DEVELOPMENT OF ECO BRICKS USING PLASTIC WASTE AND RECYCLED CONSTRUCTION MATERIALS AS SAND

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Abstract - This project is all about creating eco-bricks from plastic waste and recycled construction materials like crushed concrete and sand. The research dives into how we can use plastic waste and crushed bricks from demolished buildings as sustainable alternatives to the usual building materials. By looking at the physical properties of these eco-bricks, the study showcases their strength, durability, and the positive impact they have on the environment. The goal is to lessen the environmental footprint of plastic waste and construction debris while providing a cost-effective and sustainable building option. The findings reveal that using recycled materials in brick production not only tackles the waste disposal problem but also helps reduce the need for natural resources, supporting circular economy practices. Additionally, the study assesses the economic viability of producing eco-bricks, taking into account material costs, energy needs, and potential market demand. Overall, it shows that developing eco-bricks from plastic waste and recycled materials can play a significant role in promoting sustainable construction practices.

Key Words: Eco-bricks, Plastic Waste Recycling, Recycled Construction Materials, Sustainable Building Materials.

1.INTRODUCTION

For a construction material to be truly sustainable, it needs to have four essential qualities: it should be environmentally friendly, structurally sound, cost-effective, and easy to produce. While traditional bricks are known for their strength, they also play a big role in depleting resources, consuming energy, and emitting carbon. That's why eco-friendly alternatives are starting to catch people's attention, especially those that use waste materials. Eco bricks, made from plastic waste and recycled construction debris like crushed bricks and artificial sand, present a promising way to tackle these issues.

The modern construction industry is grappling with serious challenges like waste management, material shortages, and environmental damage. Plastic waste, which doesn't break down, piles up in landfills and oceans, creating significant environmental risks. At the same time, if demolished construction materials aren't reused, they just add to urban solid waste. By incorporating this waste into brick production, we have a chance to turn environmental problems into valuable resources.

This study is all about figuring out how swapping out natural sand for crushed construction debris and plastic waste impacts brick performance. We're looking at important factors like compressive strength, water absorption, density, and durability. Bricks face all sorts of physical and environmental challenges—think moisture, temperature changes, and weight—so what they're made of is super important for their long-term success.

Waste-based bricks are particularly significant in areas where plastic use and construction are on the rise. By redirecting plastic and demolition waste away from landfills and using them in building materials, we're promoting a circular economy. Plus, using these eco-friendly bricks in non-load-bearing roles, like pavements, partition walls, and rural housing, can really help lessen the environmental impact of construction projects.

While traditional bricks rely heavily on natural sand and clay, this study is diving into the possibilities of sustainable alternatives that don't sacrifice key engineering qualities. Successfully creating these eco bricks could lead to greener infrastructure, lower material costs, and better waste management—making it a vital move toward sustainable development in our built environment.

2. LITERATUR REVIEW

Dinesh S. and colleagues [1] took a closer look at how we can use waste plastic to make bricks and paver blocks. Their research laid out the specific mix ratios and casting methods for creating these plastic-infused bricks, highlighting how this approach not only reduces water absorption but also boosts strength. They pointed out that waste plastic serves as a binding agent and enhances the thermal resistance of the bricks, making it a promising alternative to traditional clay bricks.

Nitin Goyal and Manisha [2] delved into the use of eco-bricks in contemporary construction. Their findings stressed the importance of substituting natural resources with recyclable materials like plastic to develop sustainable and budget-friendly building units. Their experiments showed that these eco-bricks achieved acceptable compressive strength and lower water permeability, proving their practicality for low-cost housing and non-load-bearing structures.

Puttaraj M.H. and his team [3] carried out an in-depth experimental study on plastic-soil bricks by mixing waste plastic with different types of soil. They aimed to find the right balance of plastic content to maximize compressive strength while keeping water absorption low. The results suggested that bricks made from these plastic-soil blends could be ideal for pavement and partition wall uses, promoting environmental sustainability through effective waste management.

Sharma and Bansal [4] conducted a thorough assessment of how plastic waste can be utilized in brick manufacturing. Their research involved creating bricks with various proportions of plastic and evaluating their performance in terms of compressive strength and durability. The study confirmed that plastic bricks present a sustainable construction option, particularly in regions facing high plastic pollution and limited access to traditional raw materials.

