MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 6 No. 4 (2025) 93-98
https://publisher.uthm.edu.my/periodicals/index.php/mari

Fabrication and Testing of Plastic Interlocking Pavements (PIP)

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DOI: https://doi.org/10.30880/mari.2025.06.04.013

Article Info

Received: 01 September 2025
Accepted: 15 October 2025
Available online: 01 December 2025

Keywords

Eco-friendly, Sand Plastic, Paver, Plastic Waste, Landscaping

Abstract

Using waste materials in buildings has attracted substantial attention in recent years due to its potential for sustainability and eco-friendliness. This study investigates the practicality of using sand plastic, a composite material from waste plastic and sand aggregates, in manufacturing pavers. The aim was to evaluate the mechanical characteristics and appropriateness of sand plastic pavers for diverse uses in building and landscaping. The experimental study entailed the creation of mixes consisting of sand and waste plastic, with different ratios of plastic to sand which are 20%, 25% and 30%. The load-bearing capacity of the generated paver samples was evaluated by conducting compressive strength tests according to standard protocols. In addition, the material's performance under various situations was evaluated by examining its water absorption, flexural strength, and durability characteristics. The findings indicated that using waste plastic in the form of sand plastic composites resulted in paver samples exhibiting favourable mechanical characteristics. The compressive strength of the sand plastic pavers demonstrated comparable values to those of conventional concrete pavers. Furthermore, the water absorption properties and durability performance indicate that these pavers have the potential to be suitable for outdoor use. This study highlights the capacity of sand plastic to serve as a sustainable substitute material for making pavers. It helps control waste by utilising abandoned plastic and offers a practical solution for improving the mechanical and environmental characteristics of construction materials. The findings provide valuable insights into the practicality of utilising sand plastic technology for creating long-lasting, environmentally friendly pavers that are appropriate for a wide range of construction and landscape application

1. Introduction

The construction sector is essential to the development of the world economy, it also has significant negative effects on natural resources and environmental degradation. Alternative building materials with less impact on the environment are becoming more and more popular in a time when sustainable building practices are crucial and environmental consciousness is rising. A potential solution to both plastic pollution and the construction industry's environmental impact is the integration of plastic waste into conventional sand and cement bricks [1].

High-Density Polyethylene (HDPE) plastic and sand in paver production holds immense significance on several fronts. This research delves into an environmentally sustainable solution by repurposing HDPE plastic and reducing plastic waste accumulation in landfills and oceans. By combining recycled plastic with sand, a readily available natural resource, this approach minimizes dependency on traditional materials, curbing the environmental impact associated with their extraction and production processes [2]. Understanding the structural integrity, durability, and performance of these materials is essential to ensure their viability in construction. Pavers are a kind of construction material that is mostly used to make hard outdoor surfaces such as patios, driveways, pathways, and even roads. Concrete, brick, stone, and other composite materials are some of the shapes, sizes, colors, and materials that these units are made of. Because of their unique design, pavers can fit or interlock tightly to create a surface that is both stable and long-lasting. Because of their resistance to erosion, heavy loads, and changing weather, they provide versatility in application. Pavers are widely used because of their good looks, simplicity of installation, and capacity to be repaired individually without compromising the structure. They are frequently chosen for construction and landscaping projects due to their robustness, low maintenance requirements, and the numerous design options they provide.

Interlocking pavements are flexible paving materials with limitless design options due to their wide range of forms, sizes, and colours [3,4]. Concrete block paving applications can be classified as roadways, commercial projects, industrial regions, household pavement, and specialised uses. Main roads, residential roads, urban regeneration, junctions, toll locations, pedestrian crossings, taxi ranks, steep slopes and walkways are all examples of concrete block paving uses for roadways. Second, commercial projects include car parks, retail centres and malls, parks and leisure centres, golf courses and country clubs, zoos, office parks, service stations, and bus terminals. Furthermore, industries and warehouses, container depots, military applications, mines, wastewater treatment plants, quarries, airports, and so on.

Table 1 *Grades of Paver Blocks for Different Traffic Categories [5]*

Sr. no	Grade. Designation of-Paver Blocks	28 Days N / mm Compressive strength	Category	Recommended thickness minimum mm	Application
1	30	30	Non-traffic	50	Building premises, monument premises, landscapes, public gardens/Parks, domestic drives, and patios, embankment slopes.
2	35	335	Light- traffic	60	Pedestrian plazas, shopping complexes ramps, carparks, office driveways, housing colonies, beach sites, tourist resorts, local authority footways, and residential roads.
3	40	40	Medium-traffic	80	City streets, small and medium market roads, low volume roads, utility cuts on arterial roads.
4	50	50	Heavy to very heavy	100	Bus terminals, industrial complexes, factory floors, service stations, and industrial pavements.

