An Experimental Study on Fly Ash Bricks and Cost Estimation Analysis

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Abstract: **Fly ash bricks can be extensively used in all building constructional activities similar to that of common burnt clay bricks. The objective of this work is to represent the information regarding Fly Ash brick properties and their uses in a most concise, compact and to the point manner. Various laboratory experiments were carried out on fly ash brick samples that are Compressive strength, water absorption, Acid test and Alkali test. Optimum mixing ratios of fly ash, lime, sand and super plasticizer (Master Glenium SKY 8233) were studied. It was observed that best compressive strength of 10, 11 and 12 N/mm^2 were obtained for C2 (Flyash-50%, Sand-30%, Lime-20% and Superplasticizer-3ml) mixing ratio for the 7th, 14th and 21st day respectively. Similarly water absorption was found to be 3.48% after 24 hours of exposure, as per norms it should not exceed 15%. After acid and alkali test the compressive strength was found to be 11.5 and 10 N/mm2 respectively. As the concentration of alkali and acid increases, the compressive strength of the sample reduces after 24 hours of exposure.**

Keywords: ***Fly ash bricks, compressive strength, water absorption, acid test and alkali test.***

I. INTRODUCTION

Fly ash is the by-product of coal combustion collected by the mechanical or electrostatic precipitator (ESP) before the flue gases reach the chimneys of thermal power stations in very large volumes. All fly ash contain significant amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), and magnesium oxide (MgO) however, the actual composition varies from plant to plant depending on the coal burned and the type of burner employed. Fly ash also contains trace elements such as mercury, arsenic, antimony, chromium, selenium, lead, cadmium, nickel, and zinc [1].

Fly ash is one of the numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards. It also contains trace amount of toxic metals which may have negative effect on human health, plants and land.

The advantages of fly ash utilization are:

- Saving of space for disposal and natural resources
- Energy saving and Protection of environment

Production of burnt clay bricks requires consumption of coal leading to green house gas emissions. The primary raw material used for bricks is the soil, which is often taken from prime agricultural land, causing land degradation as well as economic loss due to diversion of agricultural land. Use of traditional technologies in firing the bricks results in significant local air pollution. The burnt clay brick industry in India produces over 180 billion clay bricks annually with a strong impact on soil erosion and unprocessed emissions. At the same time, the thermal power plants in India continue to produce a huge amount of fly ash, disposal of which poses significant challenges for the power plant [2]. The cementitious binder, fly ash–lime–gypsum (Fa L–G), finds extensive application in the manufacturing of building components and materials such as bricks, hollow bricks and structural concretes [3-6,8].

II. MATERIALS USED

Materials

The materials used for making fly ash based geopolymer bricks are low-calcium dry Fly ash, Sand, Lime and Super plasticizer.

Lime

Fat lime used for finishing coat in plastering white i.e. Class C lime was use in this work.

Sand

Deleterious materials, such as clay and silt in sand, shall preferably be less than 5 percent. It is screened to 1.18mm mesh size.

Super plasticizer

Polycarboxylic Ether based Master Glenium SKY 8233 was used in this work.'

Fly ash

Fly ash used in this study was low-calcium (Class F) dry fly ash from Dandeli paper mill.

Preparation of Fly ash Composite Material

The fly ash is chosen for its low lime content as well as its availability in abundance. On the basis of the literature reviewing, lime proportions was kept constant i.e. 20% of fly ash (by weight) were selected.
Similarly, percentages of sand were (0, 10, 20, 30, 40) % of fly Ash (by weight). The optimum dosage of super plasticizer was decided to add 0.2%, based on the experimental study.

The additives selected are commercially available which are lime and Super plasticizer. Depending on the sample dimension, different composition of fly Ash, Lime, Sand and Super plasticizer, were added with water and are thoroughly mixed by hand.

Then it was kept inside an iron mould for 24 hour for moisture homogenization. The samples were cast to iron mould of size100x100x100mm. The samples were taken out of mould after 24 hours and it was kept for curing under jute bag.

*Mixing Proportions***:** Table 1 below mentioned the variable test parameter.

