



Research On Eco-Bond Fly Ash Brick

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Abstract: The use of fly ash composites has gained significant attention due to their superior mechanical properties, including excellent tensile, compressive, impact, and hardness characteristics. These composites are often used as reinforcements in various applications. Several fabrication techniques, such as in-situ deposition, hand-up lay, and compo-casting, have been explored to create these materials. However, a systematic correlation between the structure and properties of fly ash composites has yet to be established. This review highlights the current state of research in the field from two perspectives: (I) the various fabrication techniques employed, and (II) the mechanical properties of the composites produced. In addition, the review emphasizes the need for a detailed structure-property correlation to optimize the performance of these materials.

In another area, hollow fly ash concrete blocks have been widely used in developing nations as construction materials. These blocks are typically made without standardized guidelines, resulting in significant variability in mechanical properties. This study investigates different methods to improve the properties of hollow fly ash concrete blocks by using new mix designs of cement and fly ash. The results demonstrate a marked increase in compressive strength compared to conventional blocks, along with improved water retention and modulus of rupture. These advancements suggest that optimizing mix designs can enhance the consistency and durability of fly ash concrete blocks.

Index Terms - Fly Ash Composites / compressive / reinforcements / optimizing / blocks / fabrication techniques.

I. INTRODUCTION

Blocks have been widely used as construction and building materials around the world for many years. Traditional block production typically involves using mixtures of clay and shale as raw materials, with processes like Moulding, drying, and firing at high temperatures. Fired clay bricks are commonly used in construction, particularly for building walls. The growing demand for building structures has driven efforts to address challenges associated with construction. Many rural brick makers use locally sourced clay, and various studies have shown that variations in clay composition significantly affect the mechanical properties of bricks. There is also notable variation in splitting tensile strength, modulus of rupture, and absorption rates across different regions. In response to environmental concerns and the need for sustainable development, researchers have explored the use of various waste materials—such as fly ash, slags, construction debris, wood sawdust, rice husk ash, and other industrial byproducts—to improve the mechanical properties of traditional clay bricks. While limited research has focused on enhancing the properties of hollow fly ash concrete blocks using waste materials, studies on other waste products like ceramic waste and fly ash have been more common. This study explores different methods to enhance the mechanical properties of hollow fly ash concrete blocks by altering the mix design. The new mix, which

includes aggregates, cement, and fly ash, is tested for compressive strength, modulus of rupture, splitting tensile strength, and water absorption capacity. The results are compared with those of hollow fly ash concrete blocks made using traditional methods, showing improvements in compressive strength and reduced water absorption.

1.1 FLYASH

Fly ash, a byproduct of coal combustion in power plants, has gained attention as a valuable additive in concrete production due to its pozzolanic properties, which improve the material's strength and durability while reducing carbon emissions associated with traditional cement manufacturing. The use of fly ash not only enhances the mechanical properties of concrete but also helps in minimizing landfill waste, thereby promoting a circular economy within the construction industry.

This dual benefit of fly ash contributes to more sustainable construction practices, as it effectively reduces the carbon footprint while simultaneously utilizing an industrial byproduct that would otherwise contribute to environmental degradation.

The incorporation of fly ash in concrete mixes has become increasingly popular among engineers and architects seeking to meet green building standards, as it aligns with the growing demand for eco-friendly construction materials. The successful integration of fly ash into concrete formulations is also supported by various research studies that highlight its performance advantages, such as improved durability and resistance to chemical attacks, further solidifying its role in advancing sustainable construction techniques. It is classified into two types: Class F, with low calcium content, typically used in concrete, and Class C, with higher calcium content, often used for soil stabilization and other applications.



Fig.1: Fly Ash (At Panki Power Plant)

1.2 CEMENT

Portland Pozzolana Cement (PPC) is a blend of ordinary Portland cement (OPC) and pozzolanic materials, such as fly ash, volcanic ash, or calcined clay. PPC is particularly suitable for your project as it integrates fly ash, aligning with the sustainable objectives of using industrial by-products for hollow fly ash bricks and adhesives.

