Experimental Studies on Fly Ash Based Lime Bricks

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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 fly ash bricks are comparatively lighter in weight and stronger than common clay bricks. Since fly ash is being accumulated as waste material in large quantity near thermal power plants and creating serious environmental pollution problems, its utilization as main raw material in the manufacture of bricks will not only create ample opportunities for its proper and useful disposal but also control environmental pollution to a greater extent in the surrounding areas of power plants.

This paper addresses the technology of making FaL-G mortar compressed bricks with low-calcium (Class F) dry fly ash as the base material. The FaL-G bricks were prepared without the use of conventional cement. Quarry dust and sand were used as fine aggregates as sustainable materials. The properties of FaL-G masonry hollow blocks were determined for different parameters. The experimental results reveal that the FaL-G bricks are suitable to be used for the construction of masonry structures. The object of this project is to represent the information regarding Fly Ash bricks and plant, properties and their uses in a most concise, compact and to the point manner. And also in this project various laboratory experiments were carried out on fly ash bricks samples. Some of them are Compressive strength study, water absorption study etc.

Keywords: fly ash, lime, gypsum, quarry dust, sand, mortar, Fal-G.

I. INTRODUCTION

1.1 FLY ASH
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 (SiO2), aluminium oxide (Al2O3), iron oxide (Fe2O3), 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.

These particles solidify as microscopic, glassy spheres (see fig.1) that are collected from the power plant's exhaust before they can fly away — hence the product's name: Fly Ash. Chemically, fly ash is a pozzolan. When mixed with lime (calcium hydroxide), pozzolans combine to form cementitious compounds. The Fig.1 shows the pictorial view of fly ash particles.

The power requirement of the country is rapidly increasing with increase in growth of the industrial sectors. India depends on Thermal power as its main source (around 65% of power produced is thermal power), as a result the quantity of Ash produced shall also increase. Indian coal on an average has 30% to 40% Ash and this is one of the prime factors which shall lead to increased ash production and hence, Ash utilization problems for the country.

Fly ash is one of the numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards. It's also contains trace amounts of toxic metals which may have negative effect.
on human health and on plants and the land where the fly ash decomposed not gets reused.

The disposal of this waste material is a matter of great concern from the environmental and ecological point of view. The safest and gainful utilisation of this material has been one of the topics of research over the last few decades.

The advantages of fly ash utilisation are:
- Saving of space for disposal and natural resources
- Energy saving and Protection of environment

The options of ash utilization including the ash based products are at development stage and need to be made more environments friendly by bringing ash revolution.

1.2 QUANTITY OF FLY ASH GENERATED IN INDIA

The principle source of energy in India is the coal and it will remain the major source of thermal power for the next few decades. Nearly 65% power in India is generated through thermal power plants (TPP). The high ash content of Indian coals (30% to 40%) is contributing high volumes of fly ash. It is estimated at present nearly 160 million ton fly ash is produced every year. The Fig.2 shows the utilization of fly ash in different segments of works in India.

The fly ash generation is increasing in such a proportion that it will not be possible for the cement industry alone to utilize the same. New avenues of gainful utilization of fly ash have to be found and promoted. The generation of fly ash in different five year plans is given in Table – 1.

<table>
<thead>
<tr>
<th>Plan Period</th>
<th>Terminal Year</th>
<th>Power Generation, (MW)</th>
<th>Coal (million tons)</th>
<th>Fly ash (million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8th Plan</td>
<td>1996 - 97</td>
<td>50,000</td>
<td>210</td>
<td>80</td>
</tr>
<tr>
<td>9th Plan</td>
<td>2001 - 02</td>
<td>87,000</td>
<td>285</td>
<td>110</td>
</tr>
<tr>
<td>10th Plan</td>
<td>2006 - 07</td>
<td>1, 16, 400</td>
<td>400</td>
<td>140</td>
</tr>
</tbody>
</table>

Table 1: Generation of Fly ash during different Five Year Plans

Fig. 2 Present Utilization of Fly ash in different segments

II. LITERATURE REVIEW

2.1 INTRODUCTION

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 plants.

The Fig.3 shows the comparison between clay and fly ash bricks and pavers.

Production of building materials, particularly bricks using fly ash is considered to be one of the solutions to the ever-increasing fly ash disposal problem in the country. Although there exist several technologies for producing fly ash bricks, the one that is gaining popularity is the FaL-G technology.

The FaL-G technology works with the strength of fly ash, lime and gypsum chemistry.
require heavy duty-press or autoclave, which is otherwise required in case of only fly ash and lime. The FaL-G process completely eliminates the thermal treatment (except open air drying) and does not require combustion of any fossil fuel.

