Fly Ash Bricks
Masonry: An Experimental Study

Abstract-
Fly ash is waste generated from combustion of coal in power generation plants. Due to its pozzolanic properties, utilized in construction industry. In this paper Fal-G brick production process, uses of rap-trap bond in Fal-G brick masonry prism test study and economy have been described. The observations, limitation and suggestions in various areas have been described.

Keywords-fly ash, rat-trap bond, prism test, environment, infrastructure, economy

INTRODUCTION
Fly ash is pozzolanic material which can be used in construction industry. The fly ash can be divided in two groups:

Low calcium fly ash is produced from combustion of bituminous coals or anthracite coals. It has low calcium (CaO) percentage about 3% and silica + alumina + iron oxide more than 70%.

High calcium fly ash is produced from combustion of sub-bituminous of lignite coals and it has about 20% of calcium (CaO) content and percentage of SiO₂+Al₂O₃+Fe₂O₃ in this fly is less than 70%.

To have better utilization of this fly ash as per Nation's policy on fly ash, trial have been made for making of bricks using fly ash, lime, gypsum and sand or quarry dust.

FLY ASH-LIME-GYPSUM BRICKS
Fly ash-lime-gypsum bricks/blacks technology has been developed successfully by National Thermal Power Corporation (NTPC), Bhanu International and Ahmadabad Electricity Company (AEC) for manufacturing bricks/blacks which can replace burnt clay bricks as walling material.

It is also known as Fly Ash-Lime-Gypsum (FaL-G) bricks. It is not a brand name but it is duct name, christened to the mix for easy identification of its ingredients.

EXPERIMENT ON STRENGTH OF FLY ASH BRICK MASONRY

The bricks used are only machine-made. The mortars used only one 1:6. Types of mortar used: (a) 1:6 [Fal-G: sand], (b) 1:6 [Cement: sand]. Five samples are prepared with 1:6 fly ash mortar and five samples are prepared with 1:6 cement mortar with 10 mm joint. Testing carried out at 14 days curing.

EXPERIMENTAL WORK
In this experiment, we used only FaL-G bricks. The bricks casted in pan mixer and brick making machine with some proportion of fly ash, lime and gypsum with quarry dust.
The bricks were cured for 21 days. After curing the bricks were tested for water absorption test and compression test.

We got water absorption = 15 % and compressive strength = 22.68 N/mm².

Then we casted prisms with use of bricks and 1:6 mortars with 10 mm bed joints.

The mortars were of two types:

- Cement: sand mortar
- Fal-G: sand mortar

Such five samples were made and cured for 14 days and compression test were done.

The table –I shows the stress at first crack and stress at failure in N/mm² after 14 days curing of masonry.

![Masonry Prism](image)

**Figure –II Masonry Prism**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Stress at first crack (N/mm²)</th>
<th>Stress at failure (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>6.616</td>
<td>7.183</td>
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<td>2</td>
<td>6.561</td>
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<td>5</td>
<td>6.660</td>
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<tr>
<td><strong>Average strength</strong></td>
<td>6.481</td>
<td>7.139</td>
</tr>
</tbody>
</table>


**STUDY OF COST-EFFECTIVENESS OF FLY ASH BRICKS IN CONSTRUCTION (Case study)**

Project - Use of Industrial wastes in Construction of Rural Housing Project for 28 L.I.G. (Lower Income Group) Units at Mahemdabad. The project consist of 28 LIG houses, a unit of Sardarnagar, Building Centre, Mahemdabad (Supported by HUDCO) Development Corporation had carried out experiments and research works to save Environment, to makes Best use of Industrial wastes like Fly-Ash Lime, sludge Gypsum Quarry Dust and slag. With use of locally available material and accepted technologies in construction industry to safer, stronger and economical construction using fly ash to the extent of 28% to 34% over the conventional practices.