The global creation of waste plastics is growing at an accelerated rate due to factors such as economic expansion and changing manufacturing and consumption patterns. From around 5 million tonnes in the 1950s to over 100 million tonnes annually, plastic products are used worldwide [2]. According to SWCorp, there is a larger percentage of plastic waste at 13% at landfills. 3,087,765 tonnes of plastic were utilised annually, or 8459 tonnes per day, in consumer products [6]. Fig 1 shows the plastic waste at the landfill area.

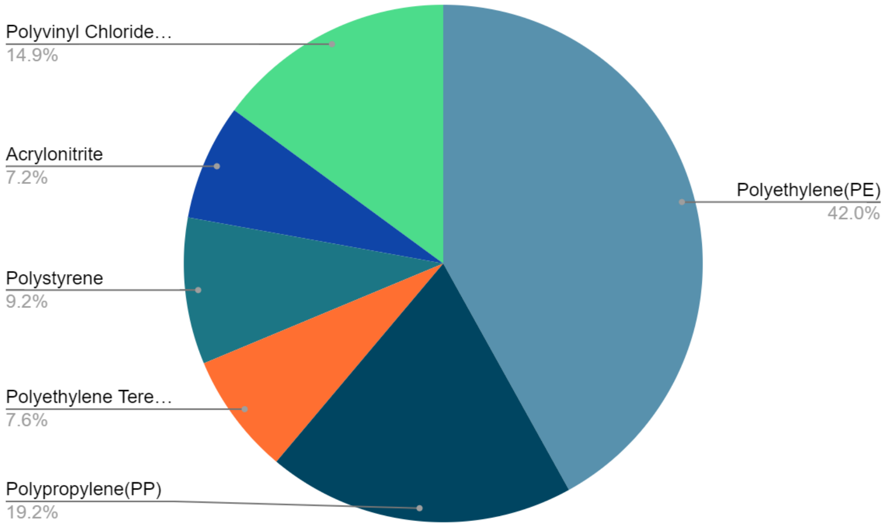

Fig. 1 *Plastic waste at landfill [6]*

2. Methods

2.1 Methods

Two series of laboratory tests were carried out on cast Plastic Interlocking Pavements (PIP) (in the size of 50 x 50 x 50 mm) to determine physical and mechanical properties. The water absorption and density tests were evaluated as physical properties and mechanical properties of the sample were assessed via a compressive strength test [7,8].

2.1.1 Water Absorption

The established standard for evaluating water absorption in paver bricks is typically governed by respected bodies like ASTM International. For instance, ASTM 140/C140M details the standardized method for conducting water absorption tests on paving bricks. The water absorption test was performed to assess the pore size and porosity in hard concrete [9]. The sample's total water absorption is known as the increase in a sample's weight due to the air moisture. The samples that harden and are removed after 24 hours have been put into a curing tank for 24 hours. After 24 hours, the samples were immediately removed from the tank and with a damp cloth, the surface was wiped. Weighed 4 samples for all the samples S1, S2, S3 and S4 and recorded the data within two minutes after removal from the water. The water absorption was calculated using Equation 1.

$$\text{Water Absorption: } \frac{W1-W2}{W2} \times 100\% \quad (1)$$

2.1.2 Density

Density is a material's mass per unit volume. This test was conducted at the UTHM laboratory by using a digital weight balance. The size of the sample used is 50 mm x 50 mm and this test was conducted for all 1 piece per sample ratio. After 24 hours of letting the sample harden, the sample is removed from the mould and continues to be weighed. The density is calculated based on equation 2.

$$\text{Density Test: } \frac{m1}{V} \quad (2)$$

where m1, mass (g) ; V, volume (cm^3)

2.1.3 Compressive Strength

The test was conducted to determine the Plastic Interlocking Pavements compressive strength in 4 different ratios (0%, 20%, 25%, 30%). Compressive testing is very important in determining compressive strength under the vertical loading for goods. This is called the crushing strength of interlocking paving blocks. About 12 specimens were tested for 50 mm thickness by using a Compression testing machine as shown in Fig. 4. All specimens were tested with a Semi Auto 3000kN Compression Machine. The compressive strength test was performed following the procedure outlined in ASTM C936/C936M.

3. Results and Discussions

3.1 Water Absorption

Water absorption was performed to determine minimum and maximum allowable water absorption rates in road construction using interlocking paving blocks. This is because the production of interlocking blocks must be resilient to the changing weather elements in Malaysia, particularly those with frequent monsoon transitions. Fig 2 shows the percentage of water absorption to the different HDPE and sand blends. From the testing, water absorption is 5.59%, 10.79%, 10.68% and 13.16% for blending HDPE and sand. It is even that minimum water absorption is 5.59% at the ratio of 0% HDPE OF sand and maximum water absorption is 13.16% at the ratio of 30% HDPE of sand. It shows the percentage of sand that will affect the sample water absorption because the characteristic of sand is high. The hypothesis for water absorption of paving blocks with HDPE is the higher amount of plastic, the higher the water absorption. The water absorption of PIPs increased proportionally with the percentage of HDPE, with all samples except the 0% HDPE ratio exceeding the 7% water absorption limit specified in ASTM C140/C140M. This increase in water absorption is attributed to variations in the water-cement ratio and HDPE replacement.

