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Manufacturing and Experimental Evaluation of Plastic–Sand Bricks Using Waste Plastic

[1]Nitin Sonavane, [2]Nandkishor Mande, [3]Shreyash More, [4]Adarsh Suryavanshi, [5]Vaibhav Bhosale, [6]Sahil Hingmire

[1-2]Assistant Professor, Department of Civil Engineering, SVERI's College of Engineering, Pandharpur, Maharashtra, India.

[3,4,5,6]UG Student, Department of Civil Engineering, SVERI's College of Engineering, Pandharpur, Maharashtra, India.

ABSTRACT: Plastic waste is a persistent environmental problem because most plastic products degrade very slowly and accumulate in landfills, waterways and open land. This study investigates the manufacture of plastic–sand bricks in which waste plastic bottles act as the binder and sieved crushed sand acts as the aggregate. The production route comprised collection, cleaning, drying, size reduction, batching, heating, mixing, molding, compaction, cooling for at least 24 hours and conditioning of the specimens. Three plastic-to-sand mixes by weight (1:3, 1:4 and 1:5) were prepared and compared with conventional bricks in terms of compressive strength and water absorption. The average compressive strengths were 9.72, 12.28 and 3.39 N/mm² for the 1:3, 1:4 and 1:5 mixes, against 5.10 N/mm² for the conventional brick, while the average water absorption values were 0.37%, 0.30% and 0.35%, against 3.00% for the conventional brick. The 1:4 mix (20% plastic by weight) gave both the highest strength (about 2.4 times that of the conventional brick) and the lowest water absorption (about 90% lower), whereas the 1:5 mix was weaker than the conventional brick. Fitted trend curves suggest that the optimum plastic content lies close to 20–22% by weight. The results indicate that plastic–sand bricks are promising for paving and non-load-bearing applications; however, standardized testing with replicate statistics, fire and thermal evaluation, durability assessment and environmental-safety review are required before any structural use is recommended.

KEYWORDS: *Waste plastic, plastic–sand bricks, sustainable construction, compressive strength, water absorption, mix proportion, recycling.*

I. INTRODUCTION

Plastic has become an everyday material in packaging, bottles, containers and consumer goods. Because most plastics resist natural degradation, discarded products accumulate in landfills, rivers and open spaces, causing pollution and placing a growing burden on waste-management systems. Reuse and recycling of waste plastic are therefore important strategies for limiting its environmental impact.

At the same time, the construction industry consumes large quantities of natural resources in the production of bricks, blocks and other masonry products. Rising demand for these materials has encouraged research into alternative products that incorporate waste. One such option is the plastic–sand brick, in which waste plastic is heated until it softens or melts, mixed with sand in predetermined proportions and cast in a mould. On cooling, the plastic solidifies and binds the sand grains into a hard block [1]–[4].

The properties of plastic–sand bricks depend on the type of plastic, the plastic-to-sand ratio, mixing conditions, compaction and the cooling process. Compressive strength and water absorption are the two basic indicators of a brick's load resistance and its interaction with water, and are therefore the properties examined here. This paper reports the manufacture of plastic–sand bricks at plastic-to-sand ratios of 1:3, 1:4 and 1:5, presents their measured compressive strength and water absorption, compares them with conventional bricks, and identifies the most promising mix among those tested. Durability, fire resistance, thermal behavior and environmental safety lie outside the scope of the present measurements and are discussed as necessary future work.

II. PROBLEM STATEMENT AND RESEARCH OBJECTIVES

A. Problem Statement

The increasing generation of plastic waste, its slow degradation and the difficulty of disposing of it safely are significant environmental concerns. Meanwhile, the construction sector needs materials that meet performance requirements while making use of waste resources. Using waste plastic as a binder and sand as an aggregate is one possible route to a more sustainable

brick, but the performance of the product is sensitive to the proportion of plastic and sand used. This study therefore examines how the plastic-to-sand ratio affects the compressive strength and water absorption of manufactured bricks and how these compare with conventional bricks.

B. Research Objectives

The main objectives of this study were to investigate the feasibility of using waste plastic in the manufacture of plastic–sand bricks and to manufacture bricks at plastic-to-sand ratios of 1:3, 1:4 and 1:5 by weight. The study further aimed to determine the compressive strength and the water-absorption characteristics of the manufactured bricks by experimental testing, and to compare the measured performance with that of conventional bricks. A final aim was to identify the most promising plastic-to-sand ratio among the mixes tested, to examine the trend of properties with plastic content, and to identify the areas requiring further investigation, including durability, fire resistance and environmental safety.

