# Utilization of Plastic Wastes in The Production of Pavement Blocks: A Study on Mechanical Properties

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## *ABSTRACT*

***This study investigates the utilization of plastic wastes, such as high-density polyethylene (HDPE), poly propylene (PP), and polyethylene terephthalate (PET) in the production of pavement block. These plastic were mixed in different ratios with cement, sand, and stone dust to produce durable and cost-effective blocks.The plastic wastes was shredded, melted (170$^0$C-290$^0$C), and mixed with fillers. The mixture was cast into moulds and tested for hardness and compressive strength). Significant improvements were observed: enhanced hardness (134N/mm$^{2,}$), satisfactory compressive strength (33.03N/m$^2$) compared to conventional blocks hardness 53.3N/mm$^2$ and compressive strength 5.08N/m$^2$) the plastic pavement blocks demonstrated superior performance. This research demonstrates the potential of plastic waste in construction, offering a sustainable solution for waste management and environmentally friendly infrastructure development.***

**Keywords: Plastic waste, Pavement blocks, cement, sand, stone dust**

## INTRODUCTION

Introduction Solid waste management has emerged as a significant challenge in Nigeria, particularly in its municipalities, which rank second highest in solid waste generation, producing nearly 0.40 kg per person per day[1]. The composition of this waste primarily includes organic and inorganic materials, classified into fermentable and non-fermentable categories. In Lagos, the situation is more pronounced, with municipal solid waste (MSW) generation averaging about 0.49 kg per person per day, exceeding the national average of 0.47 kg. Alarmingly, plastics constitute 14% of the total waste generated in the West Zone, where Lagos is located, reflecting an increasing trend compared to other regions. Traditional waste management practices, such as burning and land filling, prevalent across many municipalities, raise significant environmental concerns. These methods release harmful emissions, including greenhouse gases like carbon dioxide, carbon monoxide, and nitrous oxide, which contribute to global warming. Moreover, the aesthetic appeal of municipal areas is undermined by an accumulation of sachet water plastic waste, which presents an opportunity for recycling into construction materials[2]. With the rising use of plastic products for packaging—ranging from shopping bags to food wrappers—the generation of plastic waste is poised to escalate in the foreseeable future. Despite the nascent stage of recycled plastic products, innovative engineering applications are emerging globally, including their use in road pavements, furniture, and fishing lines; however, the application of recycled plastics in paving units remains underutilized. Given the pressing need for effective plastic waste management, exploring alternative solutions becomes paramount. Certain plastics, such as high-density polyethylene (HDPE), polypropylene (PP), and polyethylene terephthalate (PET), possess unique properties that make them viable substitutes for traditional construction materials. Their inherent durability, lightweight nature, and thermal insulation capabilities offer significant advantages, including enhanced water percolation, reduced storm water runoff, and minimized maintenance issues. Incorporating plastic waste into construction not only reduces material costs and supports a circular economy but also promotes sustainability by lowering carbon footprints and increasing design flexibility. This study aims to investigate the feasibility of integrating plastic waste into pavement blocks, focusing on their mechanical properties. By highlighting the potential of plastic waste in construction, the research seeks to provide a sustainable solution to waste management and contribute to environmentally friendly infrastructure development.

## MATERIALS AND METHOD

### *Sample Collection*

Plastic waste samples were collected from a plastic processing outlet located along Farin Gada Road, Jos. The collected samples were sorted through physical examination and subsequently confirmed using Fourier Transform Infrared (FTIR) analysis to identify the types of plastics present.

### *Sample Preparation and Processing*

### *Shredding of the Sample*

The sorted plastic waste was processed using a locally fabricated shredder, reducing the plastic into smaller pieces to facilitate the melting process.

