 24 hours. The % of water absorption in clay brick as 14.59 to 25.46 and 30% for pond ash brick.

Kabiraj et al. (2012) has done a experimental investigation and feasibility study on stabilized compacted earth block using local resources. In this study is carried out mainly to find out a suitable mix proportion to blend locally available materials such as soil, sand, clay, grits, jute, etc., with cement for making compacted earth block for construction of affordable residential building and the results were studied.

Musa Alhassan 2011 In this investigations to study the effect of rice husk ash on cement stabilized laterite with respect to compaction characteristics, California bearing ratio, unconfined compressive strength tests, indicated that there was a general decrease in maximum dry density and increase in optimum moisture content with increase in RHA content (2-8%) at specified cement contents. It was also found that there was a tremendous improvement in CBR and UCS value with increase in RHA content at specified cement contents to their peak value between 4-6% RHA.

P.J.Walker 2010 investigated that the striking contrast between CSEB and conventional bricks is the energy consumed during the production process and carbon emission. CSEB brick creates 22 kg CO₂/tone compare to that of concrete blocks (143 kg CO₂/tonne), common fired clay bricks (200 kg CO₂/tonne) and aerated concrete blocks (280 – 375 kg CO₂/tonne) during production. In average, cement stabilised earth bricks consumed less than 10% of the input energy as used to manufacture similar fired clay and concrete masonry unit.

III. MATERIALS USED

➤ **FLY ASH:**

To sustain the natural resources and save agriculture land fly ash were used as an alternate material for clay soil. In India two third of the Electricity is consumed from Thermal Power plants. Main source for Thermal Power is Lignite. Burning of Lignite produces residue in huge amount. Obtaining 1500 Megawatts produces residues and Fly Ash in large scale.

This much of residue can be reused as an alternate material of Masonry units. It takes major constituents in brick in the range of 50% - 60%. Fly ash is fine, glass-like powder recovered from gases created by Coal-fired electric power generation plant. Since, the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and of size from 0.5 μm to 10 μm. They consist mostly of Silicon dioxide (SiO₂), Aluminium oxide (Al₂O₃) and Iron oxide (Fe₂O₃).

➤ **STEEL MILL SCALE:**

Mill scale is a steelmaking by-product from the rolling mill in the steel hot rolling process. Mill scale contains both iron in elemental form and three types of iron oxides: wustite (FeO), hematite (α-Fe₂O₃) and magnetite (Fe₃O₄). The chemical composition of mill scale varies according to the type of steel produced and the process used. The iron content is normally around 70 %, with traces of non-ferrous metals and alkaline compounds.

Depending on the process and the nature of the product, the weight of mill scale can vary between 20 and 50 kg/t of hot rolled product.



Fig 1. Before grinding of steel mill scale



Fig 2. After grinding of steel mill scale

The average specific production of this by-product is typically around 35 - 40 kg/t. In Spain some 44,000 tons of mill scale are generated each year. In view of this fact, in order to utilize this waste product in appropriate manner. This steel mill scale was collected in Dindigul Steel Rolled Mill private limited. We suggest it having vast potential to introducing in Fly ash brick alternating to Quarry sand.

IV. EXPERIMENTAL METHODOLOGY

The modular brick samples of size 230 mm x 110 mm x 76 mm were casted as per IS 12894- 2002 using various mix proportions. The mix proportions are arrived by using Steel mill scale and Fly ash.



Fig 3. Casting of Fly ash bricks with Steel mill scale through wire cut machine.

V. EXPERIMENTAL SETUP

The specimen should be passes through the following tests after 21 days from curing:

- Compressive strength tested as per IS: 3495 (part 1)-1992.
- Water absorption tested as per IS:3495 (part 2)- 1992.
- Effloresence test as per IS: 3495 (Part 3)- 1992.
- Density test
- Triplet Prism Test

➤ Compressive Strength

Compressive strength test were carried out for bricks with different mix proportion of carbon buster. The specimen was tested after 21 days of curing. The specimen is placed between two plywood sheets of each having 3mm thick and carefully centered in compression testing machine. The compression load is noted. The compressive strength is the ratio of compression load to the area of brick loaded. An average of three specimens are taken as the compressive strength.



Fig : 4.(a) Testing of bricks



Fig : 4.(b) Testing of bricks



Fig : 4.(c) Failure Pattern after conducting the compressive strength test

➤ **Water Absorption**

In the Water absorption test procedure, the dry weight of brick is measured and noted as weight (W1). Then the dry brick is completely immersed in water at room temperature for 24 hours. After 24 hours bricks are removed from the water allowed to drain for 3 minutes and wipe out any traces of water with damp cloth. Now measured and as the specimen weight (W2).