![Typical Section-Diag Type C](image)

**Figure-III Plan and elevation of typical LIG House**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Variants</th>
<th>UnitCost (Rs.)</th>
<th>Unit</th>
<th>Comprehensive k.m.</th>
<th>Total (Rs. 1000 250 sq. ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fly ash brick</td>
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<td>500</td>
<td>100</td>
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<tr>
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<td>Fly ash block</td>
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<td>Cement</td>
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<tr>
<td>5</td>
<td>Sand</td>
<td>3500</td>
<td>500</td>
<td>100</td>
<td>250</td>
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<tr>
<td>6</td>
<td>Labour</td>
<td>4000</td>
<td>500</td>
<td>100</td>
<td>250</td>
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<tr>
<td><strong>Total Fly ash brick</strong></td>
<td>1500</td>
<td>500</td>
<td>100</td>
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<td><strong>Total Fly ash block</strong></td>
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FINDINGS OF CASE STUDY
Thus Sardarnagar Building center (supported by HUDCO) at Mahemdabad, Dist. Kheda, Gujarat, has achieved economy of 28% to 34% over the conventional practices and saving of environment is advantage.

The cost of developed plot of 88.39 m² area would be Rs. 29,750.

Two demonstrative houses executed had with stood the strong earthquake, that shock the Gujarat state on 26.01.2001

NEW TECHNOLOGY FOR MASONRY WORK
RAT-TRAP BOND
A brick placed on edge in 1:6 mortars as shown in figure is a rat-trap bond.

ADVANTAGES
1) Compared to a 230 mm thick solid brick wall, consumption of brick is reduced by 25% in rat-trap. Due to this reduction in number of bricks, the consumption of cement mortar is also reduced.
2) Stability of wall is not affected as the excess material is eliminated from around the center line.
3) Acts as a good thermal insulator.
4) Plastering of the outside face is not needed.
5) Labour intensive technology.

DISADVANTAGES
1. Not a good sound insulator.
2. Excavation of soil needed for the manufacturing of bricks may lead to environment problems.
Rat-trap bonded brick masonry has been widely used in Kerala, West Bengal and many other locations. Many buildings which were constructed decades ago have proved that this type of walling technology is durable and the maintenance costs are low. On an average, a rat-trap bonded brick wall needs cleaning of the external surfaces after every three year and the expenditure for this purpose is 1.25 man days of unskilled labour per 10.00 m² of wall area.

OBSERVATIONS AND SUGGESTIONS
India's power generation has undergone a tremendous growth since independence. The production of ash also increased from 110-130 million tones in 2010-11 to 150-170 million tones in 2020-21, likely to cross 200 million tones in next decade. The ash should be managed properly or otherwise it will cause land, air and water pollution and there is a serious concern about utilizing it to the maximum extent.

It is obvious that building the infrastructure will require large quantities of construction materials. At the same time, due to the growing worldwide concern for climate change caused by the "greenhouse" gases such as CO₂, gas emissions.

In order to pursue the goal of infrastructure development in a sustainable manner it would be necessary to use much larger amount of industrial by-products such as fly ash in place of virgin raw materials.

Fly ash has potential for the development of new environment friendly, economical and safe building materials. The performance characteristics of fly ash based materials show good results.

OBSERVATION
Unfortunately, despite increasing awareness of potential of fly ash, the response of Indian builders and material manufactures towards fly ash utilization has been quite lukewarm until recent past with the level of utilization in Indian context being a meagre 5%.
Utilization in construction industry mostly by brick manufacturing. Gainful utilization of fly ash in the production of bricks/blocks could serve the dual purpose of conserving valuable agricultural land and augmenting brick production in the country.
Fly ash bricks are being produced on a large scale by the West Bengal Power Development Corporation Ltd. (WBPDCCL) near its plant at Kolaghatover 25 million clay-fly ash bricks have been produced in the country by NTPC, and other public sector undertaking as well as private bricks manufacturers.
A Vishakhapatnam based non-profit organization namely Bhanu International has developed a process of FaL-G products. Technologies for manufacturing fly ash lime bricks have been developed by the leading research laboratories in India like CBRI, CFRI, NCB, NCL, NRDC, ACC.
Utility of fly ash as viable building material is now beyond doubt. With view to giving fillip to the increased use of fly ash-based building components, the Government of India has been announcing concessions and incentives in the past three Union Budgets. Excise duty has been exempted on materials and components having 25 percent or more fly ash content.
Transforming fly ash into an asset, for that BMTPC and Ministry of Urban Development has been engaged in providing technical back-up service for establishing new fly-ash, lime brick plants making available technology profiles, preparation of feasibility reports, etc.