### *Design and Fabrication of Mould and Heating Barrel*

A custom mould was designed and fabricated from mild steel, utilizing a 3mm sheet for the body and a 5mm plate for the base to withstand the high temperatures involved in the melting process. The moulds were crafted in various shapes and sizes, featuring grips to prevent slippage during operation. The dimensions of the heating barrel used in this process were as follows:

length = 26.5 cm, breadth = 8 cm, height = 6 cm.

### *Melting of Plastic*

Following shredding, the plastic was placed into a steel heating barrel, heated with a gas burner to facilitate melting. A digital temperature and humidity sensor (DHT11) was employed to monitor and record the melting temperature of the plastics, which included materials such as soda bottles, chairs, and buckets. The melting temperature ranged from approximately 170°C to 260°C. The melting points of PET, HDPE and PP are 240°C - 260°C, 120°C - 140°C, and 160°C - 170°C respectively.

### *Production of Pavement Blocks*

Pavement blocks were produced by mixing molten plastic with various aggregates in different proportions, after the plastic was shredded into smaller sizes; it was then poured into the heating barrel made of steel iron that has been heated with a gas burner underneath to supply heat for melting. A digital temperature and humidity sensor DHT11 which uses sensors to sense and read the temperature values and humidity was use to measure the melting temperature of the plastic. The melted plastics were a combination of different plastic materials which include soda bottles, chairs, car bombers and buckets. The combined shredded plastic starts melting at about 170$^0$C to about 290$^0$C as measured by the Temperature thermometer. The proportion of 1.5 kg plastic, 0.5-2.5 kg varying amounts of sand, cement and stone dust were selected for a comprehensive evaluation of the composite material's properties, to identify the optimal mix for best performance, understand how each material composition affects the composite's properties, balance strength, durability, and determine the ideal ratio for cost-effectiveness and sustainability ensure industry standard compliance (ASTM C672-17) and (ACI 201.2R-08), for easier selection of the most suitable composite composition for specific applications, such as construction (foundations, walls) infrastructures (bridges, road),or industrial settings (warehouses), considering factors like load-bearing capacity, exposure to hard chemicals, and environmental conditions. The melting ratio variations are shown below:

Table 1: Melting Ratio Variation for Plastic Pavement Blocks

| **S/N** | | **Molten Plastic (kg)** | **Stone Dust (kg)** | **Sand (kg)** | **Cement (kg)** |
|---|---|---|---|---|---|
| **1** | **Control** | - | - | 0.3 | 0.7 |
| **2** | **Plastic + Stone Dust** | 1.5 | 0.5 | - | - |
| | | 1.5 | 1.0 | - | - |
| | | 1.5 | 1.5 | - | - |
| | | 1.5 | 2.0 | - | - |
| | | 1.5 | 2.5 | - | - |
| **3** | **Plastic + Sand** | 1.5 | - | 0.5 | - |
| | | 1.5 | - | 1.0 | - |
| | | 1.5 | - | 1.5 | - |
| | | 1.5 | - | 2.0 | - |
| | | 1.5 | - | 2.5 | - |
| **4** | **Plastic + Sand + Cement** | 1.5 | - | 0.3 | 0.2 |

| | | | | | |
|---|---|---|---|---|---|
| | | 1.5 | - | 0.7 | 0.3 |
| | | 1.5 | - | 1.0 | 0.5 |
| | | 1.5 | - | 1.3 | 0.7 |
| | | 1.5 | - | 1.5 | 1.0 |
| **5** | **Plastic + Stone Dust + Cement** | 1.5 | 0.3 | - | 0.2 |
| | | 1.5 | 0.7 | - | 0.3 |
| | | 1.5 | 1.0 | - | 0.5 |
| | | 1.5 | 1.3 | - | 0.7 |
| | | 1.5 | 1.5 | - | 1.0 |

Plates 1a & 1b: Melting of the plastic waste

### *Casting*

The melted plastic was then poured into the already prepared mould with oil rub around the mould edges and allowed to take the shape of the mould freely to enable it get to every side of the mould in its molten form and for easy removal from the mould, this is for the pure plastic sample. While for the plastic-sand sample, the melted plastic was mixed manually in the barrel with different proportion of sand before the casting process.