Calculate the Water Absorption as

$$\text{Water Absorption in percentage (\%)} = (W2 - W1) / W1$$

Where

W2 – wet mass of brick in kg

W1 – dry mass of brick in kg



Fig: 5. Water Absorption Test For Various Mix Proportioning Of Steel Mill Scale

➤ **Density Test**

Density is how dense an object, it is calculated by dividing the mass by volume of an object. Density can be changed by changing the size or shape of the object. The standard international unit to measure density is kilogram per cubic meter (kg/m³).

$$\text{Density} = \text{Mass} / \text{Volume}$$



Fig: 6 Density Test

➤ **Efflorescence Test**

A standard soaking in water test can determine the porosity of bricks, which can then be used as an indication of the potential for the development of problems related to the penetration of salts and other materials into the units, such as salt attack and efflorescence.



Fig: 7 Efflorescence



VI. RESULTS AND CONCLUSION

➤ **Compressive strength test**

The determination of compressive strength of the prepared samples was carried out as per standard practiced. The following Table 1 shows the compressive strength of various mix proportion of samples after testing. The specimen was tested after 21 days of curing.

Compressive strength = Compressive load / Area(N/mm²)
 Area = (230 x 110) mm²

Table 1 compressive strength test result for cement

S.NO	PERCENTAGE OF STEEL MILL SCALE	AVERAGE PEAK LOAD (kN)	COMPRESSIVE STRENGTH (N/mm ²)
1.	0	35	4.60
2.	10	40	6.15
3.	20	60.1	12.25
4	30	71.3	14.3
5	40	66.8	13.10

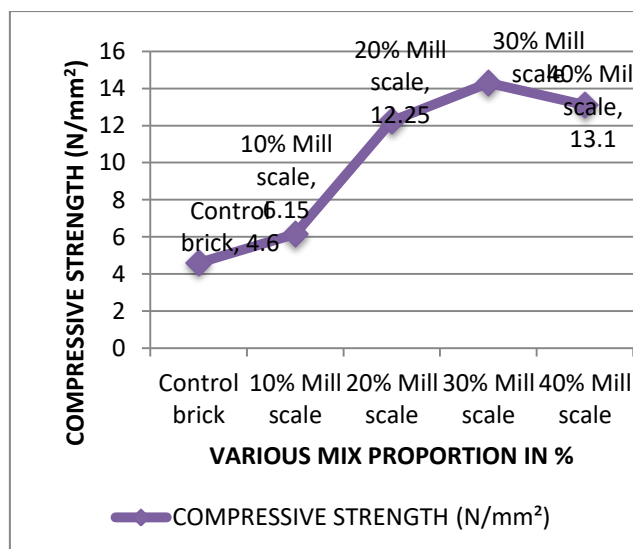


Fig 8 Variation in Compressive strength test Steel mill scale in Fly ash brick

➤ **Water Absorption test**

The determination of water absorption of the prepared samples was carried out as per standard practiced. The following Table 2 shows the water absorption of various mix proportions of samples after testing. The specimen was tested after 21 days of curing.

Table 2 Water absorption test result for Fly ash Brick

S.no	Dry weight of brick (M ₁)	Wet weight of brick (M ₂)	Avg. Percentage increase in weight %
1.	2.76	3.25	9.76
2	2.65	3.06	9.31
3	2.72	3.11	8.235
4	2.85	3.21	8.92
5	2.90	3.02	9.35

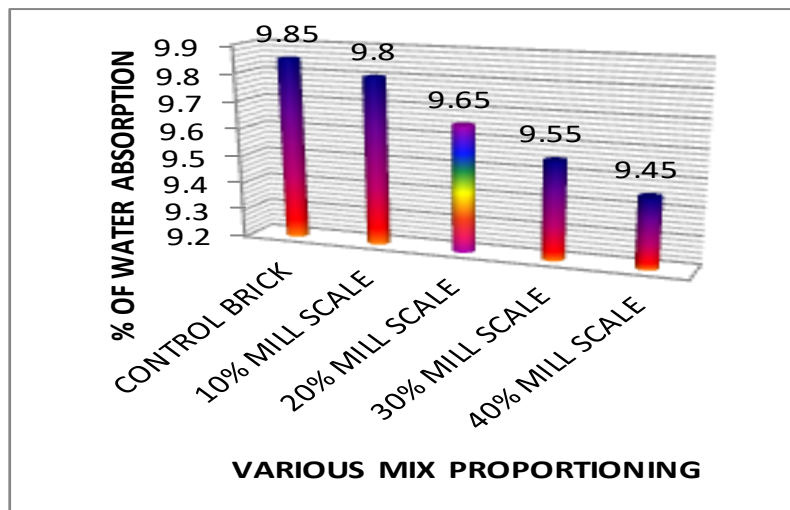


Fig 9 Water absorption test result for Fly ash brick

➤ **Density test**

The determination of density of the prepared samples was carried out as per standard practiced. The following Table 3 shows the density of various mix proportions after testing.

