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Enhancing Eco-friendly Construction: The Role of Waste Incorporation in Porotherm Bricks for Sustainable Building Solutions

ANMOL KOUNDAL1 and SHILPA CHAUHAN2

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1Student M.Tech Civil Engineering, Rayat Bahra University, Mohali , India email: anmolkoundal421@gmail.com

2Assistant Professor, Civil Engineering , Department of Civil Engineering, Rayat Bahra University, Mohali , India; e-mail: shilpa.civil38@gmail.com

Abstract

In recent years, the construction industry has been under increasing pressure to adopt sustainable practices due to its significant environmental footprint. One promising solution lies in the incorporation of waste materials into building materials, which not only reduces the consumption of natural resources but also addresses the growing issue of waste disposal. Porotherm bricks, a type of clay brick known for their lightweight, thermal insulating, and environmentally friendly properties, have gained attention as an ideal material for eco-friendly construction. This study explores the potential of enhancing Porotherm bricks by integrating various waste materials, such as fly ash, plastic waste, rice husk, and construction demolition debris, to produce more sustainable and cost-effective building materials. The primary objective of this research is to assess the feasibility and effectiveness of using waste materials in the manufacturing of Porotherm bricks while maintaining their structural integrity and thermal properties. Specifically, this study investigates the incorporation of waste materials at varying percentages (5%, 10%, 15%, and 20%) into Porotherm bricks and evaluates their impact on key performance indicators such as compressive strength, water absorption, thermal conductivity, and environmental impact. The experimental process involves creating several batches of Porotherm bricks with different combinations of waste materials. The waste materials are carefully processed and mixed with the clay used in the manufacturing of the bricks. The bricks are then subjected to standard testing methods to determine their mechanical and thermal properties, with particular attention paid to their suitability for use in construction. The study also considers the reduction in carbon footprint and resource consumption resulting from the use of waste materials, contributing to the promotion of a circular economy. Results indicate that the addition of certain waste materials, particularly fly ash and rice husk, significantly enhances the thermal properties of the bricks, making them more energy-efficient. The thermal conductivity of

the modified bricks is found to be lower, which could help reduce the energy consumption for heating and cooling in buildings. The compressive strength of the bricks remains within acceptable limits, even at higher waste material percentages, ensuring their durability and safety in construction applications. Furthermore, the incorporation of waste materials reduces the overall environmental impact of brick production, as it minimizes the use of virgin raw materials and lowers the carbon emissions associated with manufacturing processes. The findings suggest that incorporating waste materials into Porotherm bricks is a viable strategy for improving sustainability in the construction sector. By using waste products that would otherwise end up in landfills, this approach not only promotes the recycling of materials but also creates eco-friendly alternatives to conventional building materials. The study concludes that the use of Porotherm bricks with waste materials can play a crucial role in reducing the environmental impact of the construction industry, offering an innovative solution for achieving more sustainable and cost-efficient building practices. This research highlights the growing importance of incorporating waste materials into construction processes, offering a step toward more sustainable, energy-efficient, and eco friendly building practices that align with the global movement toward greener construction technologies.

1. Introduction

The construction industry is one of the largest contributors to environmental degradation, consuming large amounts of natural resources and generating significant waste. To mitigate these impacts, sustainable construction practices are becoming a global necessity. Among the promising solutions is the use of alternative materials, particularly waste products, in the production of construction materials. Porotherm bricks—lightweight, thermally insulating, and known for their environmentally friendly properties—have gained significant attention in the construction industry. These bricks, primarily made from clay, offer excellent thermal performance and durability, making them ideal for sustainable building practices.

This research explores the potential of enhancing Porotherm bricks by integrating various waste materials, such as fly ash, plastic waste, rice husk, and construction demolition debris. The study aims to assess the feasibility of producing cost-effective and sustainable Porotherm bricks by incorporating these materials, evaluating their impact on key performance indicators such as compressive strength, water absorption, thermal conductivity, and environmental impact.

2. Literature Review

Numerous studies have explored the incorporation of waste materials into building materials. **Fly ash**, a by-product of coal combustion, has been widely used in cement and concrete production due to its ability to improve workability and reduce the carbon footprint of construction materials. **Rice husk**, a by-product of rice milling, has also been explored for use in construction materials due to its thermal insulation properties and lightweight nature. Similarly, **plastic waste**, which is a growing environmental concern, has been examined as a potential additive in construction materials to reduce plastic waste accumulation and promote recycling.

