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Eco-Friendly Paving Tiles from Recycled Plastic for Sustainable Building Applications

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Abstract

This study investigates the feasibility of using plastic waste as a partial or full replacement for cement in the production of paver blocks. The primary objective is to reduce both the cost and environmental impact associated with traditional concrete paver blocks. India generates approximately 6 million tonnes of plastic waste annually, with very slow degradation rates, leading to long-term pollution concerns.

In this project, waste plastic was combined in varying proportions with sand and/or fly ash to create paver blocks. These blocks were then tested for performance characteristics, and the results were compared against existing data in the literature. The findings demonstrate the potential of this method to offer a sustainable, low-cost construction material, while simultaneously addressing the plastic waste crisis.

Keywords: Paver blocks; Plastic waste; Fly ash; Sustainable construction; Recycling; Waste valorization

Introduction

Plastic waste has emerged as a critical global issue, intricately linked to broader challenges concerning resource scarcity, energy sustainability, and environmental degradation [1, 2]. Plastics, primarily derived from non-renewable petroleum-based resources, have seen a dramatic rise in global consumption—from approximately 5 million tonnes in the 1950s to nearly 100 million tonnes today. This exponential growth has contributed significantly to the mounting burden of municipal solid waste, with plastics now comprising around 3–7% of the total waste generated worldwide.

In India, plastic waste accounts for an estimated 1–4% of municipal solid waste by weight. Although the country boasts the highest recycling rate in the world at 60%—a figure that far exceeds those of China (20%), Europe (20–40%), Japan (39%), South Africa (16%), the UK (17.7%), and the USA (28%)—the remaining unrecycled plastic continues to pose serious environmental and public health risks. The most common methods of plastic waste disposal in India include land filling, incineration, and open littering. Of these, open littering is particularly harmful, as it often results in plastics escaping formal waste management systems altogether, leading to clogged drainage systems, soil contamination, and hazards to terrestrial and aquatic ecosystems [3].

Despite these challenges, recent research has identified the potential of using plastic waste as a raw material in construction applications. Studies have demonstrated that waste plastics can be effectively repurposed into construction components, such as bricks or blocks, offering a promising solution for producing low-cost, durable building materials, especially in disaster-prone and remote regions.

Building upon this concept, the present study explores the use of waste plastic in the production of paving tiles (also known as paver blocks). The primary aim is to evaluate the feasibility of replacing conventional cement-based materials with plastic waste-either partially or fully—to produce eco-friendly and economically viable alternatives to traditional paving units. This paper focuses on analyzing the physical and mechanical properties of plastic-based paver blocks formulated with varying proportions of sand and/or fly ash [4]. The results are compared against conventional concrete blocks and previously published benchmarks to assess performance, durability, and sustainability.

Ultimately, this work aims to promote an innovative and scalable approach to plastic waste management that not only reduces environmental burden but also contributes to sustainable infrastructure development, particularly in underserved communities.

Materials and Methodology

Materials

Waste Plastic

The primary raw material used in this study is post-consumer plastic waste, sourced from local municipal collection points and nearby garbage disposal sites (see Figure 1). The collected waste includes a mix of commonly discarded plastic types such as low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), and polystyrene (PS) [3].

The plastics were initially washed with water and detergent to remove contaminants like mud, grease, and other foreign materials. After drying in ambient air, the plastics were further cleaned using high-pressure water jets to ensure the removal of any residual impurities. Larger pieces were manually cut down and then processed in a plastic shredder to produce flakes ranging from 5 mm to 10 mm in size (Figure 2). These clean, dry plastic pieces formed the base material for block production.

River Sand

Natural river sand was used as a filler and structural component in the plastic composite. Sand samples were randomly selected from heaps used by local construction contractors (Figure 3). The sand, golden in color, was sieved through a 600-micron mesh to ensure uniform particle size. The specific gravity of the sand was measured according to IS: 2720 (1980). The properties are hereby mentioned in Table 1.