1. Key Characteristics of PPC

- Composition: 65–70% Ordinary Portland Cement (OPC).
- 25–30% Pozzolanic material (e.g., fly ash).
- 2–5% Gypsum.

2. Pozzolanic Reaction:

Pozzolanic materials in PPC react with calcium hydroxide produced during hydration, forming additional calcium silicate hydrate (C-S-H), which improves the cement's durability and strength over time.

3. Fineness:

PPC is finely ground, enhancing workability and coverage, which is particularly beneficial in producing hollow bricks and adhesives.

4. Hydration:

PPC exhibits slower hydration compared to OPC, which reduces heat generation and minimizes cracks in the structure.

Advantages of PPC for Hollow Fly Ash Bricks and Adhesives

1. Durability:

Higher resistance to chemical attacks like sulfates and chlorides, making it ideal for bricks and adhesives used in harsh environmental conditions.

2. Strength Development:

PPC develops strength gradually, ensuring long-term structural integrity of the hollow bricks and adhesive bonds.

3. Cost-Effectiveness:

Pozzolanic materials, particularly fly ash, are cost-effective and abundant, reducing the overall cost of cement production.

4. Sustainability:

Incorporating fly ash into PPC reduces the carbon footprint by lowering clinker content, contributing to environmental conservation.

5. Workability:

The finer particles and smoother consistency of PPC improve the workability of the mix, aiding in the uniform casting of hollow bricks and smooth adhesive application.



Fig.2: OPC Cement

1.3 SAND

Fine sand, also known as fine aggregate, plays a crucial role in the construction industry due to its contribution to workability, strength, and finish of materials. In your project focusing on hollow fly ash bricks and fly ash-based adhesives, fine sand is a vital component for achieving the desired material properties.

Characteristics of Fine Sand

1. Particle Size:

Fine sand consists of particles smaller than 4.75 mm, as defined by IS: 383-1970.

It typically belongs to Zone II or Zone III grading, depending on its fineness modulus.

2. Texture:

Fine sand has a smooth and consistent texture, enhancing workability in cementitious mixes.

3. Density:

The bulk density of fine sand ranges between 1500–1700 kg/m³, contributing to the material's overall strength and stability.

4. Water Absorption:

Fine sand generally absorbs 1–2% of its weight in water, which must be considered in mix design to maintain workability and prevent shrinkage.



Fig.3: Fine Sand

1.4 EXPANDED CLAY AGGREGATE

Expanded Clay Aggregate (ECA) is a lightweight, porous aggregate created by expanding clay at high temperatures. It is commonly used in construction for applications such as lightweight concrete, insulation, and even in the production of certain building materials like fly ash bricks. In your project, ECA can play a significant role in improving the overall properties of hollow fly ash bricks and adhesives.

Characteristics of Expanded Clay Aggregate (ECA)

1. Particle Size:

ECA particles range from 2 mm to 10 mm in size, making it suitable for use in lightweight concrete and other building materials.

ECA can be used in varying grades based on the required application.

2. Texture:

The surface of ECA is rough and porous, which enhances bonding with other materials like cement and adhesives. Its porous structure allows for good insulation properties.

3. Density:

The bulk density of ECA is generally around 600–800 kg/m³, significantly lower than traditional aggregates.

This low density makes it ideal for producing lightweight construction materials, reducing the overall weight of the fly ash bricks.

4. Water Absorption:

ECA has a high-water absorption rate due to its porous structure, typically around 20–30%.

This property needs to be accounted for in the mix design to ensure proper curing and strength development.



Fig.4: ECA

II. OBJECTIVE

1. Develop hollow fly ash bricks with enhanced strength, reduced weight, and improved thermal insulation using fly ash, fine sand, and expanded clay aggregate (ECA).
2. Formulate fly ash-based adhesives to provide strong bonding for hollow bricks, ensuring optimal workability and performance.
3. Promote sustainability by utilizing fly ash and other eco-friendly materials, reducing reliance on traditional building materials.
4. Conduct rigorous testing to evaluate the mechanical properties, durability, and thermal conductivity of the bricks and adhesive.

