NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 12, ISSUE 4, April – 2026

PERFORMANCE ANALYSIS AND ENVIRONMENTAL IMPACT OF WASTE PLASTIC-SAND COMPOSITES: A REVIEW

Mr.Durvesh Vibhte [1],
Mr.Siddhraj Pawar [2],
Ritesh Suryawanshi[3],
Rutuja Kale [4],
Mr. Shubham Patil 5,
Dr.Amol Yadav [6]
[1]durveshvibhute2004@gmail.com,[2]siddhupawar4900@gmail.com,[3]riitesh.50@gmail.com,[4]rutujakale177@gmail.com,[5]Patilshubham0105@gmail.com,[6] amolyadav@jspmjscoe.edu.in JPSM's
Jaywantrao Sawant College of Engineering , Hadapsar ,Pune -028
Department og Mechamical Engineering

Abstract

The rapid escalation of non-biodegradable plastic waste, particularly High-Density Polyethylene (HDPE), Polypropylene (PP), and Polyethylene Terephthalate (PET), has emerged as a critical global environmental challenge, contributing to soil infertility and marine pollution. Concurrently, the construction industry faces a depletion of natural resources like river sand and clay. This review paper investigates the feasibility of waste plastic-sand composites as a sustainable alternative to conventional masonry units. By synthesizing experimental data from various studies, this paper analyzes the mechanical and physical properties of bricks manufactured through thermal-mechanical processes using varied plastic-to-sand ratios (ranging from 1:1 to 1:4). Key performance indicators such as compressive strength, water absorption, and fire resistance are evaluated. Findings consistently demonstrate that plastic-sand bricks exhibit significantly lower water absorption (often <1%) and comparable or superior compressive strength (up to 25 MPa) relative to traditional clay bricks. Furthermore, this review explores advanced characterization through software-based stress analysis (ANSYS) and the environmental benefits of diverting plastic from landfills into the circular economy. The study concludes that while these composites offer a high-strength, lightweight, and cost-effective solution for structural and non-structural applications, further research into fire retardancy and long-term UV degradation is essential for widespread industrial adoption.

Keywords: Plastic Waste, Sustainable Construction, Compressive Strength, Circular Economy, Plastic-Sand Bricks, Performance Analysis.

1.Introduction:

The rapid industrialization and shifting consumption patterns of the 21st century have led to a staggering increase in the generation of non-biodegradable waste. Among these, plastic waste—specifically High-Density Polyethylene (HDPE), Polypropylene (PP), and Polyethylene Terephthalate (PET)—presents one of the most significant environmental threats to modern society [4], [6]. Due to its chemical stability, plastic can persist in the environment for hundreds of years, leading to soil degradation, clogging of urban drainage systems, and catastrophic impacts on marine ecosystems [4].

Currently, conventional disposal methods such as landfilling and incineration are increasingly viewed as unsustainable due to land scarcity and the emission of toxic greenhouse gases.

Simultaneously, the global construction industry is grappling with the depletion of natural resources. The manufacturing of traditional burnt clay bricks requires the excavation of fertile topsoil and consumes vast amounts of energy during the kiln-firing process, which releases significant carbon dioxide into the atmosphere [7]. There is, therefore, an urgent need for "green" building materials that can reduce the environmental footprint of the construction sector while providing a viable secondary life for waste polymers.

The development of waste plastic-sand composites has emerged as a promising solution within the framework of a circular economy [6]. By utilizing molten plastic as a binder and sand or industrial by-products as aggregates, it is possible to produce masonry units that do not require water for curing or high-temperature firing. Recent experimental investigations have suggested that these composites can achieve compressive strengths comparable to, or even exceeding, those of traditional first-class clay bricks [3], [5]. Furthermore, the inherent hydrophobic nature of polymers grants these bricks near-zero water absorption, offering a distinct advantage in damp-proofing and durability [8].

This review paper provides a comprehensive analysis of the performance and environmental impact of waste plastic-sand composites. It synthesizes findings from current literature regarding manufacturing methodologies, mechanical performance across different mix ratios, and structural stability verified through software-based simulations [2]. By identifying existing research gaps and comparing experimental outcomes, this study aims to evaluate the feasibility of plastic-sand bricks as a mainstream, sustainable alternative in the modern construction landscape.