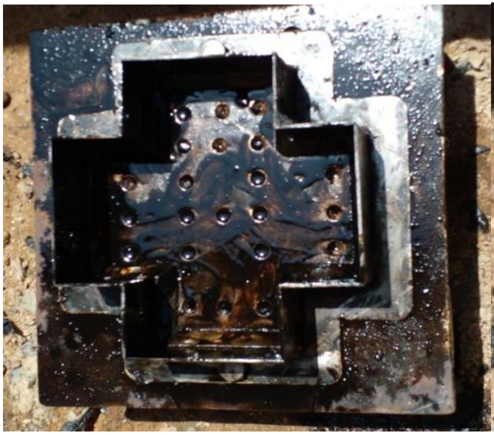

Plate 2a: Greasing of mould

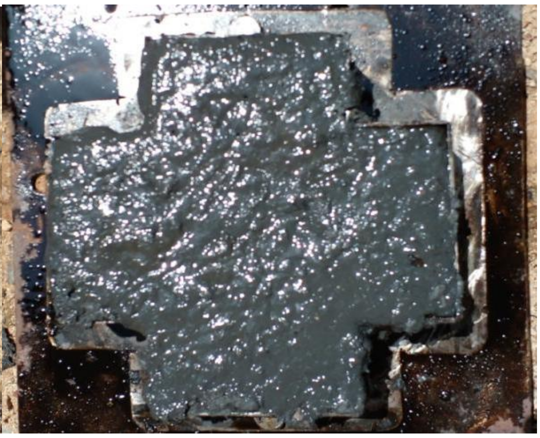

Plate 2b: Casting of the pavement block

***Removal of mould***

After the melted plastic was poured into the mould and allowed to take the shape of the mould, then allowed to cool under natural cooling process for 45 minutes. The mould was then removed to allowed free access of air for complete cooling. At this stage the plastic or plastic-sand interlocks were fully produced. And was allowed to stay for one month before the mechanical tests were done to test the properties of the tile and make comparison between the different samples.

Plates 3a & 3b: Developed plastic pavement block composites

***Mechanical tests***

The composite samples were air cured for 28days to assess their long-term strength and durability, following (ASTM C192/C192M) standards. They were prepared into different dimensions according to the various American Society for Testing and Materials (ASTM) Standard before carrying out the test analysis. The following mechanical tests were performed on the sample to test the integrity of the tile. These tests included; compression test and hardness test.

***Compression test***

Compressive test was carried out using Universal testing machine where the sample was prepared according to ASTM D695 standard, then loaded to the universal testing machine and subjected to control compressive loading for a period of time until failure occur. The mechanical properties such as minimum loading and maximum shear stress were determined. The result was then tabulated and displayed on the PC screen and printed out. The composite were air-cured at ambient temperature and relative humidity

Plate 4a: Universal Testing Machine

Plate 4b: Composite sample for Compressive strength test

***Hardness test***

The hardness test was conducted to evaluate the resistance of composite materials to indentation and wear. The hardness values were measured using the Vickers Hardness testing machines. Vickers hardness testing is carried out using ASTM E384 standard.