Table 1: Variable Test Parameters

Brick Code	Flyash (Wt %)	Sand (Wt %)	Lime (Wt %)	Super plasticizer (ml)	Curing Process
B1	50	40	10	03	Under Jute Bag
B2	60	30	10	03	Under Jute Bag
C1	40	40	20	03	Under Jute Bag
C2	50	30	20	03	Under Jute Bag
C3	60	20	20	03	Under Jute Bag
C4	70	10	20	03	Under Jute Bag
C5	80	00	20	03	Under Jute Bag
S1	40	40	20	2.5	Under Jute Bag
S2	50	30	20	2.5	Under Jute Bag
S3	60	20	20	2.5	Under Jute Bag
S4	70	10	20	2.5	Under Jute Bag
S5	80	00	20	2.5	Under Jute Bag

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

1. Compressive Strength

Compressive Strength was determined by applying load on the specimen using a Compressive Testing Machine [9, 10].

Specifications:

Company Name : Survey and Scientific Syndicate

Name of the Equipment: Auto Level/Dumping Level/Tilting Level/ CTM

Power Supply: 440 Volts, 3 phase Supply

Model No.: LM-17-519

Serial No. : 83069

Made in : India

The optimum value of mixing of Lime was studied with 10% and 20% mixtures. Results obtained in 10% mixture of Lime shows less Compressive Strength of 4.6 N/mm^2 and 5.6 N/mm^2 for B1 and B2 samples (3ml Super plasticizer). For 20% Lime mixture the Compressive Strength was increased to 9, 12, 10, 7 and 6 N/mm^2 for C1, C2, C3, C4 and C5 respectively after curing for 21 days (3ml Super plasticizer).

After testing it was found that the Compressive Strength of optimum mixing ratio i.e. C2 was found to be maximum with 3ml of Super plasticizer. The quantity of Super plasticizer was decreased by 3 to 2.5 ml, it was observed that there was a decrease in Compressive Strength. Optimum values of Lime mixing ratio was thus identified to be 20% and 3 ml as optimum mixing of Super plasticizer.

The test data shows that compressive strength was maximum for 21st day when compared to 7th and 14th day respectively. The figure1 for Compressive strength is shown below.

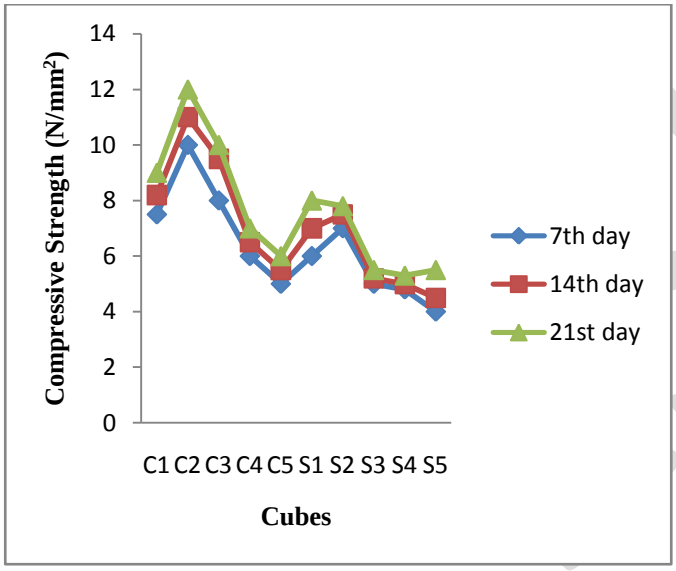

Fig. 1: Compressive Strength after curing for 7, 14 and 21 days

2. Water Absorption Test

The test data shows that there was increase in weight after it was kept in water for 24 hours (figure 2). The water absorption was up to 13.19% for S5 Fly Ash bricks (figure 3).

Optimum mixing ratio i.e. C2 had a water absorption of 3.48%. A standard norm [12] says that a good Fly Ash based brick should not exceed more than 20% water absorption.