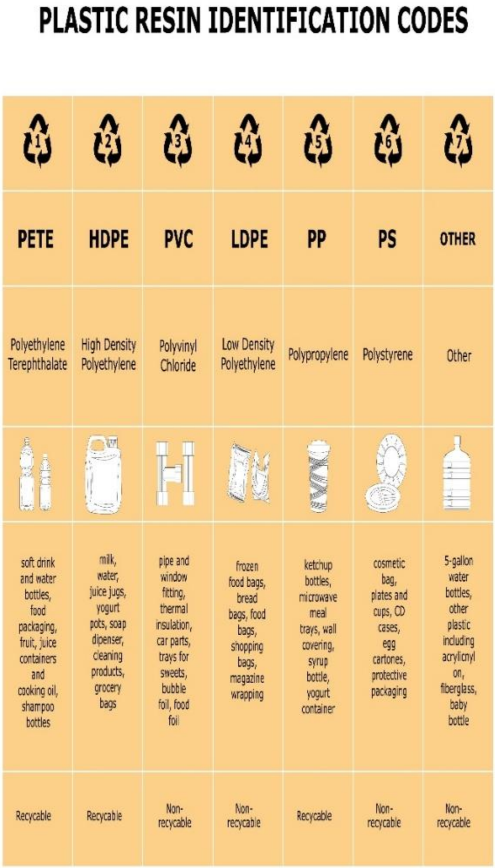
2. Materials and Their Properties:

The production of plastic-sand bricks involves two primary components: a polymer binder and a mineral aggregate. The interaction between these materials determines the final density, thermal stability, and load-bearing capacity of the brick.

2.1. Waste Plastic (The Binder)

The reference literature identifies several types of thermoplastic waste used as a binding agent. Unlike thermosetting plastics, these can be repeatedly melted and reshaped, making them ideal for brick manufacturing.

- **Polyethylene (PE):** High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) are the most common binders cited. HDPE, found in milk jugs and detergent bottles, provides high strength and a melting point of approximately 130°C–170°C [4], [8].
- **Polypropylene (PP):** Used in bottle caps and food containers, PP is noted for its higher melting point (approx. 160°C–170°C) and superior chemical resistance [8].
- **Polyethylene Terephthalate (PET):** Common in water and soda bottles, PET has a high melting point (approx. 250°C–260°C). While it offers excellent tensile strength, it requires more energy to process [4].



PLASTIC RESIN IDENTIFICATION CODES

1	2	3	4	5	6	7
PETE	HDPE	PVC	LDPE	PP	PS	OTHER
Polyethylene Terephthalate	High Density Polyethylene	Polyvinyl Chloride	Low Density Polyethylene	Polypropylene	Polystyrene	Other
soft drink and water bottles, food packaging, fruit, juice containers and cooking oil, shampoo bottles	milk, water, juice jugs, yogurt pots, soap dipenser, cleaning products, grocery bags	pipe and window fitting, thermal insulation, car parts, trays for sweets, bubble foil, food foil	frozen food bags, bread bags, food bags, shopping bags, magazine wrapping	ketchup bottles, microwave meal trays, wall covering, syrup bottle, yogurt container	cosmetic bag, plates and cups, CD cases, egg cartones, protective packaging	5-gallon water bottles, other plastic including acrylicnyl on, fiberglass, baby bottle
Recycable	Recycable	Non-recycable	Non-recycable	Recycable	Non-recycable	Non-recycable

Table: Plastic resin codes[4]

2.2. Aggregates (The Filler)

Aggregates provide the structural "skeleton" of the brick, while the plastic fills the voids to bind the particles together.

- **River Sand:** Traditionally used due to its availability, though environmental regulations are limiting its extraction. It provides a smooth finish and consistent bonding [3].
- **Manufactured Sand (M-Sand):** A common alternative to river sand, M-Sand is used in several studies to ensure a consistent grain size distribution, which is critical for reducing voids in the composite [5].
- **Glass Powder:** A notable variation found in the literature involves the partial replacement of M-Sand with crushed glass powder. Studies indicate that adding glass powder (10% to 40%) can enhance the aesthetic finish and potentially improve compressive strength due to the pozzolanic properties of glass [5].