Plate 5a: Vickers Testing Machine

Plate 5b: Composite Sample for Hardness Test

## RESULTS AND DISCUSSION

### HARDNESS TEST

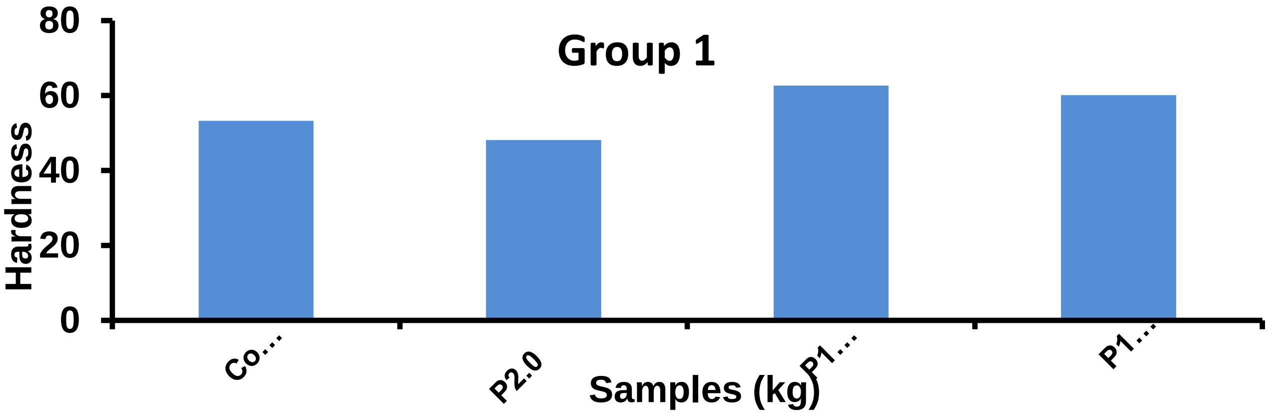

**Fig 1:** Hardness test of group 1

As shown in Figure 1, the hardness test results indicated significant variations among the samples. The control sample had a hardness of 53.3 N/mm², while the pure plastic sample measured 48.1 N/mm². The addition of 0.2 kg of sand, 0.2 kg of stone dust, and 0.3 kg of cement to 1.5 kg of plastic significantly increased the hardness to 62.1 N/mm², highlighting the critical role of cement in enhancing hardness due to its high calcium oxide content and binding properties[3]. These findings are consistent with previous research on cement-based composites[4]. However, incorporating stone dust into the plastic-cement mixture resulted in a slight decrease in hardness to 60.1 N/mm², attributed to the added bulk and stability[5]. The optimal plastic-to-cement ratio of 1:0.2 achieved the highest hardness, while the inclusion of sand and stone dust maintained acceptable hardness levels, supporting the development of durable and sustainable construction materials[6]. In summary, adding cement to plastic enhances hardness, with a 1.5 kg to 0.3 kg ratio resulting in 62.1 N/mm², making it an ideal choice for durable and eco-friendly solutions.