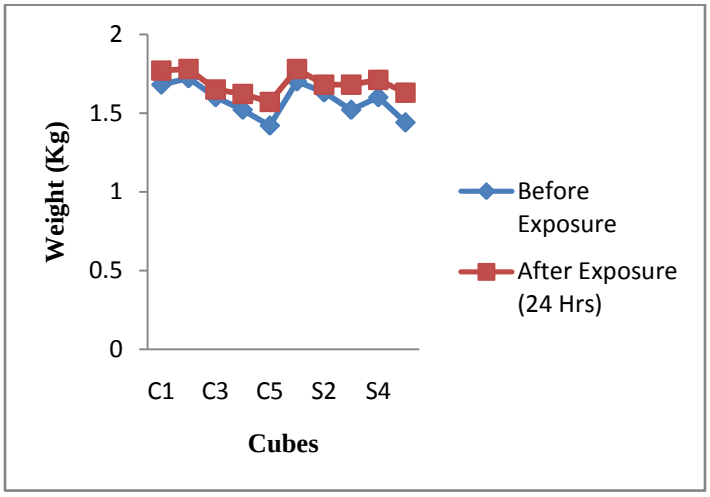

Fig. 2: Weight of cubes before and after exposure

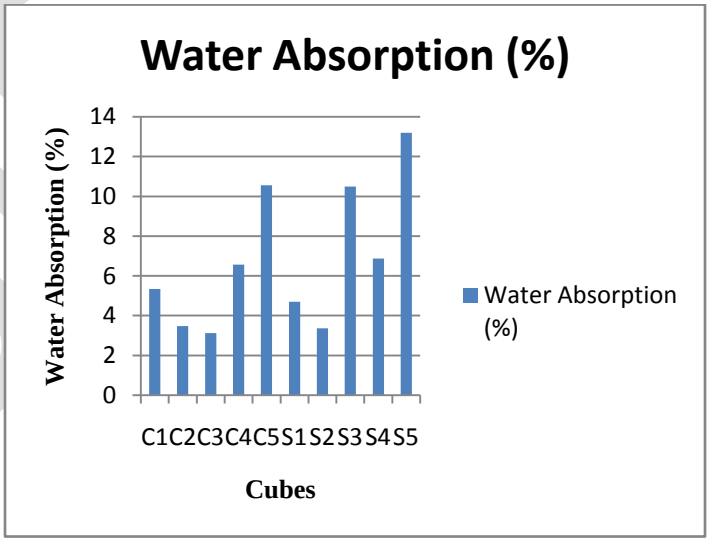

Fig.3: Percentage of Water Absorbed after exposure to 24 hours

3. Acid Resistance Test

Acid Resistance was evaluated based on the visual appearance, change in mass and change in compressive strength after exposure [11].

Figure 6 and Figure 7 compares the visual appearance of bricks after soaking in 3% and 2% Hydrochloric acid solution for 24 hours and left in ambient conditions of the laboratory. It can be seen that the specimen exposed to 3% Hydrochloric acid undergoes disintegration of the surface. The damage to the surface of the specimen increased as the concentration of the acid solution increased.

For 3% Hydrochloric acid solution there was mild reduction in compressive strength (figure 4). For 2% Hydrochloric acid solution there was negligible reduction in

mass and compressive strength (figure5). Anything above 2% acid concentration causes destruction of brick and compressive strength. The mechanism of failure of structure is predicted to be because of Super plasticizers which will lose its settings or by lime which reacts with acid, the type of reaction and the mechanism of failure is yet to be studied.

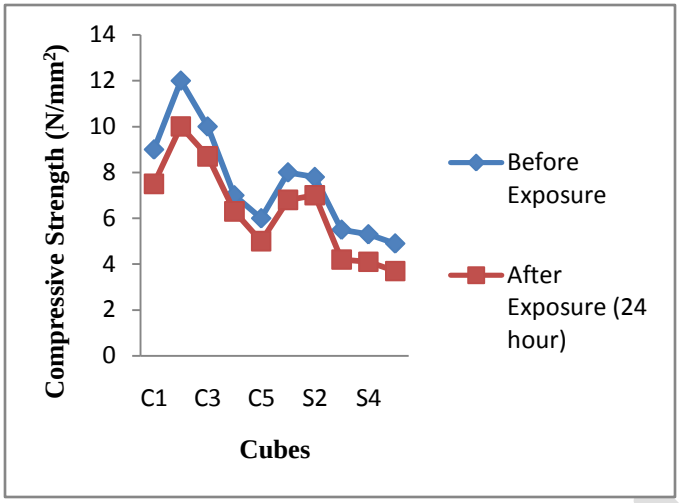

Fig. 4: Change in Compressive Strength after 24 hours of exposure to 3% HCl solution