2.3. Chemical and Physical Properties

The synergy between these materials results in a composite with unique properties:

- **Hydrophobicity:** Because plastic is naturally water-repellent, the resulting bricks show near-zero water absorption, preventing issues like efflorescence (white salt deposits) seen in clay bricks [8].
- **Thermal Stability:** The materials must be processed below their degradation temperatures to avoid the release of toxic fumes.

- **Adhesion:** The strength of the brick is highly dependent on the "Plastic to Sand" ratio. If plastic content is too low, the sand particles will not be fully coated; if too high, the brick may become overly ductile and prone to deformation under heat [3].

3.Manufacturing Methodology:

he production process is generally categorized into five sequential stages, as synthesized from the experimental setups in the literature.

3.1. Waste Collection and Pre-processing

The first step involves sourcing waste plastic (HDPE, LDPE, PP, or PET). As noted in **[7]** the plastic must be thoroughly cleaned to remove organic contaminants, oils, or food residues that could weaken the bond between the polymer and the sand. Once cleaned, the plastic is shredded into small flakes or granules (approximately 2mm to 5mm) to ensure uniform melting.

3.2. Heating and Melting (Thermal Treatment)

The shredded plastic is placed in a metal container or a specialized heating furnace. The heating temperature is a critical variable:

- For **LDPE/HDPE**, the temperature is maintained between **150°C and 200°C** [**8**].
- For **PET**, the temperature must reach above **250°C** [**4**].

The plastic is heated until it reaches a semi-liquid or molten state. Continuous stirring is required to prevent the polymer from burning or undergoing thermal degradation, which would release toxic fumes and reduce the brick's strength.

I. 4.3. Mixing with Aggregates

Once the plastic is molten, the aggregate (River Sand, M-Sand, or Glass Powder) is added. Most studies, including **[3]** and **[5]**, test various "Plastic to Sand" ratios, such as **1:1, 1:2, 1:3, and 1:4** by weight.

- **LR5** highlights a specific variation where **Glass Powder** is introduced as a partial replacement for sand (10%–40%) during this mixing phase to study its impact on the composite's density and finish.

The mixture is stirred vigorously until every sand particle is thoroughly coated with the molten polymer binder.

II. 4.4. Molding and Compaction

The hot, viscous mixture is quickly transferred into steel or cast-iron molds of standard brick dimensions (typically $190 \times 90 \times 90$ mm).

- **Compaction:** Pressure is applied either manually or using a hydraulic press to eliminate air voids. As identified in **[1]**, proper compaction is essential to achieve high compressive strength and low porosity.
- **Surface Finishing:** The top surface is leveled to ensure the brick meets dimensional tolerances.

III.4.5. Cooling and Demolding

The molds are allowed to cool at room temperature for approximately 24 hours. Because the plastic acts as a solidifying binder upon cooling, these bricks do not require the 28-day water curing period necessary for cement-based bricks, nor the 48-hour kiln firing required for clay bricks [**7**]. Once solidified, the bricks are removed from the molds and are ready for testing or application.

4. Performance Analysis:

The performance of plastic-sand bricks is evaluated through a series of mechanical and physical tests, often compared against the standards set for traditional burnt clay bricks (such as IS 3495).

• 4.1. Compressive Strength

Compressive strength is the primary indicator of a brick's structural viability. The literature suggests that the strength is highly sensitive to the **Plastic:Sand ratio**.

- **Optimal Ratios:** Studies by **Sahani et al. [3]** and **Nayak et al. [4]** indicate that a ratio of **1:3 or 1:4** generally yields the highest compressive strength, often exceeding 20 MPa.
- **Effect of Plastic Content:** Increasing the plastic content (e.g., a 1:1 ratio) can make the brick more ductile and less capable of bearing heavy loads. Conversely, too little plastic results in poor bonding and brittle failure.
- **Additive Impact: Aleena et al. [5]**found that replacing a portion of M-sand with **Glass Powder** (up to 20%) can further enhance compressive strength by reducing the void ratio within the composite.