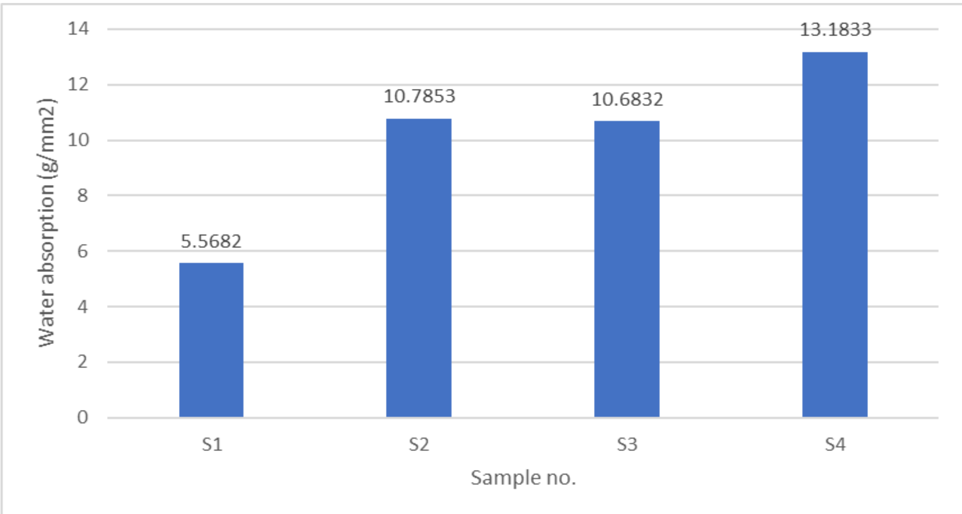

Fig. 2 *Data and Results for Water Absorption*

3.2 Density Test

By measuring the mass of the concrete per unit volume, the density test verifies that the mix meets the requirements for strength and quality. Fig 3 shows the result of the sample after curing about 7 days which is (S1, S2, S3, S4) 1.90 kg/ m^3, 1.64 kg/ m^3, 1.59 kg/ m^3, and 1.50 kg/ m^3. The highest density is found in sample 1 which is 1.90 kg/ m^3 at 0% plastic ratio. The lowest density can be found in sample No. 4 where 1.50 kg/ m^3 at 30% plastic ratio. The graph shows that the density is decreased by increasing HDPE amounts. This shows HDPE is very light compared to the sand. The results show the density of the plastic waste (HDPE) is lighter than sand, that why replacing some of the sand with plastic waste (HDPE) will make the bricks lighter. Despite the lower density of PIPs with 20% to 30% HDPE compared to the control, all samples met the density requirements of ASTM C140/C140M, which range from 1.5 kg/m^3 to 2.4 kg/m^3.