Fly Ash

Fly ash, an industrial byproduct generated from coal combustion in thermal power plants, was incorporated as an additional binder and filler. Class-F fly ash was used in this study, procured from a local supplier (Figure 4). Its inclusion is intended to improve the thermal and mechanical properties of the paver blocks. The properties are hereby mentioned in Table 1.

Preparation of Test Specimens

To fabricate the test specimens, a simple thermal melting and manual molding process was followed:

1. A narrow neck metal reactor was preheated to a temperature of approximately 250°C.

2. One kilogram of shredded plastic was introduced into the heated reactor, where it melted almost instantaneously. No toxic gases were observed during this process.

3. Pre-weighed amounts of river sand and/or fly ash, based on the desired mix ratio, were gradually added to the molten plastic. The materials were stirred continuously to ensure homogeneous mixing.

4. The resulting mixture was immediately poured into pre-cleaned steel molds of dimensions 70 mm × 70 mm (Figure 5). Manual compaction was applied (without hydraulic pressing) to minimize internal porosity.

5. The molded specimens were allowed to air-cool and harden for 24 hours. Shrinkage of 1–2% was observed upon cooling.

For comparative testing, standard-size commercial fly ash bricks were cut into 70 mm × 70 mm samples using a hacksaw, while A-grade earthen bricks (255 mm × 120 mm × 72 mm) were tested in their original form as per IS standards.

Compressive Strength Testing

The compressive strength of the prepared plastic paver blocks (70 mm × 70 mm), commercial fly ash blocks (70 mm × 70 mm), and earthen bricks (255 mm × 120 mm × 72 mm) was evaluated (IS: 516 (Part 1), 2021) using an AIM317EAN2 compression testing machine (M/s AIMIL, India) (Figure 6).

For each block type, five specimens were tested, and the maximum load at failure was recorded. The average compressive strength was calculated using the formula:

Compressive strength (N/mm^2) = [Ultimate load in N / Area of cross section (mm^2)].

Similarly tensile strength has been measured using the formulae $f_{ct} = 0.7\sqrt{f_{ck}}$ N/mm^2

Fire Resistance Test

Given that plastic is inherently flammable, evaluating the thermal stability of the paver blocks is essential. The specimens were subjected to incremental heating in an oven, starting from 50°C up to 200°C, with each temperature held for 2 hours (IS 3809:1979).

It was observed that composite plastic-sand paver blocks remained structurally intact up to 180°C due to the insulating effect of the sand. Beyond this threshold, minor surface cracking appeared, and further heating led to gradual deterioration.

Water Absorption Test

To assess porosity and durability, the water absorption capacity of each specimen type was tested:

1. Dry weight of each sample was recorded.

2. Samples were immersed in clean water for 24 hours.

3. After immersion, specimens were wiped with a wet cloth and reweighed.

4. The percentage of water absorption was calculated based on the weight difference between the dry and soaked states.This test helped determine the material's resistance to moisture ingress and potential degradation over time (IS 2386 (Part 3), 1963).

Hardness Test

Surface hardness was evaluated using the Mohs scale (IS 12608 (1989)). A scratch test was conducted by attempting to mark the surface with:

- A sharp steel tool (Mohs hardness = 5)
- A sharp glass plate (Mohs hardness ≥ 6)

No visible scratches were observed in either case, indicating a high surface hardness of the plastic paver blocks, confirming their structural robustness (Figure 7).

Results and Discussion

A series of experimental batches were prepared using various combinations of shredded plastic waste, river sand, and fly ash. The mechanical and physical properties of the resulting paver blocks—including compressive strength, tensile strength, water absorption, and fire resistance—were assessed and compared with commercial alternatives and existing literature [5, 6].

Table 2 presents a summary of the measured values for different block types, alongside reported reference data where available.