• 4.2. Water Absorption

This is where plastic-sand bricks significantly outperform traditional bricks.

- **Results:** While conventional clay bricks have a water absorption rate of **15% to 20%**, the plastic-sand bricks reviewed in **[8** [8]and **[7]** show absorption rates as low as **0.11% to 0.5%**.
- **Technical Advantage:** This near-zero absorption prevents the common issue of **efflorescence** (salt deposits) and protects the internal structure from moisture-related degradation, making them ideal for high-humidity or water-logged areas.

• 4.3. Weight and Density

- **Lightweight Nature:** Plastic-sand bricks are consistently reported to be **15% to 30% lighter** than traditional bricks.
- **Impact on Construction:** As highlighted in the review by **Al-Sinan & Bubshait [6]**, the lower density reduces the "dead load" on a building’s foundation, potentially lowering the overall structural cost of the project.

• 4.4. Software-Based Stress Analysis

A unique contribution to this performance analysis comes from **Kamble & Pol [2]**, who utilized **ANSYS and ETABS** to simulate the behavior of these bricks.

- **Findings:** The simulations demonstrated that a G+2 (Ground + 2 floors) residential structure built with plastic-sand bricks maintains structural integrity under standard loading conditions.

- **Stress Distribution:** The software analysis showed that the stress distribution in a plastic-sand brick wall is uniform, confirming that the material behaves predictably as a structural unit.

Table.4.1 average findings across the reviewed literature

Property	Plastic-Sand Bricks	Conventional Clay Bricks	Reference Source
Compressive Strength	5.0 – 25.0 MPa	3.5 – 10.5 MPa	[1,2,3]
Water Absorption	0.1% – 1.5%	12% – 20%	[7,8]
Efflorescence	Nil	Slight to Heavy	[7]
Weight	1.8 – 2.5 kg	3.0 – 3.5 kg	[6]
Software Verification	Verified (ANSYS/ETABS)	Not Applicable	[2]

5. Environmental and Economic Impact:

The integration of waste plastic into masonry units offers a dual-benefit strategy: it addresses the global plastic waste crisis while providing a cost-effective alternative to traditional construction materials.

5.1. Environmental Benefits and Sustainability

- **Waste Diversion and Landfill Reduction:** As highlighted in **[6]l**, the primary environmental driver is the diversion of non-biodegradable polymers (HDPE, LDPE, PP) from landfills and oceans. By "locking" plastic into a solid composite, the risk of microplastic shedding into the soil and water is significantly mitigated.
- **Conservation of Natural Resources:** Traditional brick manufacturing relies heavily on the excavation of fertile topsoil (clay) and the extraction of river sand. Using waste plastic as a binder reduces the demand for these finite natural resources, preserving biodiversity and agricultural land [7].
- **Reduced Carbon Footprint:** Unlike conventional bricks that require high-temperature kiln firing (up to 1000°C), plastic-sand bricks are produced at much lower temperatures (150°C–270°C). This process eliminates the massive carbon dioxide emissions associated with coal-fired kilns and does not require water for curing, leading to significant energy and water savings [7], [8].

5.2. Economic Analysis

- **Raw Material Cost:** The primary raw material—waste plastic—is often available at a negligible cost or can even generate revenue through waste management partnerships. Studies in **[1]** and **[4]** indicate that the overall material cost per brick is substantially lower than that of cement or clay bricks.
- **Lightweight Advantages:** Because these bricks are roughly **20–30% lighter** than traditional units, they reduce transportation costs. Furthermore, as noted in the structural analysis in**[2]**, the reduced dead load on a building’s frame can lead to smaller foundation sizes, resulting in secondary savings in steel and concrete.
- **Zero Curing and Firing Costs:** The elimination of the 28-day water curing period and the expensive kiln-firing stage accelerates the production cycle, allowing for faster ROI (Return on Investment) for manufacturers.

5.3. Contribution to the Circular Economy

The transition from a "take-make-dispose" model to a circular economy is a central theme in recent literature [6] Plastic-sand bricks represent a "closed-loop" system where post-consumer waste is repurposed into long-term infrastructure. This not only provides an economic incentive for waste pickers and recycling industries but also aligns with global Sustainable Development Goals (SDGs) regarding responsible consumption and production.