III. LITERATURE REVIEW

1. Mohamed Vadel Bebana, Khadija Ziat, Nawal Semlal, Mohamed (20 November 2019) examines the use of artificial neural networks to predict the compressive strength of geopolymer blocks made with Moroccan fly ash and phosphogypsum. Two types of neural networks, the multilayer perceptron (MLP) and radial basis function (RBF), were used. A dataset of 99 experimental observations was applied for training and testing the models. The study involved optimizing the MLP architecture by determining the number of hidden layers, neurons in each layer, and the activation function, followed by an evaluation of the model's predictive accuracy. Results showed that the MLP model with two hidden layers (8 and 10 neurons) and a hyperbolic tangent activation function performed best. The study concludes that artificial neural networks are effective tools for accurately evaluating the properties of geopolymer materials.

2. Basumajumdar et al. studied in 2004, examined the reaction between fly ash (FA) and lime for brick manufacturing. The study found that FA reacts with lime at normal temperatures in the presence of moisture to form compounds with cementitious properties. The research focused on the reaction between FA and lime in a compacted form, measuring the free lime (CaO) remaining in the mix after different curing periods. The results showed that lime interacts with oxides like silica, alumina, and iron oxide in FA to create various bearing phases, which react with water to form hydrates that maintain the strength of the FA-lime compacts. The study concluded that the optimal compaction pressure for these compacts using a water/steam process is between 200–250 kg/cm².

3. Panuwat Joyklad, Nazam Ali, Qadeer Hussain (August 2018) The paper by Panuwat Joyklad, Nazam Ali, and Qadeer Hussain (August 2018), "Execution of Empty Block Made of Fly Ash, Concrete, and Sand," reviews strategies for enhancing the mechanical properties of Concrete Composite Interlocking (CCI) blocks. The study focuses on developing new mix designs using fly ash, cement, and sand to improve performance. Experimental results highlight significant increases in compressive strength, along with enhancements in water absorption and modulus of rupture, compared to conventional CCI blocks. These findings demonstrate the potential of the proposed mix designs to improve the structural properties and durability of hollow CCI blocks, offering an effective alternative in construction.

4. Gadling et al. conducted a comparative review of conventional clay bricks and fly ash bricks, focusing on the benefits of utilizing fly ash as a raw material to reduce solid waste and environmental pollution. The study reported that fly ash bricks achieved an average compressive strength of 1305 psi (9 N/mm²) and identified a 40% fly ash and 60% clay mix as optimal for the production of fired bricks. The inclusion of fly ash not only conserves land resources but also enhances the properties of bricks at higher

firing temperatures. Fly ash reduces the density of bricks, making them lighter without altering hydration properties. Furthermore, fly ash bricks demonstrated improved resistance to salt crystallization cycles, attributed to a reduction in surface area, indicating better durability compared to conventional bricks.

5. K. Gourav, B. V. Venkatarama Reddy (June-July 2014) The review and experimental study by K. Gourav and B. V. Venkatarama Reddy (2014) examine the characteristics and masonry performance of fly ash-lime-gypsum bricks, positioning them as a sustainable alternative to traditional masonry units. By incorporating 10% lime and 2% gypsum, these bricks achieve compressive strengths of 8–10 MPa, low water absorption, and excellent durability. The addition of sand to the fly ash mix enhances density, while the masonry exhibits higher flexure bond strength compared to burnt clay brick masonry. The review highlights the environmental and economic advantages of utilizing industrial by-products like fly ash, offering a cost-effective and high-performing solution for construction. The study concludes that fly ash-lime-gypsum bricks are a durable and sustainable material, suitable for structural applications and a promising alternative to conventional bricks.

