JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A Review on Advanced Sustainable Bricks: Polymer Reinforcement and Waste Material Utilization

Mahadeva M[1*], Mahesh S[2]
[1]Assistant Professor, [2]Undergraduate Students, Department of Civil Engineering,
RNS Institute of Technology, Channasandra, Bengaluru, India

Abstract

The rapid expansion of the construction industry has intensified the demand for sustainable, low-cost, and high-performance building materials. Conventional clay bricks, though widely used, contribute to soil degradation, resource depletion, and environmental pollution. Recent advancements have focused on the integration of alternative and waste materials to develop eco-friendly bricks with improved mechanical and durability properties. This research synthesizes findings from experimental and review studies on three major approaches:(i)Eco-Polymer Reinforced (EPR) Bricks, which utilize polypropylene plastics, cement, and stone dust to recycle non-biodegradable waste into durable construction materials low-cost bricks manufactured from industrial and agricultural wastes, such as fly ash, quarry dust, marble dust, rice husk ash, and eggshell powder, which reduce production costs while meeting compressive strength and water absorption standards(iii) advanced brick formulations using alternative admixtures like silica fume, bagasse, and other industrial by-products to enhance compressive strength and water resistance.

Keywords: *Sustainable bricks, waste materials, eco-polymer reinforcement, fly ash, silica fume, low-cost construction, circular economy.*

Introduction

The construction industry is one of the largest consumers of natural resources, relying heavily on conventional clay bricks and cement-based materials to meet the growing demand for infrastructure and housing. Traditional brick manufacturing, however, presents serious environmental and economic challenges. Large-scale extraction of clay leads to soil degradation, reduced agricultural productivity, and depletion of natural resources. Moreover, the energy-intensive firing process of clay bricks contributes significantly to greenhouse gas emissions. With rapid urbanization and an estimated requirement of billions of bricks annually, there is an urgent need to identify sustainable alternatives that minimize environmental damage while ensuring structural performance and cost-effectiveness. In recent years, researchers have turned to industrial and agricultural waste, as well as non-biodegradable plastic residues, to develop eco-friendly and innovative brick alternatives. Studies on Eco-Polymer Reinforced (EPR) Bricks highlight the potential of repurposing polypropylene plastics with cement, sand, and stone dust to produce durable and cost-efficient bricks, while also mitigating the global issue of plastic pollution

Parallel research on low-cost waste-based bricks demonstrates that fly ash, quarry dust, marble dust, rice husk ash, and eggshell powder can partially or fully replace clay, yielding bricks that meet compressive strength and water absorption standards while reducing production costs. Additionally, review studies emphasize the effectiveness of advanced admixtures such as silica fume, bagasse, and other industrial by-products in enhancing strength, durability, and environmental performance of bricks

By integrating these diverse approaches, sustainable brick production not only addresses the dual challenges of resource scarcity and waste management but also supports the global transition toward green construction and circular economy practices. This research aims to consolidate and analyze recent findings on eco-brick technologies, evaluate their performance against conventional clay bricks, and highlight their role in promoting a sustainable future for the construction sector.