Compressive and Tensile Strength Analysis

The compressive strength of plastic-sand-fly ash composite blocks showed considerable enhancement over conventional fly ash and earthen blocks. Mix B2 (Plastic : Sand : Fly Ash = 1 : 2 : 2) recorded a strength of 12.68 N/mm², which is more than double that of commercial fly ash and concrete blocks.

The best performing batch was B4, with a high compressive strength of 16.91 N/mm², though still lower than a reported value of 25 N/mm² for similar composites [6]. It is worth noting that B4 used a significantly lower sand content (1: 0.4), suggesting that reduced filler material results in higher plastic density and strength.

Tensile strength, derived from compressive values, followed a similar trend. B4 again topped with 2.87 N/mm^2, indicating better resistance to cracking and improved flexibility compared to inorganic brick types.

Water Absorption Characteristics

Water absorption in plastic-based paver blocks was significantly lower than in conventional masonry materials. All plastic-based mixes had values below 1%, with B2 recording the lowest at 0.89%, signifying excellent resistance to moisture ingress.

In contrast, fly ash and earthen bricks exhibited water absorption rates as high as 8.94%, which compromises durability in humid or rainy environments. This property alone makes plastic paver blocks highly suitable for outdoor applications.

Fire Resistance and Durability

Fire resistance testing confirmed that the plastic composite blocks remained stable up to 180°C. Beyond this point, structural cracks were observed. However, this temperature threshold is adequate for most civil applications, especially in non-load-bearing, pedestrian, or landscaping uses. The presence of sand enhances fire resistance by acting as a thermal barrier.

Surface Hardness and Finish

Scratch tests using steel and glass tools (Mohs hardness = 5–6) confirmed that the plastic composite surfaces were highly resistant to surface deformation, suggesting excellent wear resistance. This quality makes them suitable for use in areas with moderate foot traffic.

Conclusion

The experimental investigation clearly demonstrates that waste plastic can be effectively utilized in the production of durable and cost-efficient paver blocks. The results confirm that incorporating plastic with sand and fly ash in optimized ratios yields blocks with superior compressive and tensile strength, minimal water absorption, and good fire resistance compared to conventional masonry materials. These plastic-based blocks not only present an innovative way to manage and repurpose plastic waste, but they also offer a sustainable alternative for construction, particularly in regions facing resource constraints. Their favorable properties make them suitable for various non-structural applications.

Based on the experimental analysis, the following conclusions can be drawn:

1.Sustainable Waste Utilization: The proposed method presents a viable solution for reusing municipal plastic waste in a productive, eco-friendly manner. This aligns with circular economy principles and can reduce landfill load significantly.

2.Superior Physical Properties: The plastic paver blocks showed enhancement in strength compared to commercial fly ash and earthen blocks. Specifically, mix ratios such as 1:2:2 (Plastic: Sand: Fly Ash) and 1:0.4 (Plastic: Sand) demonstrated exceptional strength and integrity.

3.Minimal Water Absorption: With absorption rates below 1%, these blocks offer strong resistance to moisture—making them highly durable for outdoor use in varying climatic conditions.

4.Thermal and Surface Resilience: The blocks maintained their form up to 180°C and exhibited high scratch resistance, making them suitable for pedestrian and light structural applications.

5.Cost-Effective and Scalable: As these blocks do not require cement or complex curing processes, they present a low-cost and easily replicable alternative for rural and urban construction.

6.Recommended Applications: Ideal for non-traffic areas (building premises, monuments, gardens, embankments) and light--traffic zones (pedestrian paths, residential roads, tourist resorts, footways).

Practical Application of the work

Plastic waste is a significant global issue, exacerbated by the lack of adequate local recycling infrastructure. A simple, low-cost technology has been developed to convert mixed plastic waste into construction materials. This study explores how varying ratios of waste plastic, sand, and fly ash affect the mechanical properties of the resulting material, comparing outcomes with published benchmarks. The approach supports community-driven waste management and has the potential to create meaningful global environmental and economic impact.

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Data Availability Statement

All data used in this study appeared in the article.

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