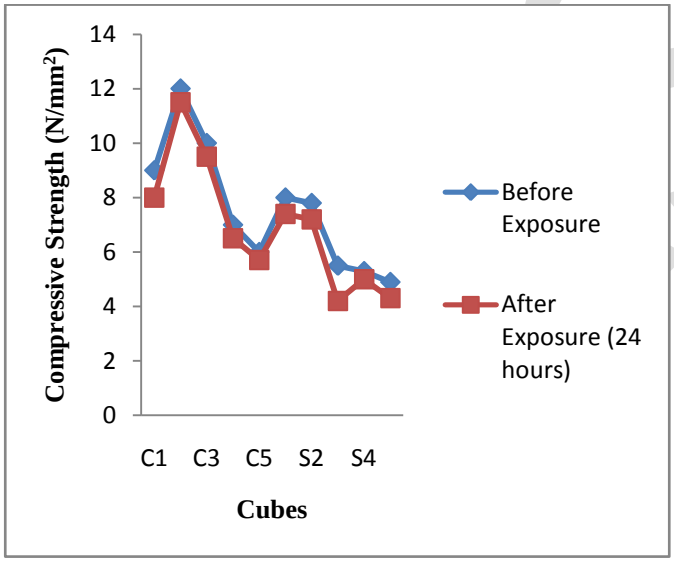

Fig. 5: Change in Compressive Strength after 24 hours of exposure to 2% HCl solution

4. Alkali Resistance Test

The visual appearance of the test specimen after exposure is shown in Figure 8. It can be seen that the visual appearance of the test specimen after soaking in 1N concentrated Sodium Hydroxide solution up to 24 hours revealed that there was no change in the appearance of the specimens. There was no sign of surface erosion, cracking or spelling on the specimen [13].

Change in Compressive Strength was determined by testing the specimen after 24 hours in 1N concentrated Sodium Hydroxide solution (figure 6).

It was seen that in 1N concentrated Sodium Hydroxide solution, there was negligible weight loss but the Compressive Strength came down by 7% to 10%.

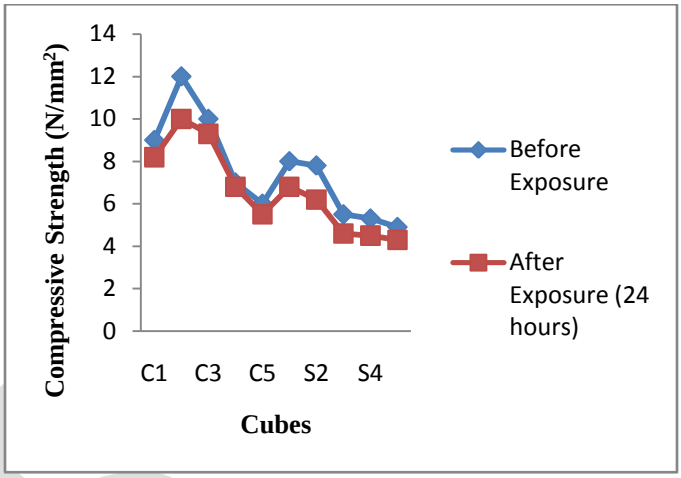

Fig. 6: Change in Compressive Strength after 24 hours exposed to 1N NaOH solution

IV. COST ESTIMATION ANALYSIS

An attempt to find the approximate cost of brick is made as follows:

Basis: 750 bricks per day.

Dimension: 100mm×100mm×100mm.