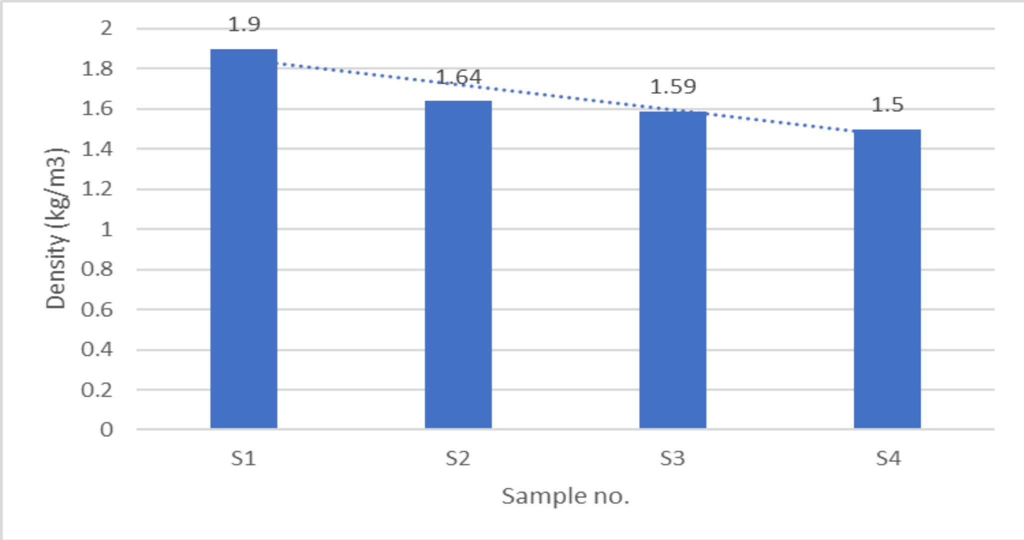

Fig. 3 *Data and Results for Density Test*

3.3 Compressive Strength

The main purpose of this test is to determine how the paver will behave or react to a compressive load by taking measurements of important factors like strain, stress, and deformation [7]. Fig 4 shows the results for the 14-day sample (S1, S2, S3, S4) are 5.491 MPa, 2.626 MPa, 2.121 MPa, and 1.381 MPa. The minimum Compressive strength is found in sample 4 which is 1.381 MPa at 25% plastic ratio and the maximum Compressive strength is 5.491 MPa at 0% plastic ratio. Meanwhile, for 28 days samples (S1, S2, S3, S4) are 8.708 MPa, 4.171 MPa, 4.099 MPa, and 1.977 MPa. The minimum Compressive strength of PIP is found in sample 4 which is 1.977 MPa at 25% plastic ratio and the maximum Compressive strength is 8.708 MPa at 0% plastic ratio. It can be seen from these results that the compressive strength is decreasing with the plastic ratio. From the observation, an extended curing age will result in a higher compressive strength value. The compressive strength of these PIPs did not meet the ASTM C936/C936M standard requirement of 50 to 55 MPa. The addition of a superplasticizer improved compressive strength to some extent, but as the percentage of HDPE increased, the strength of the sand bricks decreased.

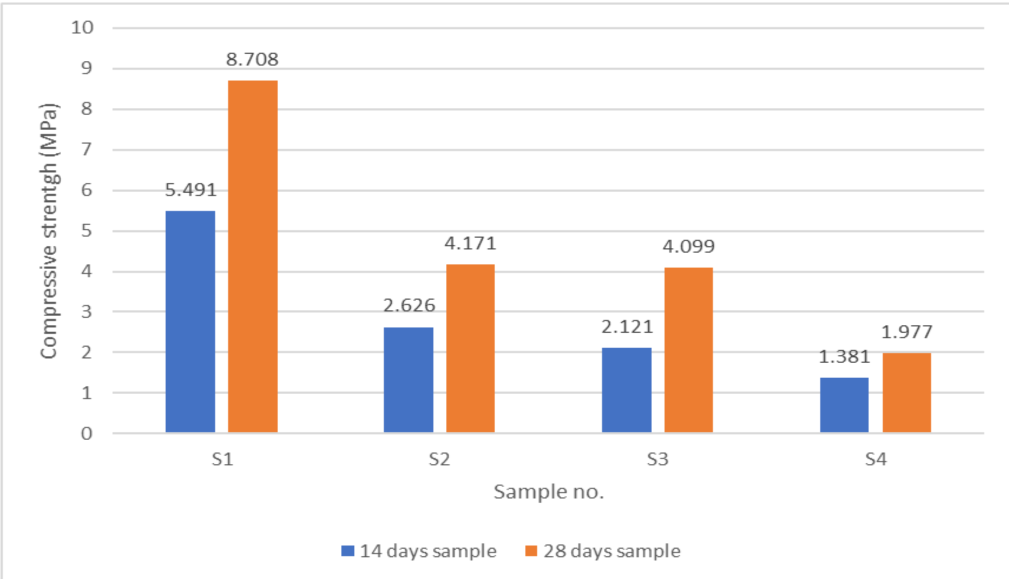

Fig. 4 *Data and Results for Compressive Strength*

4. Conclusion

In conclusion, the present findings from laboratory tests on plastic interlocking pavements (PIP) regarding compressive strength, water absorption, and density. It concludes that using HDPE as a sand replacement in PIP can create sustainable sand pavers, but those with 20%-30% HDPE do not meet the ASTM C936/C936M compressive strength standard. While superplasticizers can enhance strength, higher HDPE content reduces durability due to lower compressive strength. Water absorption increases with HDPE content, exceeding the 7% limit, which aids stormwater management in permeable paver systems. Density decreases with higher HDPE content, but all samples meet the ASTM C140/C140M range, resulting in lightweight, easier-to-handle pavers that reduce labour costs.

Further studies are needed to optimize HDPE replacement in PIP mix design. Recommendations for future research include exploring different mix design ratios and water-cement ratios, varying the percentage of HDPE replacement to gather more data, conducting additional tests such as thermal conductivity, and using superplasticizers to find the most suitable ratio for PIP.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (VOT Q146).

Conflict of Interest

There is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design, data collection, and manuscript preparation****: Muhamad Fatih Bin Khamsani, Muhamad Ammar Danial Bin Mohd Zamri, Muhammad Faiz Bin Mohd Talha, Aslila Binti Abd Kadir. All authors reviewed the results and approved the final version of the manuscript.*

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