Raut et al. [5] provided an extensive overview of bricks created from a variety of industrial and agricultural byproducts. Their research gathered insights on alternative building materials, including bricks made from fly ash, rice husk ash, and marble dust. The study concluded that using these waste materials not only lessens environmental harm but also improves the properties of bricks when designed with specific mixes.

Gnanavel and Saravanakumar [6] zeroed in on creating sustainable bricks from plastic waste. They explored the thermal properties, weight reduction, and compressive strength of these plastic bricks. Their findings indicated that these bricks are lightweight, offer excellent thermal insulation, and are ideal for non-structural uses, thus supporting the sustainable construction movement.

Kumar and Kaur [7] investigated eco-bricks made from plastic waste and foundry sand. Their research looked into how foundry sand can partially replace traditional aggregates. The results showed that these eco-bricks can achieve the necessary compressive strength while providing a sustainable way to reuse both plastic and foundry waste.

Khalid et al. [8] examined the use of recycled construction and demolition materials in brick production. Their study brought together previous research on waste-based bricks, emphasizing the mechanical and physical properties of bricks made from concrete rubble, ceramic waste, and plastic. The authors highlighted how these materials contribute to promoting circular economy practices in the construction sector.

Singh and Siddique [9] assessed the structural characteristics of bricks made from plastic waste and quarry dust. Their study focused on compressive strength, density, and water absorption across different mix ratios. The experimental results demonstrated that quarry dust improves the structural performance of plastic bricks, making them suitable for lightweight construction.

3. OBJECTIVES

1. To design and develop eco-bricks by partially or fully replacing natural sand with recycled construction materials such as demolished brick crush and artificial sand, along with plastic waste as a binding component.

2. To prepare multiple mix proportions by varying the content of plastic waste and recycled aggregates and cast the brick specimens accordingly.

3. To evaluate the physical and mechanical properties of the developed eco-bricks, including compressive strength, water absorption, density, and durability.

4. To compare the performance of eco-bricks with that of conventional clay bricks and cement-sand bricks based on standardized testing.

4.MATERIALS

4.1 Plastic Waste (Binding Agent):

Thermoplastic waste will be the main ingredient and binding agent in creating eco-bricks. This type of plastic was chosen because it can be recycled and makes up about 94% of the plastic waste in India. The process involves melting down the thermoplastic waste, which then wraps around and binds recycled construction materials—like crushed bricks and artificial sand—into a solid brick shape. By taking advantage of the unique properties of thermoplastics, these eco-bricks are expected to perform better, with less water absorption and greater compressive strength. To maintain consistency in production, we'll carefully identify and document the sources and specific types of thermoplastic waste, as illustrated in Figure 1.

Figure 1 Plastic waste collection

4.2 Recycled Construction Materials as Sand:

This research will delve into the potential of using recycled construction materials as an alternative to traditional sand. We'll take a closer look at specific types of recycled materials, like crushed concrete and demolition waste, focusing on their availability and how well they fit the bill. The goal here is to embrace the principles of a circular economy by making use of waste products in the construction sector, which can help lessen our environmental footprint and reduce reliance on natural resources (as illustrated in Figure 2).

Figure 2 Recycled Construction Materials

4. 3 Water:

Water may not be a part of the final brick itself, but it plays a crucial role in cleaning up plastic waste.

2.4 Equipment and Tools:

We're going to use some standard equipment and tools for brick manufacturing, which include:

A. A furnace (Bhatti) to melt down the plastic waste.
B. Molds to give the bricks their shape.

Figure 3 Furnace (Bhatti)

5. METHODOLOGY

This approach takes a thorough, step-by-step look at how to research and develop eco-bricks, ingeniously using plastic waste as a binding agent. What makes it unique is its use of recycled construction materials, providing a sustainable and durable alternative to traditional sand. The whole process dives deep into the properties of various materials, leading to the development of enhanced fabrication techniques. This is followed by rigorous performance testing and culminates in a comprehensive evaluation of both environmental and economic impacts. The ultimate aim is to create a genuinely viable and sustainable construction material for the future.