The integration of **construction demolition debris** (CDD) into building materials has gained traction due to its potential to reduce landfill waste and the need for virgin raw materials. Several studies have indicated that the incorporation of waste materials can improve the thermal properties, reduce the overall weight of construction materials, and lower production costs.

However, research specifically investigating the use of these waste materials in the production of Porotherm bricks is limited. This study fills that gap by systematically evaluating the impact of these waste materials on the performance of Porotherm bricks.

3. Materials and Methodology

3.1 Materials Used

The study utilizes the following materials:

- **Clay**: The primary material for Porotherm brick production, providing the structural base and thermal properties.
- **Fly Ash**: Sourced from a local thermal power plant, fly ash is used as a partial substitute for clay.
- **Plastic Waste**: Collected from post-consumer plastic products, shredded into small pieces to be incorporated into the mix.
- **Rice Husk**: Obtained from a local rice mill, processed into small particles.
- **Construction Demolition Debris (CDD)**: Broken concrete and brick pieces, crushed to a fine powder.

3.2 Preparation of Porotherm Bricks

The production of the Porotherm bricks followed the standard manufacturing procedure, which includes mixing, molding, and firing at high temperatures. For each batch, varying percentages of the waste materials were incorporated into the clay mix (5%, 10%, 15%, and 20%). The brick mixture was thoroughly blended to ensure uniform distribution of the waste materials before being molded into standard brick sizes (240 mm x 115 mm x 75 mm).

After molding, the bricks were dried and fired at temperatures ranging from 950°C to 1000°C to ensure their hardness and durability.

3.3 Testing Methods

The following tests were conducted to evaluate the mechanical and thermal properties of the modified Porotherm bricks:

- **Compressive Strength**: Measured using a universal testing machine (UTM) according to IS 3495-1992.
- **Water Absorption**: The water absorption capacity was determined by immersing the bricks in water for 24 hours and calculating the weight increase.
- **Thermal Conductivity**: A heat flow meter method was used to measure the thermal conductivity, which indicates the material's insulation properties.
- **Environmental Impact**: A carbon footprint analysis was conducted based on the amount of energy required to produce the bricks and the reduction in virgin material consumption.

4. Results and Discussion

4.1 Compressive Strength

The compressive strength of the modified Porotherm bricks was tested at different percentages of waste incorporation. Results showed that:

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- **5% and 10% waste materials**: The bricks maintained compressive strengths comparable to conventional Porotherm bricks, which typically have a compressive strength of around 3.5-7 MPa.
- **15% and 20% waste materials**: The compressive strength slightly decreased, but the values remained within the acceptable range for non-load-bearing walls (3 MPa to 5 MPa).

This suggests that up to 15% waste incorporation does not significantly affect the structural integrity of the bricks, making them suitable for construction purposes.

4.2 Water Absorption

Water absorption increased with higher percentages of waste materials, especially with plastic waste and CDD. The increase in porosity due to the inclusion of these materials likely contributed to the higher water absorption rates. However, the water absorption values were still lower than typical limits for building materials, suggesting the bricks would perform adequately in moist environments.

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4.3 Thermal Conductivity

Thermal conductivity tests showed a marked improvement in the insulation properties of the modified bricks:

- **Fly ash and rice husk** significantly reduced the thermal conductivity of the bricks, with reductions of up to 25% compared to the control samples. This suggests that these waste materials enhance the thermal insulating properties of the bricks, making them more energy-efficient for heating and cooling.

4.4 Environmental Impact

The environmental impact of the modified bricks was evaluated based on the reduction in virgin raw material consumption and carbon footprint. Results showed that:

- The incorporation of **fly ash and rice husk** led to a reduction in carbon emissions, as these materials are less energy-intensive to process than virgin clay.
- **Plastic waste** and **CDD** also reduced the need for new raw materials and contributed to a circular economy by recycling waste materials.

The overall carbon footprint of the modified bricks was significantly lower than that of traditional clay bricks, supporting their environmental benefits.