III. SIGNIFICANCE OF THE STUDY

The manufacture of plastic–sand bricks offer a way of managing plastic waste while developing an alternative masonry product. Its significance lies in several aspects.

Plastic waste utilization is the first benefit: the method provides a route for reusing plastic that might otherwise be disposed of improperly. It also explores a brick made from waste plastic and sand as a substitute for conventional bricks in suitable applications, and it may reduce dependence on some conventional brick-making materials and processes. Mechanically, the study shows how the plastic-to-sand ratio influences load-bearing capacity, while all tested plastic–sand mixes absorbed far less water than the conventional bricks used for comparison. Comparing three ratios identifies a suitable proportion on the basis of measured strength and absorption, and the results provide a starting point for durability, fire, thermal and environmental studies.

IV. LITERATURE REVIEW AND RESEARCH GAP

A. Literature Review

The use of waste plastic in construction materials has attracted considerable attention as a way of reducing plastic waste and developing alternative building products. Review articles have surveyed the incorporation of plastic waste into bricks, blocks, pavers and composite products and have described the main manufacturing routes and the factors that govern product quality [1], [2], [4], [8], [9]. Broader reviews of recycling and of the benefits and risks of placing plastic waste in construction materials stress that the polymer type, contamination and end-of-life behavior must be considered alongside mechanical performance [6], [7].

Experimental studies have examined plastic–sand and related composites in several forms, including interlocking paving bricks, paver blocks with fibre reinforcement, bricks containing mixed plastic waste and foundry sand, and low-cost bricks made from non-segregated plastic waste [3], [10]–[15]. A common observation across this literature is that mix proportion, aggregate characteristics, processing temperature, compaction and cooling all influence the final strength and water uptake of the product.

Occupational-health and environmental aspects of small-scale plastic-brick production, particularly emissions during heating, have been raised as an important concern [5], [7].

Compressive strength indicates the resistance of a brick to load, while water absorption indicates its porosity and interaction with moisture. Testing both properties across several mixes allows the influence of sand content on bonding and strength to be understood, and comparison with conventional bricks places the results in a practical context.

B. Research Gap

Because performance depends strongly on composition and process, locally prepared mixes need to be compared directly under common manufacturing and testing conditions. The present study addresses this by manufacturing bricks at three plastic-to-sand ratios (1:3, 1:4 and 1:5) and comparing their compressive strength and water absorption with those of conventional bricks tested in the same programme. Its specific contribution is a comparative experimental evaluation of these mixes and an indication of the trend of properties with plastic content. The study is limited to the properties measured; durability, fire behavior, thermal performance, economics and environmental safety remain to be investigated.

V. MATERIALS AND METHODOLOGY

A. Materials

The materials used were waste plastic, crushed sand and a metal brick mould. Discarded plastic bottles were collected, washed to remove dust and impurities, and dried to remove moisture before heating; after cooling,

the plastic acts as the binder that holds the sand particles together. The specific polymer type was not identified in the project report. Crushed sand served as the aggregate and was sieved through a 600 µm sieve to remove oversize particles and impurities and to obtain a uniform material. A metal mould was used to shape the hot plastic–sand mixture into brick specimens of consistent form.

B. Mix Proportions

Three plastic-to-sand mixes were prepared, with proportions expressed by weight. The corresponding percentages are given in Table 1.

Table 1. Mix proportions of the plastic–sand bricks (by weight)

Sr. No.	Mix designation	Plastic: Sand	Plastic (%)	Sand (%)
1	Mix 1	1:3	25.00	75.00
2	Mix 2	1:4	20.00	80.00
3	Mix 3	1:5	16.67	83.33

C. Manufacturing Procedure

The manufacturing sequence is summarized in Fig. 1 and described in the paragraph that follows.

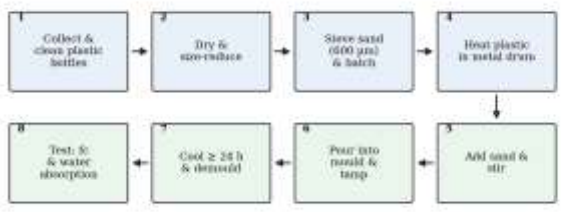


Fig. 1. Manufacturing process of plastic–sand bricks.