IV. RESEARCH METHODOLOGY

1. Blending of raw materials (Cement, Fine Aggregate, Expanded Clay Aggregate and Fly Ash.)

Collect the necessary raw materials, including cement, fine aggregate, Expanded Clay Aggregate, and fly ash, which will be used for the preparation of the concrete mix.

2. Various tests on materials.

Perform various tests on the raw materials to determine their suitability and quality. This includes tests for particle size distribution, moisture content, specific gravity, and other relevant properties of cement, aggregates, and fly ash.

3. Water Content Determination:

Determine the water content of both the aggregates and fly ash to ensure proper water-cement ratios during mix preparation.

4. Preparation of Samples:

Prepare fly ash brick samples for testing, ensuring they have a standard size of 400mm x 230mm x 200mm with two hollows of diameter of 110mm and depth 200mm, in line with industry norms for consistency and ease of testing.



Fig.5: Sample

5. Concrete Mix Design:

Design the concrete mix for M25 grade as per the relevant IS codes, considering the specific characteristics of the raw materials, including the use of fly ash as a partial replacement for traditional aggregates or cement.

6. Curing of Samples:

Leave the prepared fly ash brick samples to cure in portable water for the required curing period, ensuring that the samples attain maximum strength and durability.

7. Determine the compressive strength after 7 days, 14 days and 28 days of curing.

V. MATERIAL SELECTION AND ITS PROPERTIES

To manufacture everyday hollow fly ash brick, you need cement, quarry dust, fine aggregates, water, and expanded clay aggregate. For regular AAC block, fly ash is not used, whereas hollow fly ash brick incorporates fly ash as a waste product. After conducting various assessments on the materials used, the following observations were made.

TABLE 1: PROPERTIES OF MATERIALS

Material	Properties of material	Observation
Cement	Specific gravity	3.15
	Consistency	31%
	Fineness	7%
	IST	30 min.
	FST	600 min.
Fine Aggregate	Size	Less than 4.75mm
	Specific Gravity	2.7
	Water Absorption	1.5%
	Shape	Angular, Rough
	Density	1600 Kg/m ³
Expanded Clay Aggregate	Size	2-10mm
	Specific Gravity	0.5-1.5
	Water Absorption	20%
	Shape	Rounded
	Density	300 kg/m ³
Fly Ash (Class C)	Size	15 μ m
	Specific Gravity	2.4
	Water Absorption	2%
	Density	2300 Kg/m ³

MIX DESIGN

Mix design refers to the process of determining the optimal proportions of fly ash, cement, sand, and expanded clay aggregate (ECA) to create lightweight, durable, and strong bricks suitable for framed structures. The mix must balance strength, density, and thermal insulation while ensuring good workability and bonding. By varying the proportions of fly ash and ECA, you can optimize the brick's compressive strength, weight reduction, and durability. A well-designed mix will enhance the performance, sustainability, and cost-effectiveness of the bricks, making them a viable alternative to traditional materials.

TABLE 2: PURPOSE AND DENSITY OF MATERIALS

Material	Purpose	Density (kg/m ³)
Fly Ash	Main ingredient for binding, reduces weight	900
Cement	Provides strength and binding	1440
Sand	Improves strength and reduces shrinkage	1600
Expanded Clay Aggregate (ECA)	Lightweight aggregate for better insulation	350
Water	Activates cement hydration	1000

Mix Proportions (By Volume & Weight for .0216m³)

We considered six different mix designs by varying Fly ash, cement and sand.