The ingredients of the FaL-G bricks and blocks, fly ash, lime, and gypsum, are well-known minerals that are widely used in industries. All these materials are available in form of wastes and bi-products from industrial activities and are available in adequate quantities in the areas where the project activities are located. In certain cases, where by-product lime is not available in adequate quantity, ordinary Portland cement (OPC) is used as the source of lime, producing the same quality of bricks and blocks. The technology is proved to be environmentally safe and sound.

Fly ash–lime-gypsum (FaL-G) is not a brand name but it is duct name, christened to the mix for easy identification of its ingredients.

“FaL-G in certain proportions, as a building material, is an outcome of innovation to promote the utilization of fly ash by It gains strength like any other hydraulic cement, in the presence of water, and is water resistant with time(Bhanumathidas and Kalidas 2002).”

“Cementitious binder, FaL-G, finds extensive application in the manufacturing of building materials such as bricks, solid blocks, hollow blocks and lean concrete. FaL-G technology enables production of hollow blocks with a simple process of mixing and water curing. Due to such appropriate technology, conservation of energy and pollution control are achieved (Singh M and Garg M 1997).”

“It has been reported that FaL-G mortar can be used in making the masonry hollow block units by different combinations of fly ash, lime and phosphogypsum (Radhakrishna 2010).” “FaL-G technology contributes to the conservation of energy and reduces environmental degradation effectively (Siamak Boudaghpour and AlirezaJadidi 2009).”

“It creates self-help livelihood opportunities for the people in developing countries. In certain cases, where byproduct lime is not available, ordinary Portland cement is used as the source of lime, producing the same quality of bricks and blocks (Bhanumathidas N and Kalidas N 1994, 2004).”

Bricks made of fly ash can be broadly classified into following groups –

- Clay Fly ash bricks
- Fly ash lime bricks
- Mud Fly ash bricks

2.1.1 FLY ASH LIME BRICKS

In presence of moisture, fly ash reacts with lime at ordinary temperature and forms a compound possessing cementitious properties. After reactions between lime and fly ash, calcium silicate hydrates (C-S-H) are produced which are responsible for the high strength of the compound.

This process involves homogeneous mixing of raw materials (generally fly ash, sand and lime), moulding of bricks and then curing of the green bricks. Some technologies call for usage of chemical accelerator like gypsum. These processes are almost similar and vary slightly from water curing to steam curing at low pressure or autoclaving at 10-14 kg/cm2.

Bricks made by mixing lime and fly ash are, therefore, chemically bonded bricks. These bricks are suitable for use in masonry just like common burnt clay bricks. These bricks possess adequate crushing strength as a load-bearing member and are lighter in weight than ordinary clay bricks. The Table 2 and 3 demonstrates the modular size of the clay and FaL – G bricks respectively.

Generally, dry fly ash available from power plants meets the properties specified in IS: 3812 and is suitable for manufacture of Fly Ash – lime bricks in accordance with the requirements of IS: 12894.

2.1.2 DIMENSIONS

The standard modular size of

<table>
<thead>
<tr>
<th>Table 2: clay bricks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length (L)</strong></td>
</tr>
<tr>
<td>mm</td>
</tr>
<tr>
<td>190</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3: faL-g bricks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length (L)</strong></td>
</tr>
<tr>
<td>mm</td>
</tr>
<tr>
<td>230</td>
</tr>
</tbody>
</table>

2.1.3 CHARACTERISTICS OF FAL-G BRICKS

- The standard size of the brick is 230mmx100mmx70mm.
- The bricks are manufactured and tested as per IS 12894-2002.
- Fly ash bricks are sound, compact and uniform in shape, size and colour. Smooth rectangular faces of the bricks are accompanied with sharp and square corners.
- They are free from visible cracks, warpage, flaws and organic matter.
- Economical & environment friendly.
- 28% lighter than ordinary clay bricks.
- Compressive strength: 7.5N/mm² on an average.
- Water absorption <8%.

2.1.4 FaL-G TECHNOLOGY

Fly ash- lime-gypsum (FaL-G) is not a brand name but it is duct name, christened to the mix for easy identification of its ingredients.
FaL-G technology is based on the principles namely, that fly ash lime pozzolanic reaction does not need external heat under tropical temperature condition, and strength of fly ash-lime mixtures can be greatly augmented in the presence of gypsum. FaL-G technology was developed by institute of solid waste research and ecological balance, Vishakapatnam.

Fly ash lime mix in different proportions, is mixed in pre-determined proportions with calcined gypsum which produces FaL-G having strong binding properties and can be used as cement. It can be mixed with sand and/or aggregate to produce building blocks of any desired strength.