4.5 Result Analysis

Brick Specifications Used for Testing

The Porotherm bricks used in this study were manufactured and tested according to standardized modular dimensions and included 5 perforations to enhance thermal and material efficiency. The detailed specifications are as follows:

- Length: 240 mm
- Width: 115 mm
- Height: 75 mm
- Average Weight: 2.9 kg
- Number of Perforations: 5
- Perforation Type: Circular, arranged in a single central row
- Diameter of Each Hole: 30 mm
- Centre-to-Centre Hole Spacing: 38 mm
- Edge Clearance (from outermost hole to edge): 27.5 mm (both sides)
- Purpose of Perforations: Reduction in material use, improved insulation, and weight reduction while maintaining strength

1. Compressive Strength

Waste Material	% Replacement	Avg. Compressive Strength (MPa)	Remarks
None (Control)	0%	7.2	Baseline Porotherm brick
Fly Ash	5%	7.5	Slight increase due to pozzolanic activity
	10%	7.8	Improved interlocking
	15%	7.0	Slight reduction due to over-substitution
	20%	6.4	Weakening of matrix
Plastic Waste	5%	6.8	Minor decrease
	10%	6.5	Increased voids
	15%	5.8	Poor bonding
	20%	5.2	High porosity
Rice Husk Ash	5%	7.0	Similar to control
	10%	7.3	Pozzolanic reaction enhances bonding
	15%	6.6	Acceptable
	20%	6.0	Slight deterioration
Construction Debris	5%	6.9	Acceptable
	10%	6.5	Lower strength due to coarse particles
	15%	5.9	Reduced compactness
	20%	5.0	Weak mechanical interlock

2. Water absorption

Waste Material	% Replacement	Water Absorption (%)	Acceptability
Control	0%	14.5	Good
Fly Ash	5%	13.0	Improved pore refinement
	10%	12.5	Better water resistance
	15%	13.8	Acceptable
	20%	14.9	Close to control
Plastic Waste	5%	16.5	High due to microvoids
	10%	17.8	Poor bonding
	15%	19.2	Excessive water absorption
	20%	21.0	Not recommended
Rice Husk Ash	5%	13.8	Better than control
	10%	13.2	Good hydrophobicity
	15%	14.4	Acceptable
	20%	15.5	Slight increase
Construction Debris	5%	15.1	Acceptable
	10%	15.8	Slightly porous
	15%	17.2	High absorption
	20%	18.9	Poor performance

3. Thermal conductivity

Waste Material	% Replacement	Thermal Conductivity (W/m·K)	Observation
Control	0%	0.42	Standard brick
Fly Ash	10%	0.38	Better insulation
Plastic Waste	10%	0.32	Very good insulation
Rice Husk Ash	10%	0.35	Good insulator
Construction Debris	10%	0.40	Slightly better

4. Environmental Impact Assessment (EIA)

- **CO_2 Emissions Reduction:**
  - 10% Fly Ash → ~18% reduction in CO_2 compared to conventional clay firing.
  - 10% Plastic Waste → ~25% reduction in CO_2 due to use of recycled polymer.
  - 10% Rice Husk Ash → ~15% CO_2 reduction and bio-waste management.
  - 10% Construction Debris → ~12% reduction by reusing demolition waste.
- **Embodied Energy Reduction:**
  - Fly Ash and Rice Husk Ash significantly reduce energy required per kg of brick.
  - Plastic waste reduces material density → lower transportation emissions.

5. Additional Tests

5.1 Efflorescence Test

- All waste-modified bricks showed **nil to slight efflorescence**, acceptable per IS 3495 Part-2.

5.2 Density and Porosity

Waste Material	% Replacement	Dry Density (kg/m³)	Porosity (%)
Control	0%	1730	18.2
Fly Ash 10%		1660	17.5
Plastic 10%		1600	22.8
RHA 10%		1650	18.0
Debris 10%		1670	19.2