1st. Material Sourcing and Preparation:

- Collection and sorting of plastic waste; acquisition of recycled construction materials.
- Processing of plastic waste (cleaning, shredding) and recycled materials.
- Preparation of any additional binding agent, if required.

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2nd. Eco-Brick Manufacturing:

- Development of mix designs with varying material proportions.
- Mixing and homogenization of the materials.
- Molding and compaction of the mixture into brick shapes.
- Curing of the bricks.

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3rd. Performance Evaluation:

- Testing of physical properties (dimensions, water absorption, density).
- Testing of mechanical properties (compressive strength).
- Assessment of durability (weathering resistance).

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4th. Data Analysis and Optimization:

- Collection and statistical analysis of test data.
- Comparison with conventional brick properties.

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5th. Reporting and Future Work:

- Documentation of the methodology and findings.
- Recommendations for future research and applications.

5.1 Analysis and design:

This section dives into the analysis of materials, the proposed mix design, and the key design considerations for creating eco-bricks that use melted plastic waste as a binder and crushed recycled red brick as a substitute for sand. The process involves getting a good grasp of the raw materials' properties, figuring out the right mix proportions based on IS Code 2212 principles, designing a manual fabrication process with standard brick-sized molds, and outlining the quality control tests that will be carried out.

Material Analysis: Plastic Waste: The main binder for these eco-bricks is melted plastic waste. It's important to document the specific type(s) of plastic being used (like LDPE, HDPE, PP, or a mix). The analysis should cover:

Source and Collection: The plastic waste was collected through efforts aimed at roadsides, waste streams from hotels, and discarded materials from local markets in Pune, as illustrated in Figure 5. The collected plastic represents a post-consumer waste stream.

Figure 5 Source and Collection

Cleaning and Preparation: The plastic waste we collected went through a detailed cleaning and preparation process. First off, we drained any water from the plastic items. Then, we let the plastic bask in the sun for about 5 hours to help it dry out and maybe even kickstart some photodegradation, although that wasn't our main goal. After sun drying, we manually twisted the plastic bottles—our main type of collected plastic—to shrink their size before sending them into a furnace (Bhatti) for melting. Inside the furnace, the plastic transformed into a thick, gooey substance, as you can see in Figure 6.

Figure 6 furnace

Binder Properties: The melted mixed plastic binder, which is sourced locally and prepared by cleaning, sun-drying, and heating twisted bottles, plays a vital role in creating eco-bricks. Its hydrophobic qualities help keep water absorption to a minimum, while its adhesive and cohesive features effectively bind the crushed red brick aggregate. This results in a compressive strength that rivals that of traditional bricks. The binder's unique characteristics, shaped by the mixed polymer composition and the melting process, are essential for the final strength, durability, and overall properties of this sustainable building material.

Recycled Construction Materials Crushed Demolished Red Brick: The manually crushed red bricks from demolished sites serve as both fine aggregate and sand.

Source: This crushed red brick material comes from construction sites in Pune that have been demolished, providing a valuable source of recycled aggregate and helping to keep waste out of landfills.

5.2 Mix Design:

The mix design for the eco-bricks was developed through experimentation, targeting a weight ratio of about 1 part melted plastic waste to 4 parts crushed brick fine aggregate and 0.5 parts crushed brick sand. Although IS Code 2212: Code of Practice for Brickwork mainly focuses on clay bricks and their application in masonry, we took its core principles into account while fine-tuning these proportions to ensure we created structurally sound masonry units. Our aim was to find a blend that allowed the melted plastic to effectively bind with the crushed brick aggregate, resulting in a robust and long-lasting eco-brick. Each eco-brick weighs in at 2.280 kg, with the estimated weights of its components detailed in Table -1.

Table -1: Mix Design

Material	Estimated Weight per Brick (kg)	Estimated Percentage (%)
Melted Plastic Waste (Binder)	0.4145	18.20%
Crushed Brick (Fine Aggregate)	1.658	72.70%
Crushed Brick (Sand)	0.2073	9.10%
Total Weight per Brick	2.28	100.00%

This specific ratio made it easy to work with during manual molding, leading to eco-bricks that had enough initial strength for handling. We used a higher amount of crushed brick, which we sourced from demolished construction sites, to really make the most of recycled construction waste. The melted plastic serves as a matrix, holding everything together nicely.