LIMITATIONS REGARDING UTILISATION OF FLY ASH
Most of the Indian TPPs (Thermal Power Plants) employ wet system of ash disposal and generally both bottom ash and fly ash are mixed together and disposed
of in "setting ponds" This makes the available ash unfit for utilization in cement, concrete cellular concrete blocks/slabs etc. due to decrease in pozzolanic activity with decrease in fineness, increase in unburnt carbon etc.

Limitations, in terms of average distance the ash can be commercially transported adds to the cost of the end products which are manufactured in the consumption centers away from the location of the power plant. There is a considerable variation in the properties of ash produced in different thermal power plant within the country, and even in the ash from single plant hopers. This leads to the restrictions in its use, particularly in case of small or medium scale entrepreneurs who are unable to meet the cost of testing.

The machines for large scale production of fly ash bricks or other products are so costly that the cost of import of these machineries is very prohibitive which makes project economically not viable. Due to higher transportation cost of fly ash as a fine and bulky material, preference is always given to a site as near as possible to thermal power plant for setting up of any manufacturing unit.

Lack of adequate support from financial institutions for funding etc.

Lack of adequate legislation for promotion of use of fly ash.

Because of the strict security and unnecessary long procedures entrepreneurs face a lot of problems in getting fly ash out from TPPs premises.

SUGGESTIONS

The detailed suggestions for quality, technology, infrastructure, and environment have been enlisted.

QUALITY

The fly ash generators in India have not yet accorded adequate recognition to bottom ash and fly ash, as two distinctly resource materials. Once this recognition is accorded bottom ash and fly ashes collected from different locations would not be mixed together and would be suitably collected in a manner as not to destroy their special features.

Quality of available fly ash can be improved by taking suitable measures through proper collections combustion of coal and transportation with storage. Each batch of fly ash could also be classified and certified at source to enable the manufacture to know what he is getting.

For testing to fly ash, suitable agency should be set up near the collection point to supply the ash of certified quality confirmed to IS: 3812-1972.

TECHNOLOGIES

Selection of fly ash brick making technology should be based on the availability of raw materials, financial strength of entrepreneurs and market characteristics.

(i) Clay fly ash brick technologies should be encouraged for conversion of large no. of clay fired brick units and urgent steps should be taken due to low investment and minimum changes.

(ii) Sand fly ash bricks should be introduced as a second step to conversion from clay fired bricks or where semi-mechanised operations are justified on the basis of market demand.

(iii) Fly ash-lime-gypsum bricks/blocks are very good products and should focus on large high quality markets where higher investment and product cost can be accepted by the market, which would ultimately find the product cost-effective.

RESEARCH AND DEVELOPMENT

(i) While technologies and processes are being developed in a number of private and government institutions in India, the potential of using fly ash and the technologies seem to have by-passed the average entrepreneur for manufacture of fly ash bricks and blocks.

(ii) While it is generally known, that lime reactivity of fly ash increases with fineness, no definitive relationship has yet been evolved in this direction. The research project needs to be done by a set of such institutions along with fly ash generators and potential entrepreneurs.

ENVIRONMENT

The dry disposal method should be encouraged and try to reduce to use of water resources.

For generators, environmental clearances should be granted only to projects, which integrate highest standards of collection and storage of fly ash. Rigid guidelines should be issued to existing projects to adhere to stringent regime for emission control and storage of dry fly ash within a specific frame time.

Use of clay for bricks manufacture costs the nation very heavily in terms of (i) permanent lose of valuable top soil which nature takes millions of years to make (ii) greater use of energy and (iii) often inferior bricks.