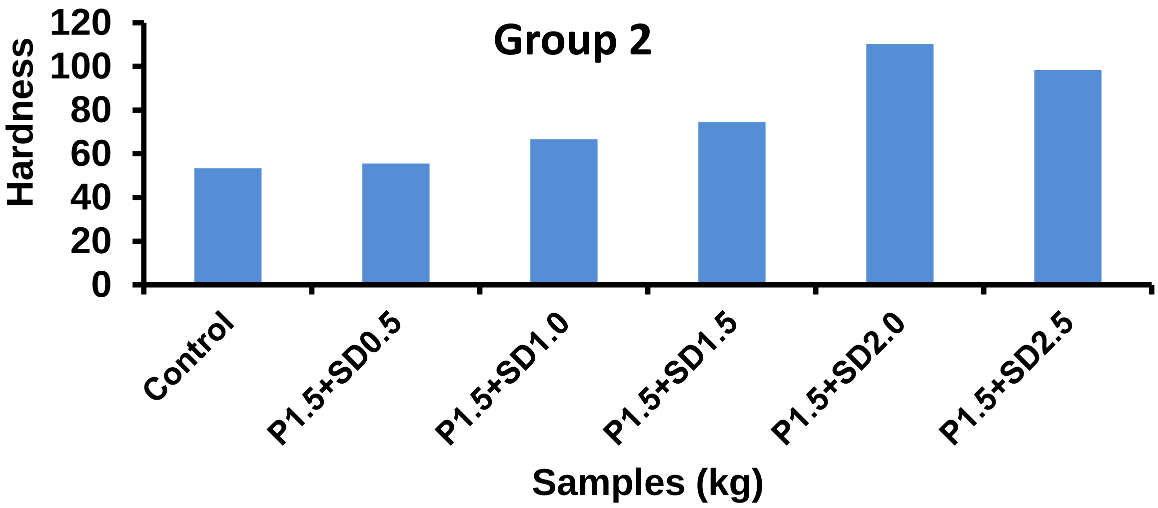

**Figure 2:** Hardness test of group 2

From figure 2, the group 2 hardness test results revealed significant enhancements with increased stone dust content in the composite. The control sample exhibited (53.3 N/mm²), hardness, whereas the composite samples demonstrated substantial increases: 1.5kg plastic:0.5kg stone dust (55.5N/mm²), 1.5kg plastic: 1.0kg stone dust (66.7N/mm²), 1.5kg plastic:1.5kg stone dust (74.6N/mm²), 1.5kg plastic: 2.0kg stone dust (110.3 N/mm²), and 1.5kg plastic:2.5kg stone dust (98.5N/mm²). The optimal ratio of 1.5kg plastic to 2.0kg stone dust achieved the highest hardness, attributed to stone dust's high silica content[5], which contributes to increased hardness due to its abrasive and filling effects[4]. The sustainable composite material, utilizing recycled plastic waste, presents a promising solution for infrastructure development, particularly durable plastic pavement blocks, roads, walkways, and industrial flooring[7]. The findings conclude that incorporating stone dust into plastic enhances hardness, making it suitable for construction applications[8], offering environmental benefits through waste reduction and potential cost savings[9].