Revised Mix Design Based on a 1:4:0.5 Ratio:
Here's how we break down the parts by weight:
• Plastic Waste: 1x
• Crushed Brick (Fine Aggregate): 4x
• Crushed Brick (Sand): 0.5x
• Adding these up gives us a total of 1 + 4 + 0.5 = 5.5 parts.

To find the weight of one part (x), we can do the math:
• x = Total Weight / Total Parts = 2.280 kg / 5.5 = 0.4145 kg

Now, let's figure out the approximate weight of each component:
• Melted Plastic Waste (1 part): 1 * 0.4145 kg = 0.4145 kg
• Crushed Brick (Fine Aggregate) (4 parts): 4 * 0.4145 kg = 1.658 kg
• Crushed Brick (Sand) (0.5 parts): 0.5 * 0.4145 kg = 0.2073 kg

Next, we'll calculate the percentage of each component:
• Melted Plastic Waste: (0.4145 kg / 2.280 kg) * 100% = 18.2%
• Crushed Brick (Fine Aggregate): (1.658 kg / 2.280 kg) * 100% = 72.7%
• Crushed Brick (Sand): (0.2073 kg / 2.280 kg) * 100% = 9.1%

5.3 Molding Process:

Mold Description: The eco-bricks were shaped using standard molds that measure 19 cm x 9 cm x 9 cm (as shown in Figure 7). It's important to pay attention to the material of the mold as well.

Figure 7 Wooden Mold

The molding technique began with melting down the prepared plastic waste in a furnace. After that, we mixed in manually crushed red brick fine aggregate with the molten plastic, followed by a thorough blend of crushed red brick sand. This composite mixture was then carefully poured and pressed into molds that are the standard size for bricks (19 cm x 9 cm x 9 cm) to ensure proper compaction and shape. Finally, we let the bricks cool and solidify, as illustrated in Figure 8.

Figure 8 Molding

Solidification/Cooling: Once the mixture was carefully poured and compacted into the molds, we capped them off and let them sit undisturbed for a vital cooling period. This important phase lasted about 3 to 4 hours. We chose this time frame to ensure the molten plastic binder had enough time to solidify completely, giving the eco-bricks the initial strength and integrity they needed for a smooth and damage-free demolding (as illustrated in Figure 9).

Figure 9 Molding

5.4 Testing:

We put the eco-bricks we made through a series of tests to see how they held up:

Hardness Test:

- Procedure: We scratched the surface of the eco-bricks with a fingernail.
- Result: No marks were left behind, which shows they have good hardness.

Soundness Test:

- Procedure: We knocked two eco-bricks together.
- Result: They didn't break and made a nice ringing sound, proving they're sound and intact.

Compression Strength Test:

- Machine Used: Universal Testing Machine (UTM).

6. Results

The compressive strength tests on the eco-brick samples using the Universal Testing Machine (UTM) gave us the following maximum failure loads:

1. Specimen 1: 122 kN
2. Specimen 2: 124 kN
3. Specimen 3: 122 kN

To find the compressive strength, we divided the maximum load at failure by the cross-sectional area of the brick. Following our method, the eco-bricks were shaped to standard dimensions of 19 cm x 9 cm x 9 cm. For the compressive strength test, we usually apply the load on the larger face of the brick. So, we calculated the loaded area as follows:

A. Length = 19 cm = 190 mm
B. Width = 9 cm = 90 mm
C. Loaded Area (A) = Length × Width = 190 mm × 90 mm = 17,100 mm^2

Using the formula: Compressive Strength (σ) = Maximum Load (P) / Loaded Area (A), we calculated the individual compressive strengths:

1. Specimen 1: σ_1 = (122 kN × 1000 N/kN) / 17,100 mm^2 ≈ 7.13 N/mm^2
2. Specimen 2: σ_2 = (124 kN × 1000 N/kN) / 17,100 mm^2 ≈ 7.25 N/mm^2
3. Specimen 3: σ_3 = (122 kN × 1000 N/kN) / 17,100 mm^2 ≈ 7.13 N/mm^2