The process began with collection and preparation of the materials: plastic bottles were collected, cleaned with water and dried, and crushed sand was sieved through the 600 µm sieves. In the batching stage, plastic and sand were weighed separately in accordance with the selected mix to ensure consistency between mixes. The prepared plastic was then heated in a metal drum, with firewood beneath the drum as the heat source, until it softened and melted sufficiently for mixing; heating was controlled to avoid uncontrolled burning or excessive thermal degradation. Measured sand was added gradually to the molten plastic and stirred continuously to obtain a reasonably uniform mixture. The hot mixture was transferred to the metal mould and compacted with a tamping rod to reduce air voids. The moulds were left undisturbed for at least 24 hours until the mixture solidified, after which the bricks were removed, identified by mix proportion and prepared for testing.

D. Experimental Testing

Compressive-strength test. Each specimen was placed in a compression-testing machine and loaded to failure. The compressive strength was calculated from Eq. (1) and the average was determined for each mix.

$$f_c = \frac{P}{A} \qquad (1)$$

where fc is the compressive strength (N/mm²), P is the maximum load at failure (N) and A is the loaded cross-sectional area (mm²).

Water-absorption test. The dry mass and the water-saturated mass of the specimens were measured, and water absorption was calculated from Eq. (2).

$$WA(\%) = \frac{W_s - W_d}{W_d} \times 100 \qquad (2)$$

where WA is the water absorption (%), Wd is the dry mass (g) and Ws is the saturated mass (g). Conventional bricks were tested by the same procedures for comparison.

VI. RESULTS AND DISCUSSION

A. Compressive Strength

The average compressive strengths are listed in Table 2 and plotted in Fig. 2. The 1:4 mix achieved the highest strength, 12.28 N/mm², followed by the 1:3 mix at 9.72 N/mm². The 1:5 mix reached only 3.39 N/mm². The conventional brick recorded 5.10 N/mm². The 1:3 and 1:4 mixes therefore exceeded the conventional brick, whereas the 1:5 mix fell below it.

Table 2. Average compressive strength of plastic–sand and conventional bricks

Sr. No.	Brick type	Average compressive strength (N/mm²)	Rank
1	Plastic–sand brick (1:3)	9.72	2
2	**Plastic–sand brick (1:4)**	**12.28**	**1**
3	Plastic–sand brick (1:5)	3.39	4
4	Conventional brick	5.10	3

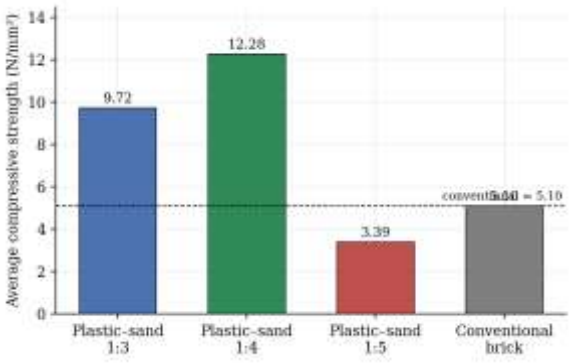


Fig. 2. Average compressive strength by brick type (dashed line: conventional brick).

B. Water Absorption

Table 3 and Fig. 3 give the water-absorption results. The 1:4 mix absorbed the least water (0.30%), followed by the 1:5 mix (0.35%) and the 1:3 mix (0.37%). The conventional brick absorbed 3.00%. All three plastic–sand mixes therefore absorbed roughly 88–90% less water than the conventional brick, consistent with the hydrophobic nature of the plastic binder, which coats the sand grains and fills pores. The differences among the three plastic–sand mixes (0.30–0.37%) are small and, without replicate statistics, should not be over-interpreted.

Table 3. Average water absorption of plastic–sand and conventional bricks

Sr. No.	Brick type	Average water absorption (%)	Rank
1	Plastic–sand brick (1:3)	0.37	4
2	**Plastic–sand brick (1:4)**	**0.30**	**1**
3	Plastic–sand brick (1:5)	0.35	2
4	Conventional brick	3.00	5

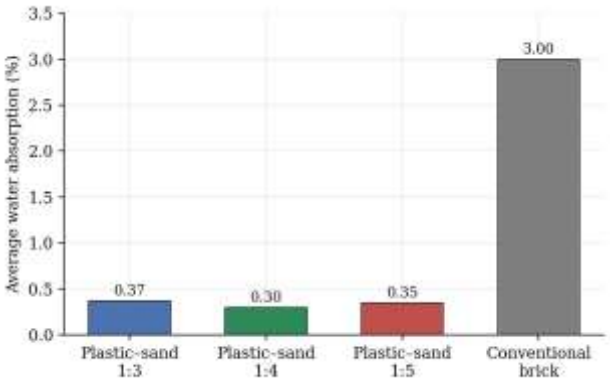


Fig. 3. Average water absorption by brick type.

