Utilisation of Industrial Waste for Manufacturing High-Performance Sustainable Brick

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ABSTRACT

The growing demand for sustainable construction materials has driven the development of eco-friendly alternatives to traditional fired bricks. This study focuses on the use of industrial by-products and alternative materials such as fly ash, ground granulated blast furnace slag (GGBS), hydrated lime, crushed sand, and Ordinary Portland Cement (OPC) to manufacture unfired composite bricks. Three different proportions of these materials were used to prepare brick samples, designated as M1, M2, and M3. For each mix, three samples were prepared for testing. The bricks were cured and tested over periods of 7, 14, and 28 days to evaluate their compressive strength and other physical properties. The results showed that mix M1 achieved the highest compressive strength of 13.04 MPa at 28 days, meeting the standards required for structural applications. The successful incorporation of waste materials not only reduces environmental impact but also provides a cost-effective and energy-efficient solution for the construction industry. This project demonstrates the viability of unfired bricks as a sustainable building material, promoting green construction practices while maintaining structural performance.

Keyword: - OPC Grade 53, Fly Ash, GGBS, Hydrated Lime, Crush Sand, Compressive Strength,

1. INTRODUCTION

The construction industry is a significant contributor to environmental degradation due to its heavy reliance on natural resources and the high energy demands of traditional materials such as fired clay bricks and cement. These materials require high-temperature kilns, leading to substantial carbon emissions and the depletion of natural topsoil. In response to increasing environmental concerns, the development of sustainable construction materials has become a priority.

Unfired bricks manufactured using industrial waste such as fly ash, Ground Granulated Blast Furnace Slag (GGBS), hydrated lime, crushed sand, and Ordinary Portland Cement (OPC) offer a viable alternative. Fly ash and GGBS, both industrial by-products, exhibit pozzolanic and cementitious properties that enhance the mechanical strength, durability, and resistance of bricks. The elimination of high-temperature firing reduces energy consumption and greenhouse gas emissions. Additionally, the use of waste materials supports the circular economy and reduces landfill burden.

1.1 Objectives

1) To develop an eco-friendly alternative to fired bricks using industrial waste.
2) To optimise the material composition for improved strength and durability.
3) To assess environmental and economic benefits by reducing CO_2 emissions and production costs.
4) To evaluate physical and mechanical properties like compressive strength and water absorption.
5) To promote sustainable and low-carbon construction practices.

1.2 applications

1) Residential & Commercial Buildings: For load and non-load bearing walls with thermal insulation benefits.
2) Affordable Housing: Ideal for cost-effective and sustainable construction.
3) Infrastructure Projects: Suitable for roads, pavements, retaining walls, and rural development.
4) Green Buildings: Supports LEED certification and sustainable urban development goals.
5) Waste Management: Encourages recycling of industrial by-products and reduces landfill usage.

2. METHODOLOGY

The methodology adopted for this study involves the experimental production of sustainable unfired bricks using industrial waste materials. The aim was to develop and analyze the performance of eco-friendly composite bricks and compare their physical and mechanical properties with those of conventional fly ash bricks.

2.1 Material Selection

The primary raw materials used in the manufacturing process include:

- Fly Ash: A pozzolanic material obtained from thermal power plants.
- Ground Granulated Blast Furnace Slag (GGBS): A byproduct of the steel industry with cementitious properties.
- Hydrated Lime: Acts as a chemical binder, enhancing the pozzolanic reaction.
- Crushed Sand (M-Sand): Used as fine aggregate to provide bulk and structure.
- Ordinary Portland Cement (OPC 53 Grade): Used for additional binding strength.

Three mix proportions were prepared (M1, M2, M3) by varying the percentages of these materials.

2.2 Manufacturing Process

The brick production process involved four stages:

2.2.1 Mixing

All raw materials were weighed accurately and mixed thoroughly. Dry mixing was followed by gradual addition of water to ensure uniform moisture distribution.

2.2.2 Molding

The homogeneous mixture was molded into standard-sized bricks using a hydraulic press machine to ensure uniform compaction and shape.

2.2.3 Curing

Bricks were subjected to water curing for 7, 14, and 28 days under ambient conditions to allow sufficient strength development.

2.2.4 Testing

Standard laboratory tests were conducted to evaluate:

1) Compressive Strength (IS: 3495 Part 1 – 1992)
2) Water Absorption
3) Density
4) Efflorescence
5) Soundness
6) Size & Shape
7) Surface Hardness (Scratching Test)

2.3 Mix Proportions

Table No. 2.1 Composition of Material:

Sample	Fly Ash (%)	Lime (%)	GGBS (%)	Crushed Sand (%)	OPC (%)
M1	35	6	25	20	14
M2	30	5	20	25	20
M3	25	5	15	30	25

3. RESULTS AND DISCUSSION

This section presents the experimental results of the various physical and mechanical tests conducted on sustainable unfired bricks. The results were analysed for three different mix ratios (M1, M2, and M3) after curing periods of 7, 14, and 28 days.

3.1 Water Absorption Test

Water absorption of bricks was evaluated as per standard testing procedure. Results are shown in Table 3.1:

Table 3.1 Water Absorption Test Results:

Sample No.	Initial Weight (kg)	Final Weight (kg)	Water Absorption (%)
M1	3.673	3.897	6.09
M2	3.676	3.833	4.27
M3	3.714	3.841	3.41

Discussion: All samples exhibited water absorption well below the 20% limit. The use of GGBS and OPC cement contributed to reduced porosity.