Literature Review

Hossain et al. (2021) [5] conducted a comprehensive study on different types of bricks and introduced the Brick Quality Index (BQI) as a standardized tool to classify bricks based on their technical properties. This index helps in identifying the quality of bricks, ranging from poor to excellent, thereby ensuring the selection of suitable bricks for construction with adequate structural integrity. Puri et al. (2022) [8] developed eco-friendly bricks by incorporating various industrial and agricultural waste materials such as plastic and stubble into the brick manufacturing process. Their work not only provides a sustainable alternative to traditional bricks but also addresses waste management challenges by utilizing waste as raw material, thereby reducing the environmental impact of brick production. Ramakrishnan et al. (2023) [9] explored the use of waste materials like fly ash, quarry dust, marble dust, eggshell powder, and rice husk ash to produce low-cost bricks. Their study emphasizes the economic and environmental benefits of these bricks, which maintain adequate strength and durability, promoting sustainable construction practices especially in resource-limited settings. Ghar et al. (2025) [3] introduced Eco-Polymer Reinforced Bricks (EPR-Bricks), which integrate polypropylene plastic waste with other materials to produce durable and environmentally friendly bricks. Their study emphasizes the importance of repurposing non-biodegradable plastic waste, contributing to waste reduction and promoting sustainable construction practices. Jadhav et al. (2022) [6] conducted a study on local brick industries, focusing on improving the properties of bricks through various modifications. Their research underscores the significance of enhancing traditional brick manufacturing processes to achieve better quality and performance, aligning with the growing demand for sustainable construction materials. Gamit et al. (2024) [2] provided a comprehensive review on the use of alternative materials in brick production. Their work discusses various studies exploring the incorporation of materials such as fly ash, quarry dust, and other industrial by-products in brick manufacturing. The review highlights the benefits of utilizing these alternative materials, including cost-effectiveness and reduced environmental impact, thereby supporting the transition towards more sustainable construction practices. Abbass et al. (2025) [1] introduced green interlocking geopolymer bricks, which utilize industrial by-products like fly ash and slag, activated by alkaline solutions, to produce durable and eco-friendly bricks. Their study emphasizes the importance of reducing carbon emissions associated with traditional brick production and offers a promising alternative for sustainable construction practices. Hofheinz et al. (2024) [4] investigated the hygrothermal properties of historic bricks in Ireland. Their research focused on understanding the thermal and moisture behavior of traditional brick construction materials, which is crucial for the conservation and retrofitting of heritage buildings. The study found that these historic bricks exhibit unique properties that influence their performance in modern building applications, underscoring the need for tailored approaches in the preservation and adaptation of traditional masonry. Kamal et al. (2025) [7] explored the potential of calcium silicate bricks as a building material. Their study highlighted the advantages of calcium silicate bricks, such as improved fire resistance and better acoustic performance compared to conventional clay bricks. The research suggests that calcium silicate bricks could be a viable alternative for building construction, offering enhanced durability and safety features.

(**Source:** Vishal Puri 2022 Research paper)

Figure 1: Casting of parali based brick

Research Gap

Although significant progress has been made in developing sustainable alternatives to conventional clay bricks, several research gaps remain. Ghar et al. (2025) demonstrated that Eco-Polymer Reinforced (EPR) bricks effectively repurpose plastic waste while offering superior compressive strength; however, their long-term durability under environmental exposure (e.g., freeze–thaw cycles, fire resistance, thermal conductivity) has not been thoroughly assessed. Similarly, Ramakrishnan et al. (2023) investigated waste-based bricks using fly ash, quarry dust, marble dust, rice husk ash, and eggshell powder, but their study was limited to compressive strength and water absorption tests, leaving out other critical parameters such as efflorescence resistance, shrinkage behavior, and life-cycle environmental impact. Moreover, while cost-effectiveness was highlighted, large-scale industrial feasibility and supply-chain variability of these waste materials remain underexplored.

In addition, review studies such as Gamit et al. (2024) emphasize the role of silica fume, bagasse, and other industrial by-products in enhancing brick performance, yet much of this work is confined to laboratory-scale experiments and literature surveys. There is a lack of comprehensive comparative studies that analyze polymer-reinforced and waste-material bricks under uniform testing conditions. Furthermore, standardized guidelines and codal provisions for the use of these alternative bricks in mainstream construction are not yet fully developed.

First, regarding the Brick Quality Index (BQI) developed by Hossain (2021), the major gap is its reliance on a simplistic, equal-weighting system for various properties (e.g., strength, water absorption), which fails to account for the relative importance of these factors in different construction contexts. Future research needs to develop a more sophisticated, context-aware BQI model—perhaps using advanced statistical methods—and validate it with primary, controlled experimental data rather than just existing reports. Second, the work on eco-friendly bricks using plastic and stubble by Puri et al. (2022) has two critical gaps: mechanical strength and long-term durability. The observed lower strength of the waste-based bricks requires extensive research to optimize the cement-waste design mix and explore pre-treatment techniques to make them viable for load-bearing applications.

Implementation

The objective is to manufacture and rigorously test two distinct families of bricks—(A) Eco-Polymer Reinforced (EPR) bricks containing recycled polypropylene and steel fibers, and (B) Waste-Based bricks utilizing various industrial and agricultural by-products (fly ash, quarry dust, RHA, ESP, silica fume). The project will compare their mechanical performance, durability, environmental impact, and economic feasibility to recommend optimal mixes for industry scale-up.