Weight of one brick= 1.5 Kg

Mixing Ratio:

Flyash–50%, Sand–30%, Lime–20% and Superplasticizer–3ml (Optimum mixing ratio i.e. C2 sample)

1. Labour cost = 250×6 members = Rs 1500/-

2. Electricity = Rs 65/-

3. Fly Ash = Rs 250/-

4. Lime = 300 gm for each brick

For 750 brick= 300×750 = 225,000gm =225 Kg

10Kg Lime= Rs 60/-

225Kg Lime=?

Cost of Lime = (225×60)/10= Rs 1350/-

5. Sand:

1 tractor = 5 tons = 5000 kg = Rs 3,500/-

450gm of Sand is required for each brick.

For 750 brick = 450×750 =337,500gm = 337.5 Kg

For 5000 Kg = Rs 3,500/-

For 337.5 Kg =?

Cost of Sand = (337.5×3,500)/5000 = Rs 236/-

6. Super plasticizer:

For each brick = 3ml

For 750 bricks = 750×3 = 2,250ml
For 20 liter = Rs 4,500/-
For 2,250ml =?
Cost of Super plasticizer = (2,250×4,500)/20,000 = Rs 506/-
Total cost for 750 bricks = 1,500+65+250+1350+236+506 = Rs 3,907/-
Cost of each brick =3,907/750 = Rs 5.2/-
Manufacturing cost of each brick = Rs 5.2/-

V. CONCLUSIONS

Based on the test results from this work, the following conclusions are drawn:

Addition of optimum or minimum quantity of Super plasticizer was identified. It was observed that by adding 2.5ml of Super plasticizer, Compressive Strength decreased as compared to the addition of 3ml Super plasticizer. As per standard norms the required Compressive Strength for Fly Ash based bricks are generally of the order 7.5-10 N/mm^2 after 21 days of curing [7]. By adding 2.5ml of Super plasticizer the Compressive Strength was less than or nearly equal to 7.5 N/mm$^{2.}$ Therefore it was decided to add another 0.5 ml and Compressive Strength was studied. It was seen that by adding 3ml the Compressive Strength raised to 12 N/mm^2 after 21 days of curing. In further experimentations 3ml of Superplasticizer was added to each of the samples.

With further studies continued for addition of optimum amount of Lime, samples were prepared with different ratios of Lime addition. Literature says minimum of 15% of Lime should be added [7]. With this reference optimum value of mixing of Lime was studied with 10% and 20% mixtures. Results obtained in 10% mixtures of Lime shows less Compressive Strength 4.6 N/mm^2 and 5.5 N/mm^2 for B1 and B2 samples after 21 days of curing. 20% of Lime mixtures showed an increase in the Compressive Strength of 9, 12, 10, 7 and 6 N/mm^2 after 21 days of curing for C1, C2, C3, C4 and C5 samples respectively.

With 7 days curing sample C2 was found to be having a Compressive Strength of 10 N/mm^2. Similarly for 14 days curing again sample C2 had a Compressive Strength of 11 N/mm^2. And after 21 days of curing C2 sample was observed to have higher Compressive Strength of 12 N/mm^2. With the above results we can conclude that the C2 sample with mixing ratio of (Fly Ash-50%, Sand-30%, Lime-20% and Superplasticizer-3ml) is the best combination for getting a good quality bricks.

For 3% Hydrochloric acid solution there was mild reduction in Compressive Strength. The Compressive Strength decreased to 15%, 20%, 13%, 7% and 10% for C1, C2, C3, C4, and C5 samples respectively. From this we can conclude that anything above 2% causes destruction in bricks and reduction in Compressive Strength.

For C2 mixture the Water Absorption was found to be 3.48% after it was immersed in water for 24 hours. Water Absorption for normal bricks should not exceed 20% [13].

From Alkali Resistance test it was found that concentration of 1N NaOH, there was negligible or slight weight loss and the compressive strength came down by 8%, 10%, 7%, 2% and 5% for C1, C2, C3, C4 and C5 samples respectively, which shows that the brick is not much resistance to Alkali solution of 1N NaOH and above concentration.

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