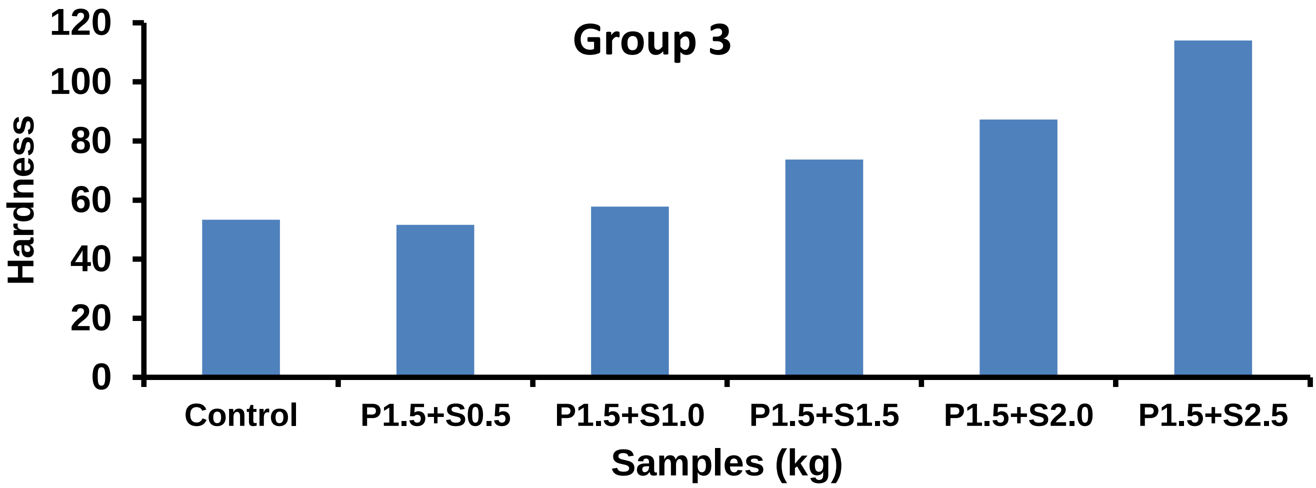

**Figure 3:** Hardness test of group 3

From figure 3, the plastic-sand composite hardness tests yielded remarkable results, showcasing the significant impact of sand content on durability. Maintaining a constant 1.5kg plastic, varying sand ratios produced substantial hardness increases: 51.6N/mm²(0.5kg sand), 57.8N/mm²(1.0kg sand) , 73.7N/mm² (1.5kg sand), 87.3N/mm² (2.0kg sand), and 114N/mm² (2.5kg sand), surpassing the control sample's (53.3N/mm²)[5]. Sand's high quartz content boosts rigidity and deformation resistance. Achieving optimal hardness at a 1.1.67 plastic-sand ratio, this eco-friendly composite demonstrates potential for infrastructure applications, including durable pavement blocks, roads, and industrial flooring[7], offering environmental benefits through reduced plastic waste[8] and cost savings[9]. The significant hardness enhancement supports the suitability of plastic-sand composites for high traffic areas providing alternative for traditional construction materials[10].