TABLE 3: MIX INDEX AND TOTAL COST

Mix Index	Cement (Kg)	Sand (Kg)	Fly Ash (kg)	Total Cost (₹)
M1	5	5	11	65.17
M2	5	4	12	63.57
M3	5	3	13	62.64
M4	6	5	10	72.48
M5	5	5	12	64.11
M6	4	5	12	55.73

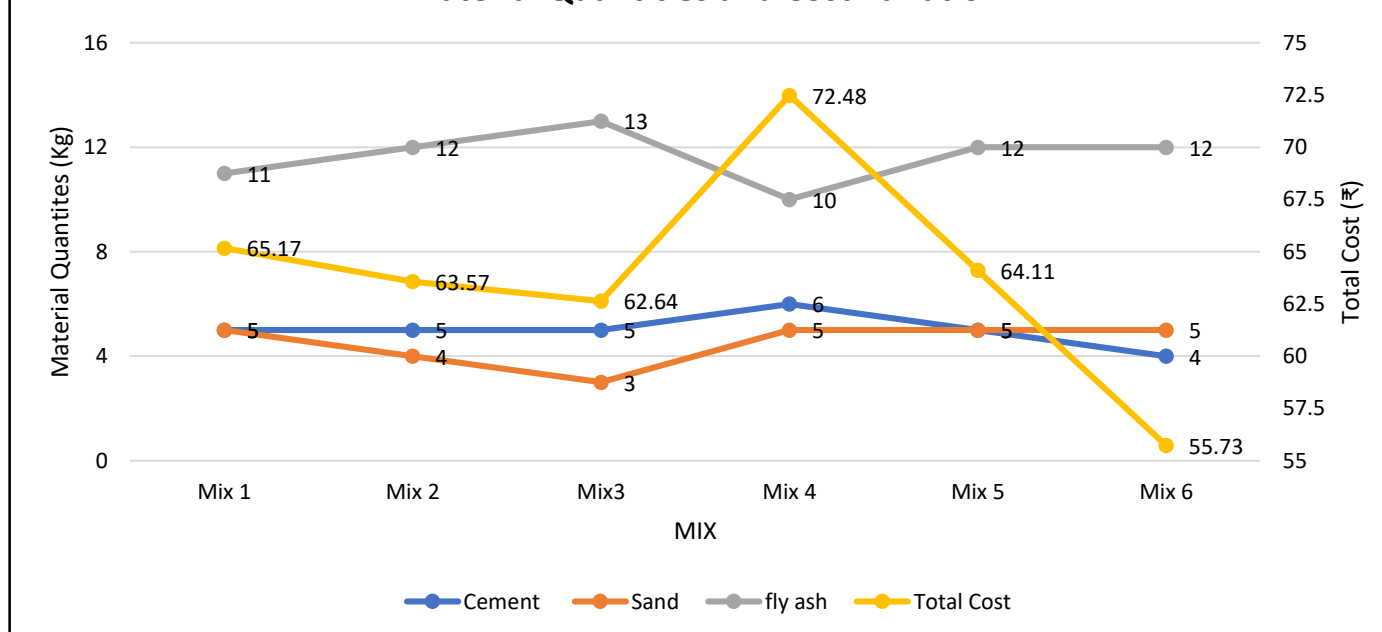
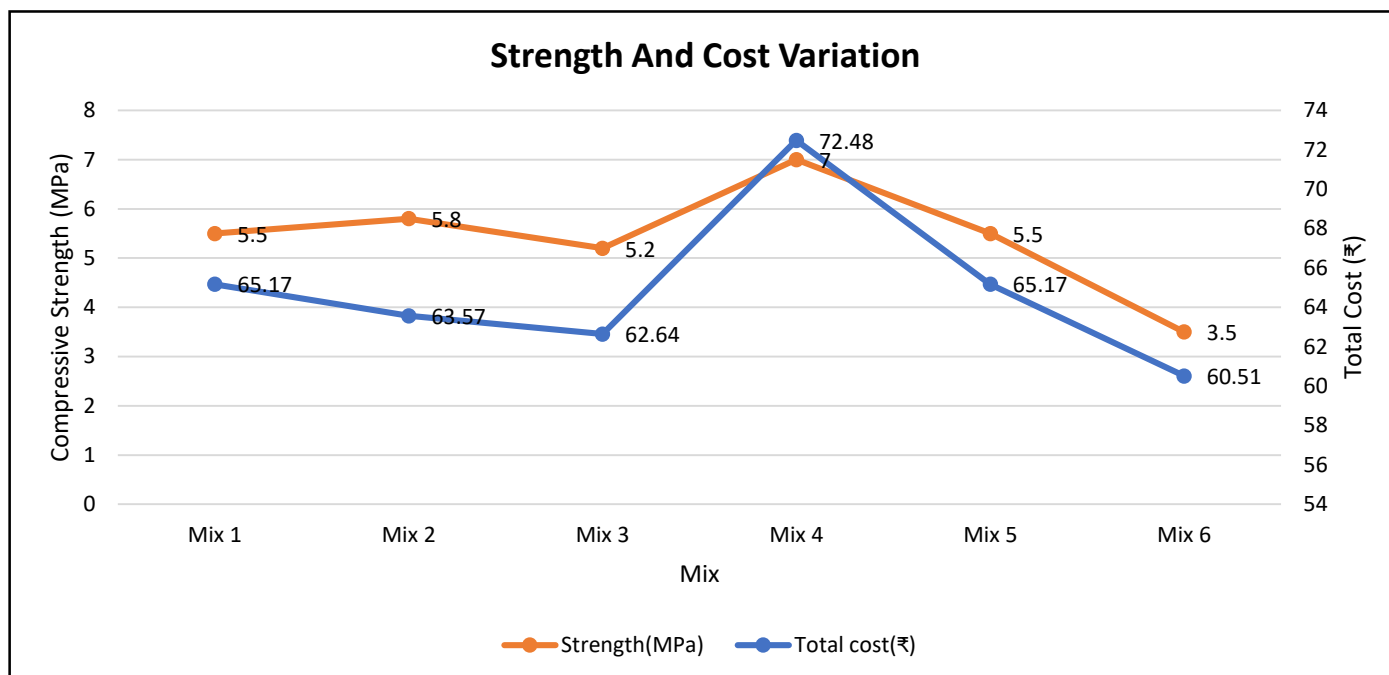
Material Quantities and Cost Variation