C. Performance Relative to Conventional Brick

Table 4 consolidates the results and expresses each plastic–sand mix relative to the conventional brick; Fig. 4 shows the same comparison graphically. The 1:4 mix improved compressive strength by about 141% and reduced water absorption by 90%. The 1:3 mix improved strength by about 91%, while the 1:5 mix lost about 34% of the conventional strength despite its low absorption.

Table 4. Consolidated results and performance relative to conventional brick

Brick type	Plastic (%)	Strength (N/mm²)	Strength vs conv.	Water abs. (%)	Abs. reduction
Plastic–sand 1:3	25.00	9.72	+90.6%	0.37	87.7%
Plastic–sand 1:4	**20.00**	**12.28**	**+140.8%**	**0.30**	**90.0%**
Plastic–sand 1:5	16.67	3.39	−33.5%	0.35	88.3%
Conventional	–	5.10	–	3.00	–

Relative values are calculated from the reported averages: strength change = (fc / 5.10 − 1) × 100; absorption reduction = (1 − WA / 3.00) × 100.

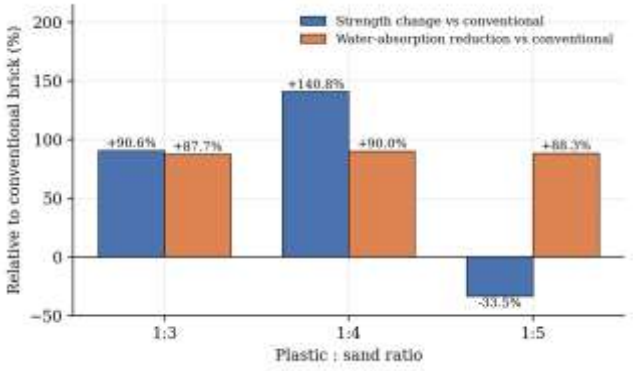


Fig. 4. Compressive strength gain and water-absorption reduction of plastic–sand bricks relative to the conventional brick.

D. Effect of Plastic Content (Trend Curves)

To visualize how properties vary with binder content, a second-order polynomial was fitted through the three measured averages against plastic content (Fig. 5). The fitted curves peak (strength) and bottom out (absorption) at plastic contents of about 21.8% and 20.5% by weight respectively, bracketing the 1:4 mix (20%). The shape is physically reasonable: with too little plastic (1:5, 16.67%) there is insufficient binder to coat the sand grains and fill voids, giving weak bonding; with too much plastic (1:3, 25%) the strength falls again, possibly because of poorer sand distribution, compaction or void

formation in the more viscous mixture. These explanations are plausible hypotheses that were not verified in this study.

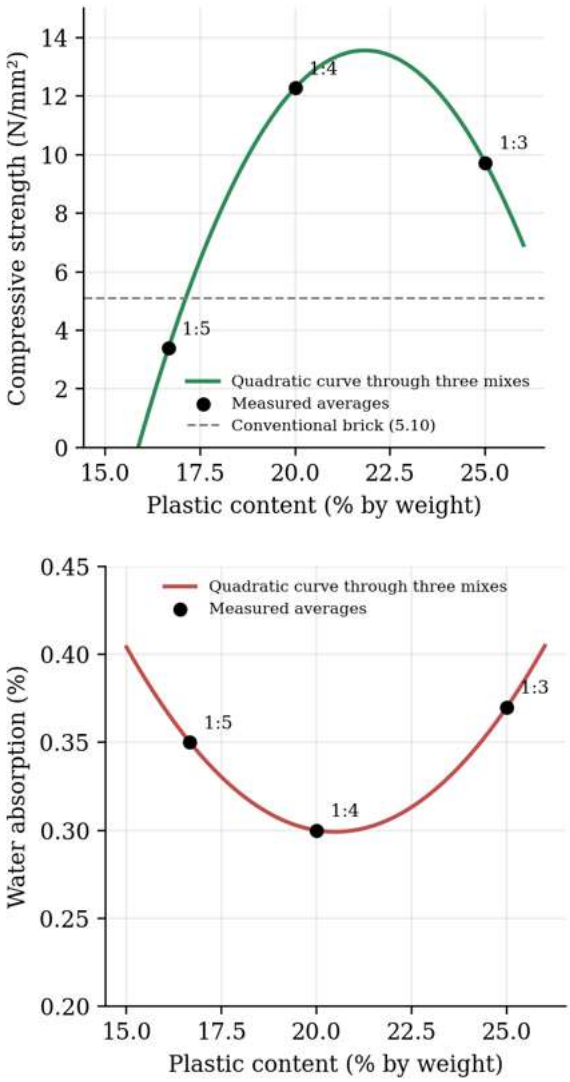


Fig. 5. Variation of (a) compressive strength and (b) water absorption with plastic content. Markers: measured averages; curve: quadratic through the three points.