Next, we found the average compressive strength of the eco-bricks by averaging the individual strengths:

Average σ = (7.13 + 7.25 + 7.13) / 3 ≈ 7.17 N/mm^2

The following table summarizes the compressive strength test results for the eco-bricks:

Table 2: Compressive Strength Test Results for Eco-Bricks

Sample ID	Maximum Load (kN)	Loaded Area (mm^2)	Compressive Strength (N/mm^2)
Eco-Brick 1	122	17100	7.13
Eco-Brick 2	124	17100	7.25
Eco-Brick 3	122	17100	7.13
Average	122.66	17100	7.17

7.DISCUSSION AND COMPARATIVE ANALYSIS

The average compressive strength of 7.17 N/mm^2 for the eco-bricks shows that they are quite sturdy, able to handle heavy loads. This is especially exciting considering they're made from recycled materials. The research highlights that the hydrophobic quality of the melted mixed plastic binder, along with its adhesive and cohesive traits, effectively holds together the crushed red brick aggregate. This results in a compressive strength that rivals that of traditional bricks. The measured strength of 7.17 N/mm^2 backs this up, providing solid proof that the melted plastic works well as a strong binding agent for the recycled aggregate. This showcases a successful material design where the natural properties of the binder lead to the desired mechanical performance in the final product.

Table 3: Comparative Compressive Strengths of Eco-Bricks vs. Conventional Clay Bricks

Brick Type / Classification	Average Compressive Strength (N/mm^2 or MPa)	Relevant IS Code / Source
Eco-Brick (This Study)	7.17	Current Research
Common Burnt Clay Brick	Minimum 3.5	IS 1077:1992
Second-Class Burnt Clay Brick	Minimum 7.0	IS 1077:1992
First-Class Burnt Clay Brick	Approx. 10.5 (105 kg/cm^2)	IS 1077:1992
Engineering Bricks	Exceeds 15	IS 2185 (Part 1):2005
Maximum Burnt Clay Brick	Up to 35	IS 1077:1992

When we take a closer look, it's clear that the eco-brick boasts an impressive average compressive strength of 7.17 N/mm^2, which is well above the minimum standard for typical burnt clay bricks at 3.5 N/mm^2. It also slightly surpasses the minimum for second-class bricks, which is 7.0 N/mm^2, and comes pretty close to the strength of first-class conventional bricks. This shows that eco-bricks not only meet but often exceed the strength requirements needed for a variety of traditional brick uses.

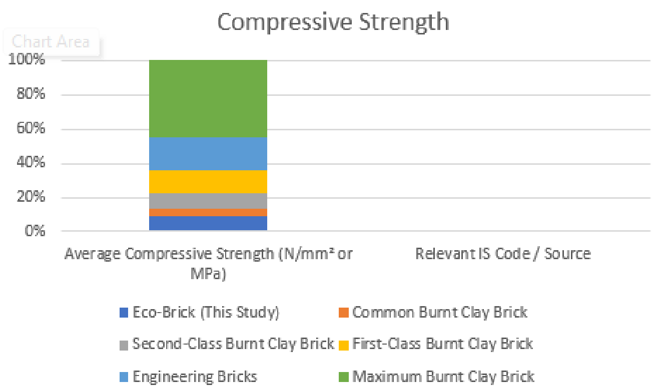

Chart -1: Average Compressive Strength

8. CONCLUSIONS

The evaluation of eco-bricks fabricated from plastic waste and recycled construction materials unequivocally demonstrates their high compressive strength, with an average value of 7.17 N/mm^2. This performance notably exceeds the minimum strength requirements for common burnt clay bricks (3.5 N/mm^2) and is comparable to or surpasses that of second-class conventional bricks (7.0 N/mm^2), showcasing their suitability for a wide range of structural applications.

The successful development and validation of these high-strength eco-bricks represent a significant advancement towards sustainable construction practices. They offer a viable and effective solution for repurposing plastic waste and construction debris, thereby reducing reliance on virgin resources and actively promoting circular economy principles within the building sector. These findings strongly support the continued research, development, and eventual widespread adoption of such innovative, eco-friendly building materials, paving the way for a more environmentally responsible and structurally sound construction industry.

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