TABLE:4 STRENGTH AND COST VARIATION

Mix Index	Strength (MPa)	Total Cost (₹)
M1	5.5	65.17
M2	5.8	63.57
M3	5.2	62.64
M4	7.0 (Highest)	72.48
M5	5.5	64.11
M6	3.5 (Lowest)	55.73



VI. RESULTS AND DISCUSSION

The compressive strength of AAC blocks and Fly Ash blocks was determined using a Compression Testing Machine (CTM). Each block was placed on the machine's platform, and a compressive load was applied gradually at a rate of 30 N/mm² per minute until the block failed. The load at the point of failure was recorded and divided by the cross-sectional area of the block to calculate its compressive strength. Each block sample was placed in the CTM, and the compressive load was gradually increased until the block failed. The ultimate load was recorded, and compressive strength was calculated using the formula:

$$\text{Compressive Strength (MPa)} = \frac{\text{Maximum Load (N)}}{\text{Cross-sectional Area (mm}^2\text{)}}$$

This test helps determine whether Fly Ash blocks meet the performance standards for load-bearing applications. The results under various curing conditions are presented in the following table (to be added), providing insight into the strength development of the blocks over time. The test was conducted on blocks with three different conditions: without curing, after 7 days of curing, and after 28 days of curing. The



Fig.6: Testing of Sample

results for both types of blocks under these conditions are presented in

Table 5: Compressive strength for 7-day curing and non-curing

Mix Index	7 Days Compressive strength in N/mm2	
	Non- Curing	Curing
M1	2.1	2.7
M2	2.6	3
M3	2.5	3.2
M4	1.8	3.5
M5	1.5	2.8
M6	1.1	2.2

the table below.