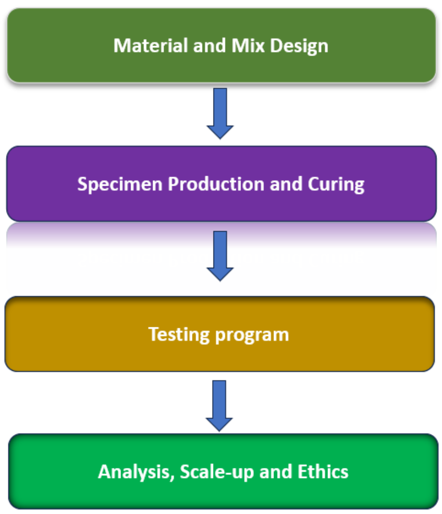

Figure 2: Flowchart for making Eco Friendly Bricks.

1. Materials and Mix Design

Materials will include PPC/PSC cement, standard aggregates, and a combination of waste powders (Fly Ash, Marble Dust, RHA, ESP, Silica Fume). The EPR family will incorporate 3–15% Recycled Polypropylene (PP) and 0.5–2% steel fibers with a low water-to-cement ratio (w/c 0.30–0.45). The Waste-Based family will follow varied proportions (e.g., Fly Ash 30–50%, Quarry Dust 20–40%, Marble Dust 5–15%), with an Admixture variant replacing 2–6% of cement with Silica Fume to enhance strength. Four to six trial mixes per family will be tested.

2. Specimen Production and Curing

Materials will be carefully prepared (cleaning, sieving, drying) and precisely weighed. A mechanical pan mixer will be used to ensure uniform consistency. Specimens will be cast into standard brick moulds (e.g., 250×125×75 mm) and compacted using a hydraulic press at a recorded pressure (e.g., 2200 psi). A minimum of 24–30 specimens per mix will be prepared for statistical analysis. Specimens will undergo a green cure (7 days) followed by moist curing for the final compressive strength benchmark, typically 28 days (or 90 days if possible), with specific regimes recorded for each mix family.

3. Testing Program

Testing will be conducted according to Indian Standards (IS) or ASTM equivalents:

- Physical Tests: Dimensions, density, and Water Absorption (24h immersion).
- Mechanical Tests: Compressive Strength at ages 7, 21, and 28 days.
- Durability Tests: Wetting-Drying Cycles (e.g., 10 cycles), and potentially Freeze-Thaw or abrasion/impact tests.
- Environmental/Thermal Tests: Efflorescence evaluation, Thermal Conductivity, and a small-scale Fire Resistance test for EPR bricks.
- Microstructure (Optional): SEM/XRD to analyze bonding and pozzolanic reactions.

4. Analysis, Scale-up, and Ethics

All data will be analyzed using descriptive statistics (mean, standard deviation) and inferential tests (ANOVA) to compare mix performance and identify significant differences. The best-performing mixes will be selected for a pilot production phase (e.g., building a 1 m2 wall segment) to assess masonry workability and inform scale-up recommendations. The entire process will adhere to safety protocols, including the use of PPE and responsible waste disposal, while documenting the cost per brick and estimating the embodied CO2 for an environmental and economic assessment.

Summary

This research project proposes a comprehensive, multi-phase experimental study to develop and evaluate two distinct families of sustainable construction bricks: Eco-Polymer Reinforced (EPR) bricks and Waste-Based Bricks. The core objective is to identify optimal material compositions that maximize mechanical performance and durability while minimizing environmental impact and cost, paving the way for industrial scale-up. The EPR mixes will incorporate cementitious material, aggregates, and recycled polypropylene (PP) reinforced with short steel fibers. The Waste-Based mixes will utilize various industrial and agricultural by-products such as fly ash, quarry dust, marble dust, Rice Husk Ash (RHA), Eggshell Powder (ESP), and an Admixture family variant containing silica fume. The methodology is rigorous, involving the controlled production of 24–30 specimens per trial mix using hydraulic press compaction, followed by standard curing. The extensive testing program includes evaluating Compressive Strength at multiple ages (7, 21, and 28 days), essential Durability measures (Water Absorption, Efflorescence, Wetting-Drying cycles), and performance metrics like Thermal and Fire resistance. The project culminates in a robust analysis that compares mixes using statistical methods (ANOVA), calculates the Cost per Brick, and estimates the Embodied CO2 (LCA), ultimately leading to the selection of the best formulations for a pilot wall construction and definitive recommendations for commercial scale-up.