6. Conclusion:

The synthesis of research from the reviewed literature confirms that waste plastic-sand composites are a technically viable, economically superior, and environmentally sustainable alternative to traditional burnt clay bricks. By utilizing non-biodegradable polymers—such as HDPE, LDPE, and PP—as a binding agent, the construction industry can play a pivotal role in the global circular economy, effectively "locking" hazardous plastic waste into durable infrastructure.

The performance analysis demonstrates that these bricks possess a unique set of engineering advantages:

- **Mechanical Strength:** With compressive strengths reaching up to 25 MPa, these composites comfortably exceed the requirements for first-class masonry units and are suitable for structural applications in low-rise buildings.
- **Durability:** The near-zero water absorption (typically <1%) provides an inherent immunity to efflorescence and moisture-related decay, a significant improvement over porous clay alternatives.
- **Structural Efficiency:** The lightweight nature of the bricks (reduced by approx. 20–30%) allows for a reduction in the dead load of structures, leading to secondary savings in foundation design and steel reinforcement.
- **Sustainability:** The manufacturing process eliminates the carbon-intensive kiln-firing stage and requires no water for curing, significantly reducing the ecological footprint of brick production.

However, for these composites to achieve widespread industrial adoption, certain challenges must be addressed. Future research should prioritize the development of standardized building codes and long-term studies on UV degradation and fire retardancy. The inclusion of additives like glass powder or fire-resistant coatings could further bridge the gap between experimental prototypes and commercial-scale implementation. Ultimately, transitioning to plastic-sand bricks offers a transformative opportunity to reconcile urban infrastructure development with environmental preservation.

Referances

[1] S. S. Chauhan, B. Kumar, P. S. Singh, A. Khan, H. Goyal, and S. Goyal, "Fabrication and Testing of Plastic Sand Bricks," IOP Conference Series: Materials Science and Engineering, vol. 691, p. 012083, 2019. doi: 10.1088/1757-899X/691/1/012083.

[2] H. D. Kamble and C. B. Pol, "Performance Analysis of Plastic Bricks for Structural Applications: A Combined Experimental and Software-based Investigation," International Research Journal of Engineering and Technology (IRJET), vol. 10, no. 7, pp. 729-735, July 2023.

[3] K. Sahani, B. R. Joshi, K. Khatri, A. T. Magar, S. Chapagain, and N. Karmacharya, "Mechanical Properties of Plastic Sand Brick Containing Plastic Waste," Advances in Civil Engineering, vol. 2022, Art. no. 8305670, 2022. doi: 10.1155/2022/8305670.

[4] S. Nayak, P. Senapati, S. Mohanty, and S. S. Nayak, "An experimental study of plastic bricks made from waste plastics," World Journal of Advanced Engineering Technology and Sciences, vol. 15, no. 1, pp. 973-978, 2025. doi: 10.30574/wjaets.2025.15.1.0265.
[5] J. K. Aleena, Sumaiha S, A. J. Aswathy, and Sarath S, "An Experimental Study on Partial Replacement of M-Sand with Glass Powder in Plastic Sand Bricks," International Journal of Research and Analytical Reviews (IJRAR), vol. 8, no. 1, March 2021.
[6] M. A. Al-Sinan and A. A. Bubshait, "Using Plastic Sand as a Construction Material toward a Circular Economy: A Review," Sustainability, vol. 14, no. 11, Art. no. 6446, May 2022. doi: 10.3390/su14116446.
[7] S. V. Biradar, A. S. Kumar, T. V. Gowri, and S. S. Alisha, "Comparative Study on Properties of Plastic Bricks with Conventional Bricks," Journal of Physics: Conference Series, vol. 2779, p. 012088, 2024. doi: 10.1088/1742-6596/2779/1/012088.
[8] G. N. Patil, M. al Yahmedi, S. M. Walke, and L. N. Rao, "Manufacturing of plastic sand bricks from polypropylene and polyethylene waste plastic," International Journal of Advanced Science and Technology, vol. 29, no. 8, pp. 2062-2068, 2020.