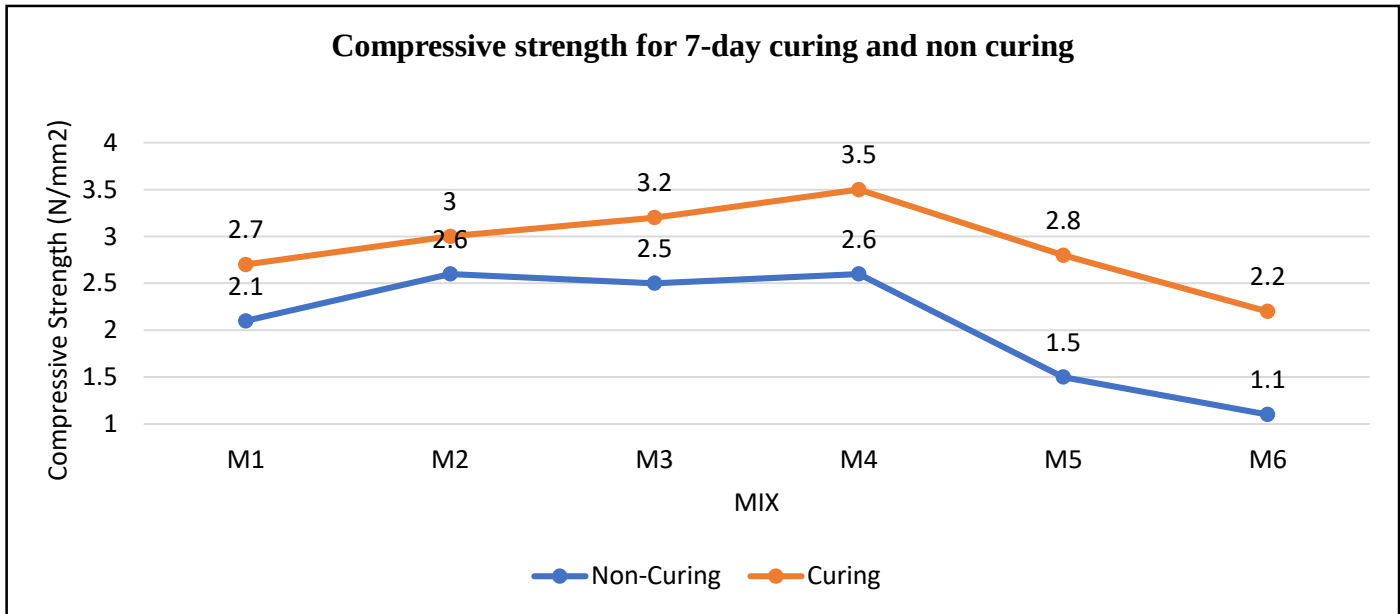
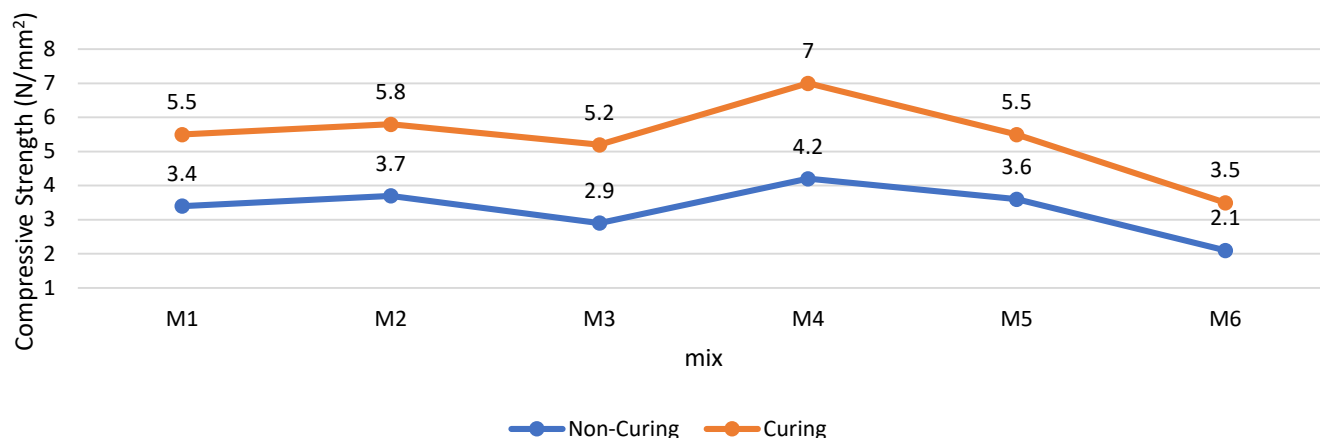