3.2 Density Test

Density was calculated based on the mass and volume of each brick.

Table 3.2 Density of Bricks

Sample No.	Volume (m^3)	Density (kg/m^3)
M1	0.001539	2386.61
M2	0.001539	2388.56
M3	0.001539	2413.25

3.3 Compressive Strength Test

Bricks were tested at 7, 14, and 28 days of curing.

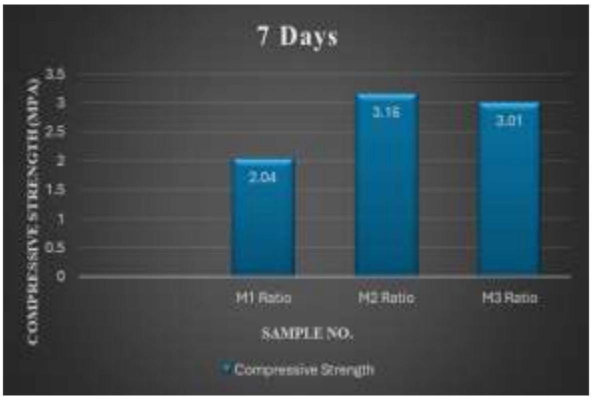

Chart-3.1 Compressive Strength of Brick 7 Days

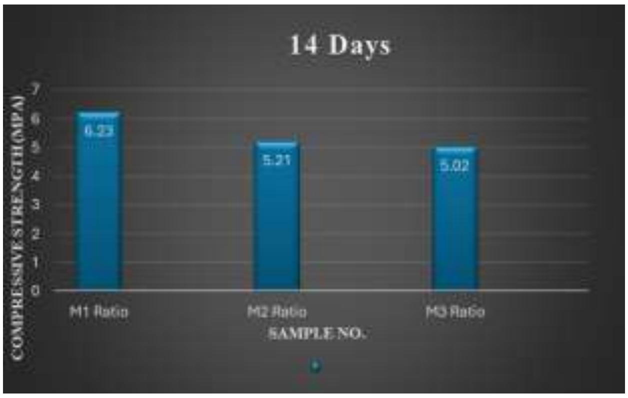

Chart-3.2 Compressive Strength of Brick 14 Days

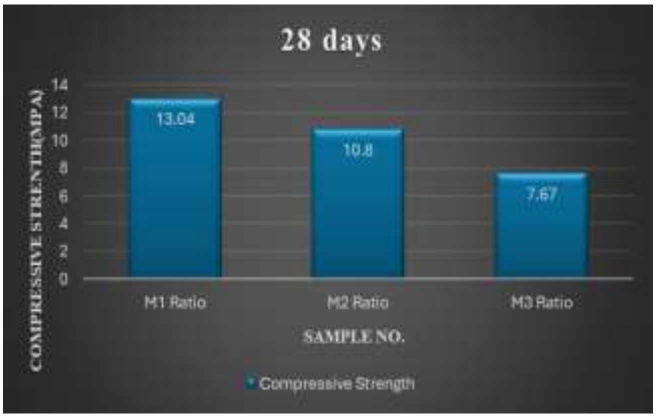

Chart-3.3 Compressive Strength of Brick 28 Days

Discussion: M1 achieved the highest compressive strength (13.04 MPa) after 28 days, exceeding the minimum standard of 7 MPa for non-load-bearing walls.

3.4 Other Physical Tests

1) Efflorescence Test: No visible white salt deposits were observed, indicating good chemical stability.
2) Scratching Test: All samples passed, confirming surface hardness.
3) Soundness Test: A clear metallic ringing sound indicated internal integrity and compactness.
4) Size & Shape: All bricks maintained standard dimensions (190×90×90 mm), with minimal deviations.

Overall Observation:

Mix M1 demonstrated superior performance across all parameters and is recommended for sustainable and durable construction. The use of industrial waste materials like fly ash and GGBS proved effective in enhancing brick properties while promoting environmental sustainability.

4. CONCLUSION

The experimental investigation into the manufacturing of unfired composite bricks using sustainable materials such as fly ash, GGBS, hydrated lime, crushed sand, and Ordinary Portland Cement (OPC) has proven to be both effective and environmentally beneficial. It was observed that the M1 mix ratio exhibited the highest compressive strength after 28 days of curing, outperforming other mixes such as M2 and M3. This indicates that GGBS, due to its pozzolanic properties, is effective as a partial replacement for cement. Other test results also showed good performance across all mixes, with only negligible differences. Therefore, M1 with a compressive strength of 13.04 MPa can be considered the optimum mix, meeting the strength requirements for non-load-bearing and select load-bearing construction applications.

The utilization of industrial by-products like fly ash and GGBS not only enhanced the strength and durability of the bricks but also contributed significantly to reducing carbon emissions and energy consumption associated with traditional fired brick production. The use of OPC and hydrated lime as binding agents further improved the structural integrity of the bricks while maintaining sustainability.

Overall, the project demonstrates that composite unfired bricks are a viable and eco-friendly alternative to conventional bricks. This approach not only supports waste management and resource conservation but also promotes cost-effective and green construction practices. With further optimization and large-scale testing, these bricks have the potential to be adopted widely in the construction industry, contributing to a more sustainable built environment.

6. REFERENCES

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