INFRASTRUCTURAL

i) Transportation of fly ash is problematic. Fly ash should be utilized close its source. While this would increase the cost of transportation of bricks, a part of the saving in cost of fly ash disposal should be used to subsidies this cost.

ii) Transportation of fly ash should be done in bulk by railway tankers or road tankers, suitably fabricated and equipped. Automatic loading and unloading through compressor/vacuum pumps mounted on the tankers should be utilized.

iii) Extensive use of technologies will also help improve the technologies and make them more commercially relevant. A few large scale demonstration projects using fly ash components need to be installed across the country.

EXPERT SYSTEM DEVELOPMENT

The various construction characteristics of basic materials, masonry parameters and strength design can be systematically and logically combined to get one step solutions. This can be achieved by developing expert system using MATLAB, C or any other programming language coupled with drafting software to generate drawings.

CONCLUSION

Fly ash utilization in the country has remained less than 10% during the past 5 years and it might take several years to reach the final goal of cent percent utilization.
Every year nearly 70 million tonnes of ash is produced in India, of which NTPC stations alone contribute to the extent of about 22 million tonnes. To utilize such a huge quantity of ash, we have to take necessary actions from government side and from non-government side for utilisation point of view.

Based on the results for the experiments done on FaL-G brick prism masonry compressive strength measured at 14 days is 85.05 kg/cm² for cement mortar (1:6) and 88.83 kg/cm² for fly ash mortar (1:6). As compare to conventional brick masonry prism compressive strength it is between 13.75 kg/cm² to 121.80 kg/cm² at 28 days strength. While FaL-G brick prism strength is 88.83 kg/cm² for cement mortar (1:6) and 85.05 kg/cm² for fly ash mortar (1:6) just in 14 days. It can be increased up to 135 kg/cm² to 145 kg/cm² at 28 days.

The results show the FaL-G bricks are more safe, economical and having higher strength compare to conventional bricks. According to case study the fly ash bricks with conventional masonry work have 28% saving in cost with common red brick and conventional masonry work. The masonry work with new technology Rat-Trap bond in fly ash bricks have 33% saving in cost as compared to common bricks.

Further Fly ash bricks have many advantages like -
- Light weight
- Economical
- Environmental friendly
- Saving of fertile land, pure water
- More compressive strength
- Use of wastage etc.

Thus, fly ash brick is one of the best uses of fly ash. It may be concluded that the use of fly ash in brick manufacturing industry is technoeconomically viable, if utilized by application of optimum technologies, which are available with commensurate levels of automation and capacity generation. Fly ash brick manufacturing is a potential field of application wherein large-scale utilisation of fly ash is possible. From the previous chapters it can be understood that fly ash bricks are better alternative to conventional burnt clay bricks in structural, functional and economic aspects. This industry has the potential to consume at least 50% of the ash production in India. By use of this aspect we can convert waste into wealth.

After looking into all the facets of fly ash brick industry and its different applications in the previous chapters, in the end it is a request to all the government and non-government organizations involved in generation, research and development and utilisation of fly ash, to extend all possible help in terms of technology, resources or finance to the entrepreneurs who are trying to come forward to set their plants inspite of tough competition and numerous set back in marketing. If this much could be done, it will prove to be a big stepping stone towards the present need of sustainable development.

FUTURE SCOPE
The list of topics given below could be studied further as an extension to the study. These topics are related to current developments in the field of fly ash utilisation and need to be studied technically and commercially.
- Fly ash for construction of roads and embankments.
- Feasibility study of the large scale Fly ash brick manufacturing units.
- Fly ash utilisation for manufacturing of Pre-Fabricated products.
- Fly ash in Aerated Autoclave Concrete.
- Considering the fly ash - lime - gypsum- sand combination idea-can be extended to manufacture cement from it.

ACKNOWLEDGMENTS
Authors are highly grateful to the authorities of Charutar Vidyamandal, Vallabh-Vidyanagar for giving the permission for the necessary experimental work in their Fly Ash Brick production plant.

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