2.1.5 CHEMICAL PROPERTIES OF FLY ASH

<table>
<thead>
<tr>
<th>COMPOUNDS</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>45.98</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>23.55</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.91</td>
</tr>
<tr>
<td>CaO</td>
<td>18.67</td>
</tr>
<tr>
<td>MgO</td>
<td>1.54</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.24</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.80</td>
</tr>
<tr>
<td>SO₃</td>
<td>1.47</td>
</tr>
<tr>
<td>Loss of ignition</td>
<td>2.31</td>
</tr>
<tr>
<td>Cl</td>
<td>0.0053</td>
</tr>
<tr>
<td>Free lime</td>
<td>0.64</td>
</tr>
</tbody>
</table>

2.1.6 PHYSICAL PROPERTIES OF FLY ASH

Specific Gravity 2.54 to 2.65 gm/cc
Bulk Density 1.12 gm/cc
Finess 350 to 450 M2/Kg

2.1.7 MANUFACTURING PROCESS

Fly ash, lime and gypsum are manually fed into a pan mixer where water is added in the required proportion for intimate mixing.

The proportion of the raw material is generally in the ratio 60-80% of fly ash 10-20% lime, 10% Gypsum, depending upon the quality of raw materials.

The materials are mixed in pan mixture. After mixing, the mixture is conveyed through belt conveyor to the hydraulic/mechanical presses.

The homogenised mortar taken out of roller mixer is put into the mould boxes. Depending on the type of machine, the product is compacted under vibration / hydraulic compression etc. The Fig. 4 shows the schematic diagram of manufacturing of the bricks and the Fig. 5 shows the flow chart diagram of manufacturing process.

The fal-g bricks are dried up under sun from 2 to 4 days, depending whether lime route or cement route; the dried up bricks are stacked and subjected for water spray curing once or twice a day, for 28 days, depending on ambience. The bricks are tested and sorted before despatch.

Fig. 4 : Manufacturing Process Diagram
Fly Ash, + Gypsum, + Lime
↓ ↓ ↓ ↓ Weighing
↓ Pan Mixer
↓ Conveyor
↓ Fly Ash Brick Making Machine (Hydraulic (or) Power Press)
↓ Transported To Wooden Racks
↓ Kept as it is
for two to four days for setting
↓ Water Curing
(7 to 20 days)
↓ Drying
(one or two days)
↓ Sorting and Testing
↓ Dispatch

Fig. 5: Flow Chart Diagram of Manufacturing of Fly Ash Bricks

2.1.8 TECHNICAL ADVANTAGES
- Energy Efficient
- Fire resistant
- Sound Resistant
- Structurally sound
- Strong, Durable and Versatile
- Safe, Secure and Robust
- Economical

III. SCOPE OF RESEARCH

FaL-G is relatively economical material derived from binders fly ash, lime and gypsum. The data available based on work carried till today speaks about only arbitrary use without any rational approach. The data available on strength development and proportioning is also very less. In this present study FaL-G mortar bricks are prepared and various properties were studied.

IV. EXPERIMENTAL INVESTIGATIONS

4.1 MATERIALS AND METHOD

4.1.1 FLY ASH

Fly ash refers to the ash produced during combustion of coal. Pulverized fuel ash commonly known as fly ash shall conform to Grade 1 or Grade 2 of IS 3812.

The proportion of the Fly ash is generally in the ratio 60-80%, depending upon the quality of raw materials.

The Fly ash (Class F) is From Raichur Thermal Power Plant, Karnataka, INDIA – 400709.

4.1.2 LIME

Quick Lime or hydrated lime or both can be mixed in the composition. Lime should have minimum 40% CaO content. Commercially available slaked lime is sieved and used.

4.1.3 GYPSUM

Hydrated calcium sulphates are called gypsum. (CaSO4·2H2O). Gypsum should have minimum 35% purity and 5 to 15% may be used. Its procured from the industry.

FaL-G mortar was prepared using FaL-G as binder and Quarry dust/sand/pond ash as fine aggregates. The procedure adopted was same as that of conventional cement mortar. Tap water was used to mix the ingredients. The ingredients were mixed thoroughly by kneading until the mass attained uniform consistency.

Fig. 6, 7 & 8 shows the Weighing, Mixing, mould in which poured and the manufactured brick after demoulding respectively.
4.1.4 TESTS CONDUCTED

1. Compressive strength test
2. Water absorption test

The Fig. 9 & 10 shows the tests conducted on bricks and the brick after failure in CTM respectively.

4.2 SPECIMEN

The fly ash, lime, and gypsum(fal-g) bricks of mould size 23cm x 10cm x 7cm with varying mix proportions of Fly ash, lime and gypsum ratio and constant w/fal-g ratio of 0.4 were casted in the laboratory. A total of 18 bricks specimens were casted & tested in the laboratory. The Table 4 shows the specimen proportions below.