Caution: a quadratic passes exactly through three points and has no residual error, so the curves are indicative only. They suggest where the optimum may lie (roughly 20–22% plastic), but this must be confirmed by testing additional ratios, for example 18–24% in small steps, with replicates.

E. Strength–Absorption Trade-off

Fig. 6 plots strength against absorption. The 1:4 mix occupies the most favorable corner (high strength, low absorption), the 1:3 mix is close behind, and the 1:5 mix shows that low absorption alone does not guarantee adequate strength. All plastic–sand mixes lie far to the left of the conventional brick, i.e. they are much less absorbent.

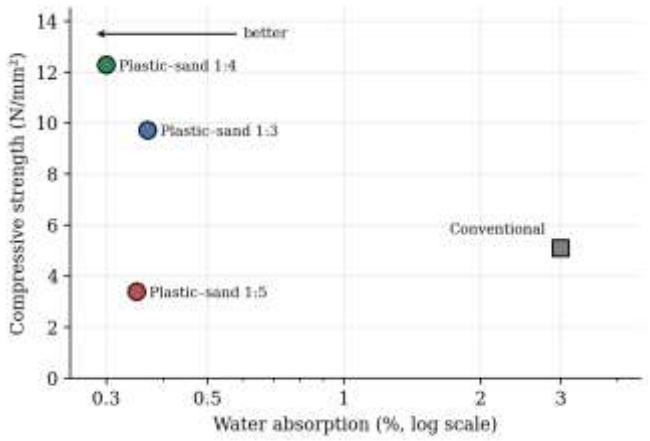


Fig. 6. Compressive strength versus water absorption for all brick types (log scale on the horizontal axis).

F. Limitations of the Present Results

Several limitations should be noted. Only average values are reported; the number of specimens per mix and the standard deviation or coefficient of variation are not given, so statistical significance cannot be assessed. The polymer was not identified, although melting behavior, emissions and binding strength all depend on it. The reported absorption of 3.00% for the conventional brick is considerably lower than values commonly quoted for clay bricks, so the reference bricks and test conditions, such as the immersion period, should be documented and verified. The testing procedure was not stated to follow a specific standard, for example the relevant Indian Standard methods for brick testing, so conformity with a standard class has not been established. Finally, fire behavior, thermal performance, long-term durability, emissions and economics were not evaluated, and heating plastic over firewood raises occupational-health concerns that must be addressed in any scale-up [5], [7].

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

This study manufactured plastic–sand bricks from waste plastic bottles and crushed sand at plastic-to-sand ratios of 1:3, 1:4 and 1:5 and compared their compressive strength and water absorption with conventional bricks. The main findings are summarized below.

The 1:4 mix (20% plastic) performed best, with an average compressive strength of 12.28 N/mm² and a water absorption of 0.30%. The 1:3 mix reached 9.72 N/mm² and 0.37%, and it also exceeded the conventional brick (5.10 N/mm²) in strength. The 1:5 mix, at 3.39 N/mm², was weaker than the conventional brick, showing that an insufficient binder content reduces strength. All plastic–sand mixes absorbed about 88–90% less water

than the conventional brick (3.00%), and the fitted trend curves point to an optimum plastic content of about 20–22% by weight, which remains to be confirmed experimentally.

Waste plastic can therefore be a viable binder for plastic–sand bricks, offering a route to reuse plastic waste in paving and non-load-bearing products. The findings are limited to the measured properties and test conditions, and further evaluation against applicable standards is required before specific building applications are recommended.

B. Future Scope

Several directions are recommended for future work. The first is mix optimization: additional ratios around 18–24% plastic should be tested with replicate specimens and statistical analysis. Durability should then be assessed through weathering, wet–dry cycling and long-term exposure. Because plastic is combustible, fire and thermal behavior, including ignition, flame spread, performance at elevated temperature and heat transfer, must be evaluated. Environmental safety also needs attention: the polymer used should be identified, emissions during manufacture measured, and leaching or release in service and at end of life assessed. Further mechanical tests such as flexural strength, impact resistance and dimensional stability would give a fuller picture of material behavior. An economic comparison with conventional bricks should include collection, processing, heating energy, labor and transport. Scale-up studies should examine consistent production with appropriate worker protection and controlled heating. Finally, standardized manufacturing procedures for preparation, heating, mixing, moulding, cooling and quality control should be developed, and the bricks tested against relevant standards for paving, partitions or other intended applications.

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