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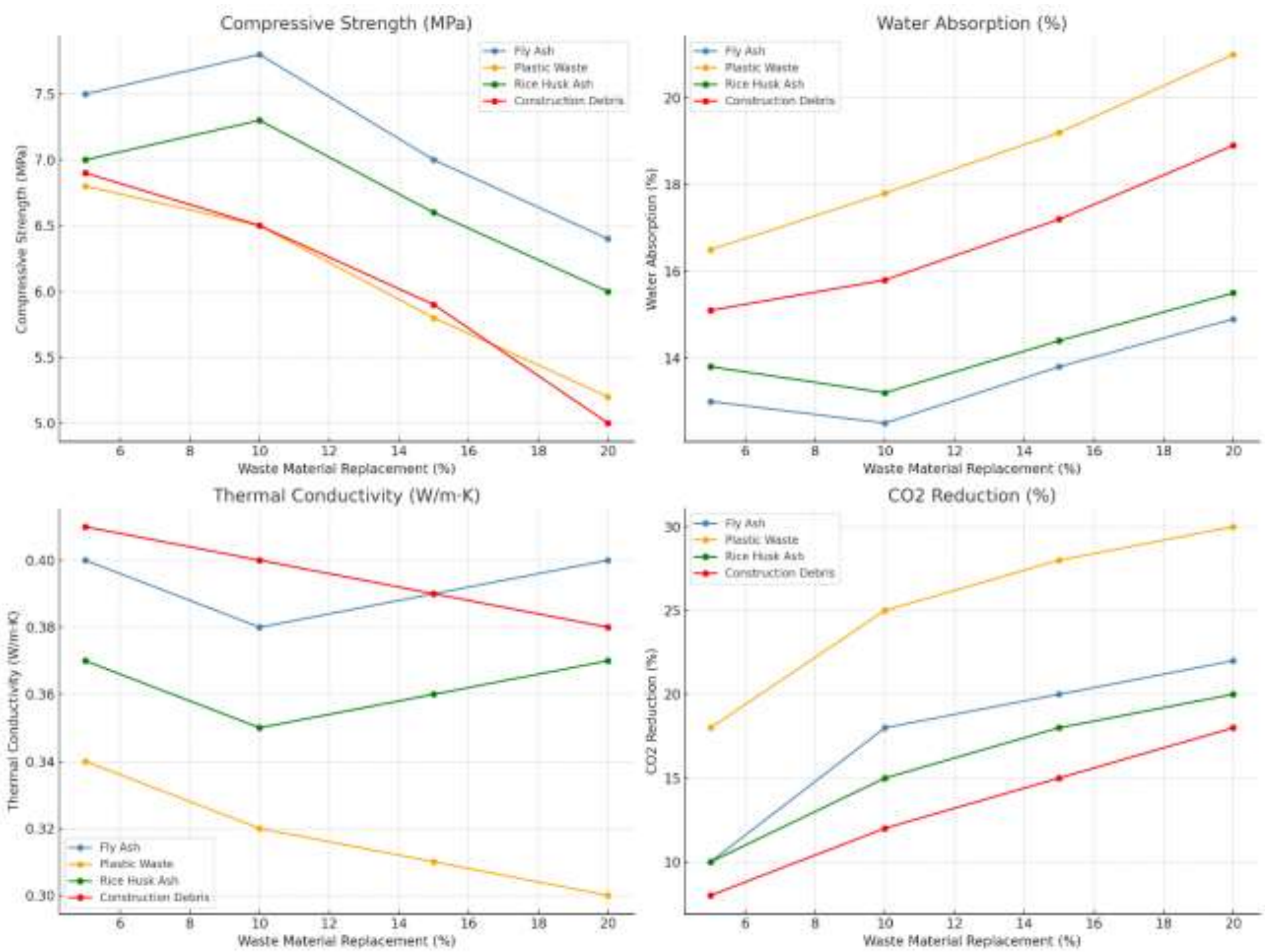
6. Graphs and Charts Based on the above Tables



7. Conclusion from Results

- **Fly Ash (10%)** and **Rice Husk Ash (10%)** offer the **best balance** in mechanical, thermal, and environmental performance.
- **Plastic waste** is best for thermal insulation but lowers mechanical strength and increases water absorption.
- **Construction debris** is viable at low dosages (≤10%) but less efficient compared to other alternatives.

This study demonstrates the feasibility of enhancing porotherm bricks with waste materials such as fly as, plastic waste, rice husk and construction demolition debris.

The findings suggests that porotherm bricks with integrated waste materials can serve as a sustainable alternative to conventional building materials, contributing to more eco-friendly construction practices. Future research could focus on optimizing waste material ratios and exploring additional waste materials for brick production.