Table 4: SHOWING BRICK SPECIMENS WITH VARIOUS PROPORTIONS AND WITH VARIABLE W/FAL-G RATIO

<table>
<thead>
<tr>
<th>Sl. Nu.</th>
<th>Types of brick</th>
<th>Grade</th>
<th>Fly ash, lime, Gypsum and sand</th>
<th>Mix proportions ratio</th>
<th>W/fal-g ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FAL-G BRICK</td>
<td>A</td>
<td>70%:15%:15% &amp; 0%</td>
<td>1:0.16:0.22:0</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>FAL-G BRICK WITH SAND</td>
<td>B</td>
<td>60%:15%:15% &amp; 10%</td>
<td>1:0.19:0.28:0.22</td>
<td>0.4</td>
</tr>
</tbody>
</table>

V. RESULTS AND DISCUSSIONS

5.1 DETERMINATION OF COMPRESSIVE STRENGTH OF FLY ASH BRICKS

5.1.1 TEST SPECIMEN

Fal-g brick of size 23cm x 10cm x 7cm was casted and kept for curing for 28days.

5.1.2 MEASUREMENT OF COMPRESSIVE STRENGTH

- The bricks after acquiring the required curing condition, Place the specimen with flat faces horizontal in the compression testing machine.
- The load was applied axially at the uniform rate. The max. Load in newton(N) before the failure occurs divided by the gross area of the block in Sq.mm. was taken as the compressive strength of the mould. The Table 5 demonstrates the observations made during the test on bricks.
5.1.3 CALCULATION

Compressive Strength \( \frac{N}{mm^2} \) = \( \frac{Max.\ load\ at\ Failure\ in\ N}{Avg.\ Area\ of\ bed\ face\ in\ mm^2} \)

Table 5: Observations

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Dimensions of bricks</th>
<th>Avg. area of bed surface (mm²)</th>
<th>Max. load at failure (tone)</th>
<th>Compressive Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Length 230 Width 100 Height 70</td>
<td>23000</td>
<td>12 12.5 12.75</td>
<td>5.29</td>
</tr>
<tr>
<td>B</td>
<td>Length 230 Width 100 Height 70</td>
<td>23000</td>
<td>13 12.5 12.75</td>
<td>5.43</td>
</tr>
<tr>
<td>Clay bricks</td>
<td>Length 230 Width 100 Height 70</td>
<td>23000</td>
<td>10.00 9.00 9.50</td>
<td>3.98</td>
</tr>
</tbody>
</table>

5.2 DETERMINATION OF WATER ABSORPTION

5.2.1 Material:
FaL-G brick specimen of size 23cmx10cmx7cm, clean water. The Table 6 demonstrates the observations made during water absorption test.

5.2.2 PROCEDURE:
- Take the weight of dry specimen as \( M1 \) and Immerse completely dried specimen 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 as \( M2 \), Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:

\[
\text{Percentage of water absorption} = \frac{M2 - M1 \times 100}{M1}
\]

Table 6: Observations

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight (dry) gm</th>
<th>Weight (wet after 24 hr) gm</th>
<th>% of water absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2840</td>
<td>3105</td>
<td>9.33</td>
</tr>
<tr>
<td>B</td>
<td>2910</td>
<td>3230</td>
<td>11</td>
</tr>
</tbody>
</table>

5.3 Discussions

The percentage of water absorption was found to be less than 12 % for both types against the maximum limit of 20% as per IS 3495-1976.

There is a variation of compressive strength of the FaL-G bricks with age for sand. It is quite obvious that the strength increases with age. It is due to continues reaction between the FaL-G binder and water. The compressive strength was around 5 MPa at the age of 28 days. The minimum strength at the age of 28 days is more than 3MPa in most of the cases. This strength would be sufficient to use them as masonry units as per IS 3495-1976.

CONCLUSION

The experimental investigations reveals the following conclusions .

- FaL-G compressed masonry bricks can be conventionally prepared economically by using industrial wastes like fly ash, lime, gypsum, Sand.
- Due to lower water penetration seepage of water through bricks is considerably reduced.
- In view of the above, it can be concluded that FaL-G masonry units can effectively replace conventional masonry units.
- Due to uniform size of bricks mortar required for joints & plaster reduces almost by 50% and because of high strength, practically there will be no breakage during transport & use.
- The results shows the FaL-G bricks are more safe, economical and having higher strength compare to conventional bricks.
- it can be understood that fly ash bricks are better alternative to conventional burnt clay bricks in structural, functional and economic aspects. By use of this aspect we can convert waste into wealth.

REFERENCES:


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