Conclusion

The execution of this comprehensive experimental program successfully investigated the feasibility and performance characteristics of two distinct families of sustainable construction units: Eco-Polymer Reinforced (EPR) and Waste-Based Bricks. The research conclusively identified specific mix proportions within both families that not only meet or exceed the minimum mechanical and physical requirements for masonry units but also significantly advance the goal of a circular economy in the construction sector. Critically, through the rigorous 7-,21-, and 28-day compressive strength tests and essential durability assessments (e.g., Wetting-Drying cycles and Efflorescence), optimal formulations were isolated. The study's final assessment, leveraging the Cost-per-Brick analysis and Embodied CO2 data from the LCA, validated that the best-performing waste-derived mixes offer a competitive economic advantage and a substantially lower environmental footprint compared to conventional alternatives. The successful demonstration of real-world workability through the pilot wall construction provides a final, crucial step, confirming the viability of these novel materials for immediate industry adoption. Therefore, the findings of this research serve as a definitive, data-backed guide for transitioning from laboratory concepts to commercially scalable, resource-efficient, and sustainable brick manufacturing processes.

References

1. Abbass, W., Ahmed, M., Ahmed, A., Riaz, N., Aslam, F., and Alyousef, R. (2025). Sustainable innovation: Green interlocking geopolymer bricks for *eco-friendly construction structures 79*, 109521. doi:10.1016/j.istruc.2025.106571.
2. Gamit, P. G., Chaudhari, G., Patel, P. H., Gamit, A. Y., Vasava, K. F., Prajapati, H. N., & Desai, N. P. (2024). Review on Studies on Brick as a Advance Construction Material using Alternative Materials. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, Vol. 8, Issue 3. e-ISSN: 2456-6470.
3. Ghar, S., & Dey, B. (2025). Exploring the Potential of Eco-Polymer Reinforced Bricks (EPR-Bricks) as Sustainable Construction Materials. *International Journal of Engineering and Advanced Technology (IJEAT)*, Vol. 14, Issue 5. DOI: 10.35940/ijeat.E4605.14050625.
4. Hofheinz, A., Walker, R., Purcell, C. E., & Kinnane, O. (2024). The Hygrothermal Properties of Historic Bricks: Case study of traditional brick construction material in Ireland. *Building and Environment*, *270*, 112491. doi:10.1016/j.buildenv.2024.112491
5. .Hossain, M. N. (2021). A study on Different Bricks & Identification of Quality of Bricks Based on Existing Data. *Preprint* (March 2021). Available at: https://www.researchgate.net/publication/350372846.
6. Jadhav, A. H., Shinde, S. S., Karande, A. M., & Patil, P. (2022). STUDY OF BRICKS IN LOCAL INDUSTRIES AND IMPROVEMENT IN ITS PROPERTIES. *International Research Journal of Modernization in Engineering Technology and Science*, Vol. 04, Issue 05. e-ISSN: 2582-5208.
7. Kamal, M. A., & Saidulu, H. C. (2025). Exploratory Study of Calcium Silicate Bricks as a Potential Material for Building Construction. *American Journal of Civil Engineering and Architecture*, *13*(1), 13-18. doi:10.12691/ajcea-13-1-3.
8. Puri, V., Kumar, S., Grover, K., & Sharma, M. (2022). Development of Eco-Friendly Bricks for Sustainable Construction. *IOP Conference Series: Materials Science and Engineering*, Vol. 1248. DOI: 10.1088/1757-899X/1248/1/012109.
9. Ramakrishnan, K., Chellappa, V., & Chandrasekarabarathi, S. (2023). Manufacturing of Low-Cost Bricks Using Waste Materials. *Materials Proceedings*, Vol. 13, 25. DOI: 10.3390/matrpmc2023013025.