Density = Weight/ volume
 Volume = (0.23 x 0.11 x 0.075) = 1.8975 x 10⁻³ m³



Table 3 Density test result for fly ash brick

S.No	Weight of brick (Kg)	Volume of brick (10^{-3} m ³)	Avg. Density (Kg/m ³)
1.	3.25	1.8975	1879
2.	3.32	1.8975	1890
3.	3.33	1.8975	1890
4.	3.30	1.8975	1861
5.	3.10	1.8975	1889

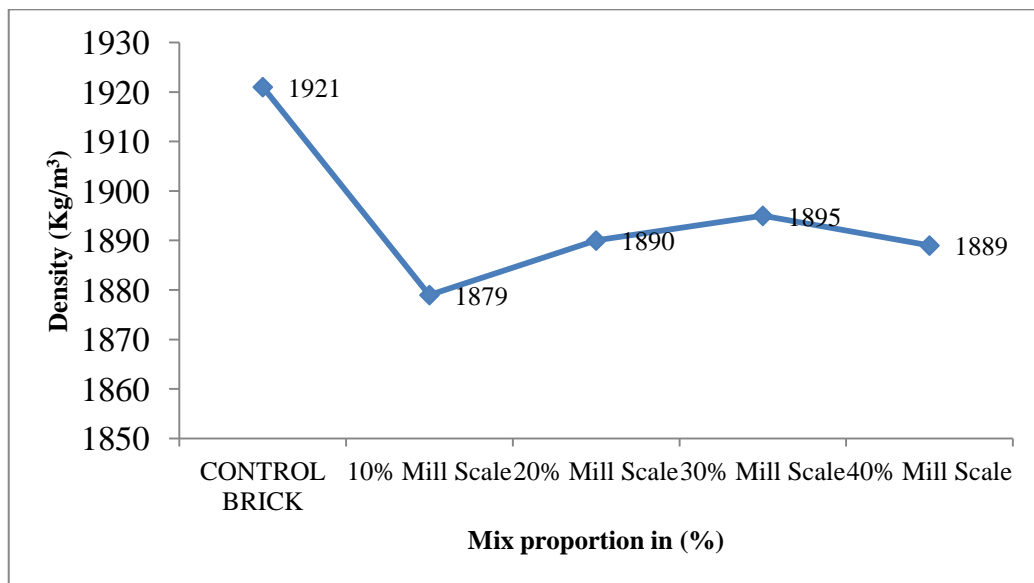


Fig 10 Variation in Density of Steel mill scale in Fly Ash bricks

➤ **TRIPLET PRISM TEST**

In this study, triplet brick prism were casted using different cement mortar proportion 1:2, 1:3 and 1:4 with bond thickness of 10mm and it is cured for 15 days. The compressive strength of brick prism are obtained from test as shown in figure 11. The average of three test specimen result for respective mortar proportions are given in table 4

Correspondingly, the stress - strain curves is shown in figure 12



Fig 11 Triplet prism test on Steel mill scale in Fly Ash bricks

S.No	Mortar Ratio	Mortar thickness (mm)	Compressive Strength of prism (MPa)
1.	1:2	10	12.3
2.	1:3	10	9.41
3.	1:4	10	6.53

Table 4 Triplet prism test on Steel mill scale in Fly Ash bricks

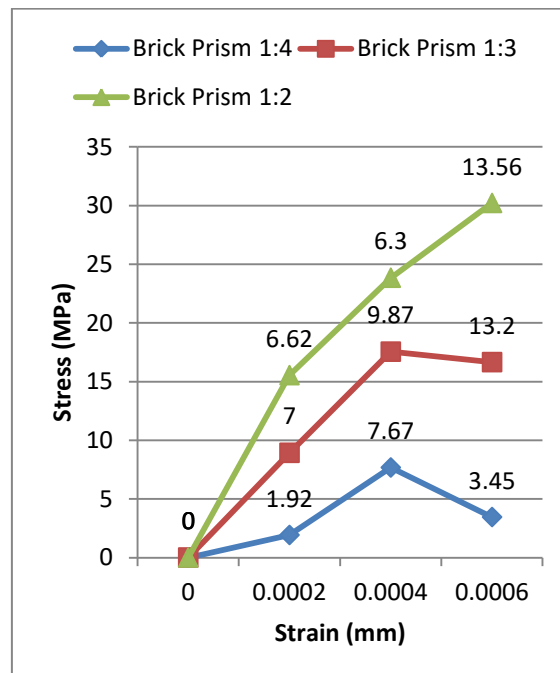


Fig 12 Triplet prism test on Steel mill scale in Fly Ash bricks

➤ **Wall panel**

The objective of this study is to determine the compressive and flexural strength of the wall panel tested according to standard test requirement, as indicated in BS 5628: PART1: 1992(4). For the cement sand mixture, the mix proportion of 1:2 (1kg of cement and 2kg of sand) with addition of water was used to make standard cement mortar. The size of wall 0.5m X 0.5m X 0.20m.