Table 6: Compressive strength for 28-day curing and non-curing

Mix Index	28 Days Compressive strength in N/mm2	
	Non- Curing	Curing
M1	3.4	5.5
M2	3.7	5.8
M3	2.9	5.2
M4	4.2	7 (Highest)
M5	3.6	5.5
M6	2.1	3.5 (Lowest)

Table 6: Compressive strength for 28-day curing and non-curing



VII. CONCLUSION

After thorough experimentation and analysis of six different mix designs, it was observed that Mix M4 yielded the highest compressive strength of 7.0 MPa after 28 days of curing. This indicates its suitability for structural applications requiring enhanced load-bearing capacity. However, Mix M4 also incurred the highest production cost of ₹72.48, which may limit its feasibility for large-scale, cost-sensitive projects.

On the other hand, Mix M2 provided a well-balanced outcome, achieving a compressive strength of 5.8 MPa with a relatively lower cost of ₹63.57. This makes Mix M2 the most practical and cost-effective solution for general-purpose construction, offering an ideal compromise between performance and affordability.

The role of proper curing was found to be crucial, with all samples showing significantly improved strength after 28 days of water curing compared to non-cured counterparts. This highlights the importance of maintaining optimal curing conditions to ensure long-term durability.

The integration of materials such as fly ash and expanded clay aggregate contributed positively to the overall performance. Fly ash enhanced the binding properties and sustainability of the bricks, while expanded clay aggregate reduced weight and improved thermal insulation, though its high-water absorption requires careful mix adjustment.

Overall, the study confirms that with an optimized mix design, hollow fly ash bricks can serve as a durable, eco-friendly, and economical alternative to conventional construction materials. Among the tested compositions, Mix M2 stands out as the most effective for real-world applications, combining strength, sustainability, and cost-efficiency.

Final Recommendation

For applications requiring **maximum strength**, Mix M4 is the optimal choice. For **general-purpose, cost-effective production**, Mix M2 is recommended as the most suitable blend, ensuring a sustainable, durable, and economically viable product.

VIII. Future Scope

The future of Eco Bond Fly Ash Bricks looks promising with several areas of potential growth and innovation:

- 1. Advancements in Material Science:** Further research into alternative binders such as geopolymer and bio-based adhesives can enhance the strength and durability of fly ash bricks.
- 2. Integration with Smart Technologies:** The use of embedded sensors in bricks to monitor structural health and environmental conditions can make construction more intelligent and sustainable.
- 3. Expansion of Market Adoption:** Increased government incentives, subsidies, and awareness campaigns can drive greater adoption in urban and rural areas.
- 4. Sustainable Construction Practices:** The growing trend toward green building certifications like LEED (Leadership in Energy and Environmental Design) can boost the demand for eco-friendly building materials like fly ash bricks.
- 5. Recycling and Circular Economy:** Developing techniques to further recycle construction and demolition waste into fly ash brick manufacturing will enhance the sustainability of the industry.

6. **Improved Manufacturing Processes:** Advancements in automation and AI-driven quality control can lead to cost-effective and large-scale production of high-quality fly ash bricks.
7. **Policy and Regulatory Support:** Strengthening environmental policies and enforcing stringent regulations on conventional brick kilns can push the adoption of sustainable alternatives like Eco Bond Fly Ash Bricks.

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