Fig 13 wall panel

➤ **Testing for compression load**

All wall panels were tested for a uniformly distributed compression load. To transfer the externally applied concentrated load as a uniformly distributed load at the top of the wall, I-Section was placed at the top of the wall. Two Displacement gauges were placed at top of the wall and the top midpoint of the wall. Using this testing arrangement, the compression load is increased with a loading rate of 0.5kN/Sec.



Fig 14 Wall Panel Test



Table 5 Wall panel test results for Fly ash bricks with Steel mill scale

S.No	Load (kN)	Linear Displacement (mm)
1	0	0
2	5	2.34
3	10	3.65
4	15	4.28
5	20	6.72
6	25	8.62

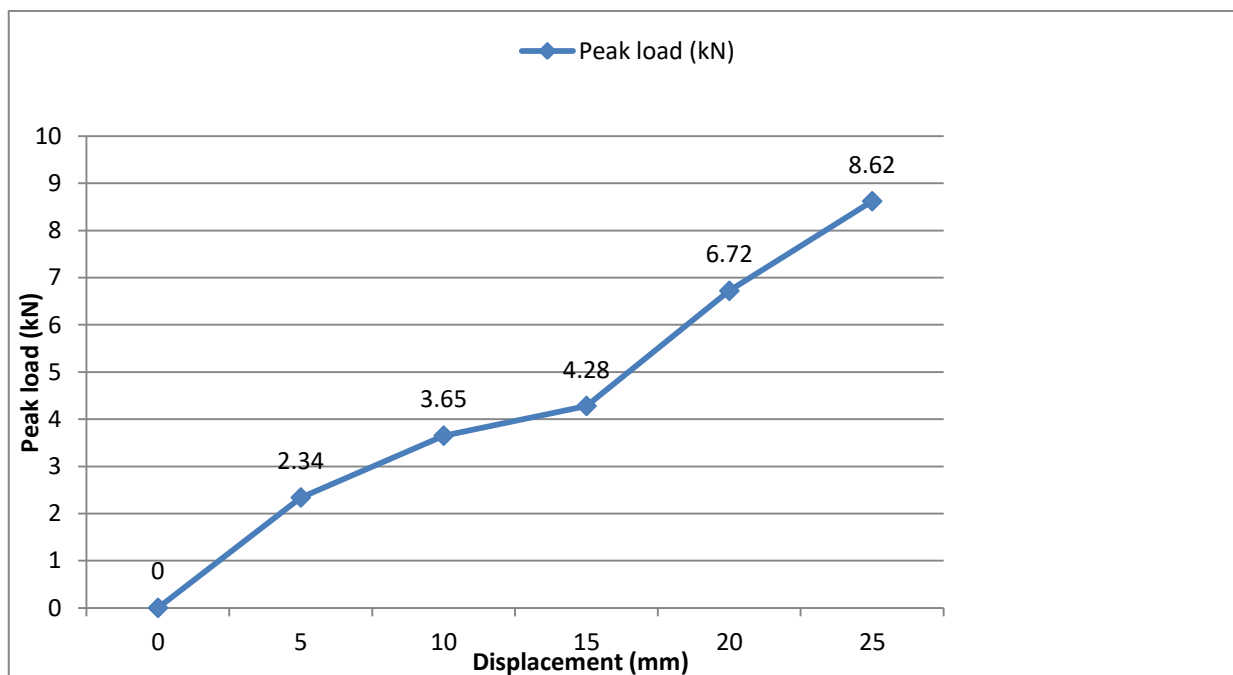


Fig :15 Load vs Deflection of Steel mill scale in Fly Ash brick

VII. CONCLUSION

Based on the experimental study, following results can be drawn regarding the strength behavior of fly ash brick using steel mill scale instead of Quarry sand.

1. According to compressive strength test, 30% of steel mill scale in fly ash brick gives optimum strength as 14.3 N/mm². As per IS: 12894-2002. The test result shows that it was higher than the permissible values.
2. According to IS: 12894-2002 (part III), In Water Absorption test, above tested values stated that water absorption are lying below the permissible limit as 15%.
3. From the experimental test results, the average compressive strength of triplet brick prism was found to be around 2.43MPa. The brick prism with mortar ratio of 1:2 exhibits higher compressive strength than other two mortar ratios. This shows that the mortar ratio plays important role in the strength of the brick masonry.
4. In wall panel test, Fly ash brick using steel mill scale as a replacement for Quarry sand was tested. According to BS 5628: PART1: 1992(4). The load Vs displacement was found out.



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