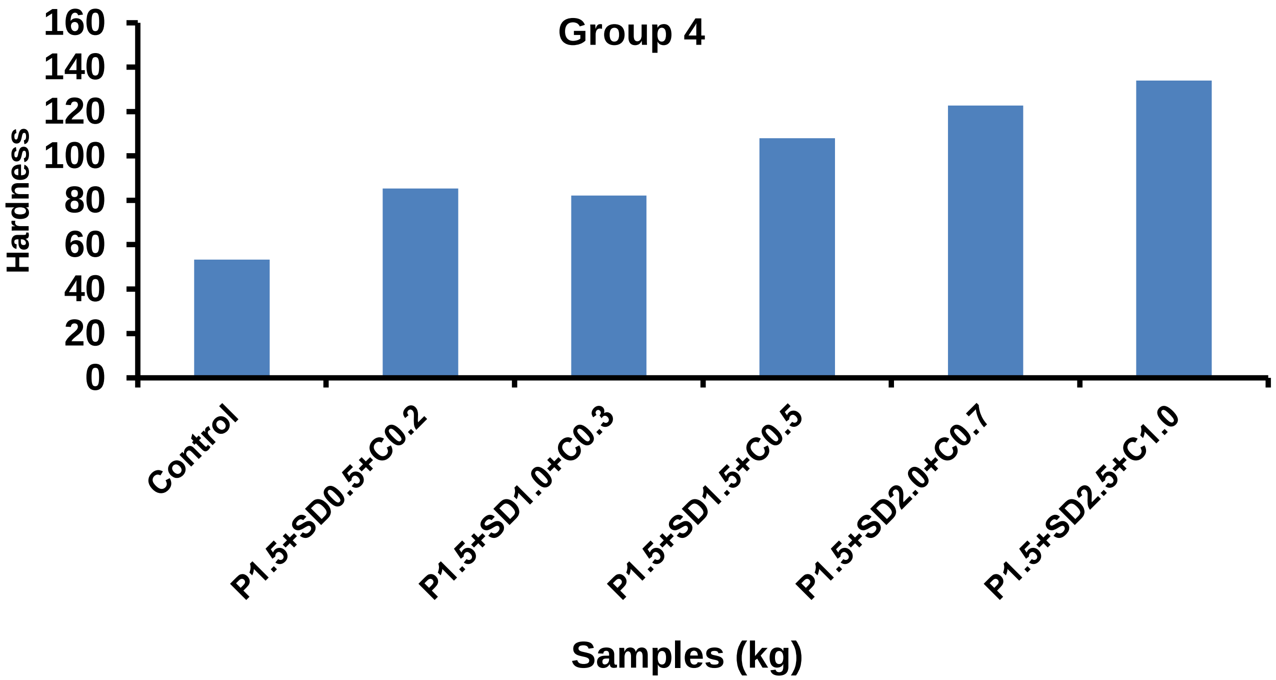

**Figure 4:** Hardness test of group 4

From figure 4 the plastic-stone dust-cement composite tile test results reveal significant hardness enhancements with increased stone dust and cement content. The optimal ratio of 1.5kg : 2.5kg stone dust:1.0kg cement achieved the highest hardness (134N/mm²) by 152%[5]. This substantial increase stems from stone dust's high silica content, boosting rigidity[4], and cement's binding properties, enhancing durability[3]. The findings demonstrate potential for infrastructure applications, including durable pavement blocks, and industrial flooring[7], leveraging recycled plastic waste and offering environmental benefits[9] and cost savings[8]. Specifically, these composites suit high-traffic areas, extreme weather conditions, and heavy-industrial use, providing a sustainable, resilient, and eco-friendly alternative to traditional construction materials[10].

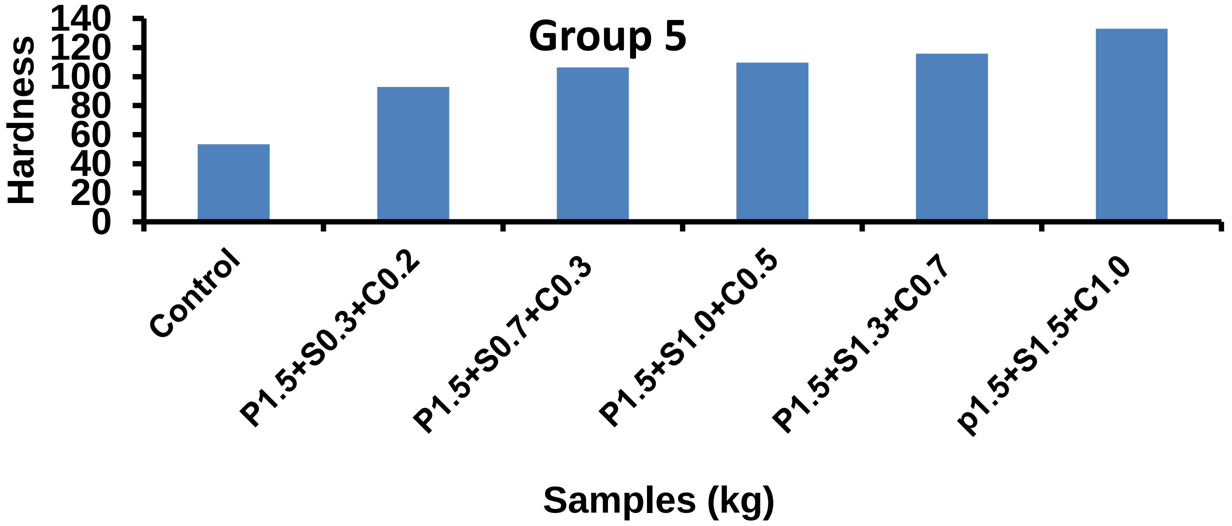

**Fig 5:** Hardness test of group 5

This current study's optimal proportion, 1.5 kg plastic, 2.5 kg stone dust, and 1.0 kg cement, achieved 134 N/mm² hardness, surpassing previous results. Singh et al.[11] reported a similar proportion (1.5 kg plastic, 1.5 kg sand, 1.0 kg cement) with 128 N/mm² hardness.

From figure 5, the plastic-sand-cement composite tile test results show significant hardness enhancements with increased sand and cement content. The optimal ratio of 1:1:0.67 (1.5kg plastic 1.5kg sand: 1.0kg cement) achieved the highest hardness (133N/mm²), surpassing the control sample (53.3N/mm) by 150%[5]. This increase stems from sand's high quartz content, boosting rigidity[4], and cement's binding properties, enhancing durability[3]. The composite's improved density, reduced porosity, and enhanced interlocking between particles contribute to its exceptional hardness[9]. High traffic locations and heavy industrial use such as roadways and industrial flooring[7] are suitable applications for this composite material.

## COMPRESSIVE STRENGHT TEST

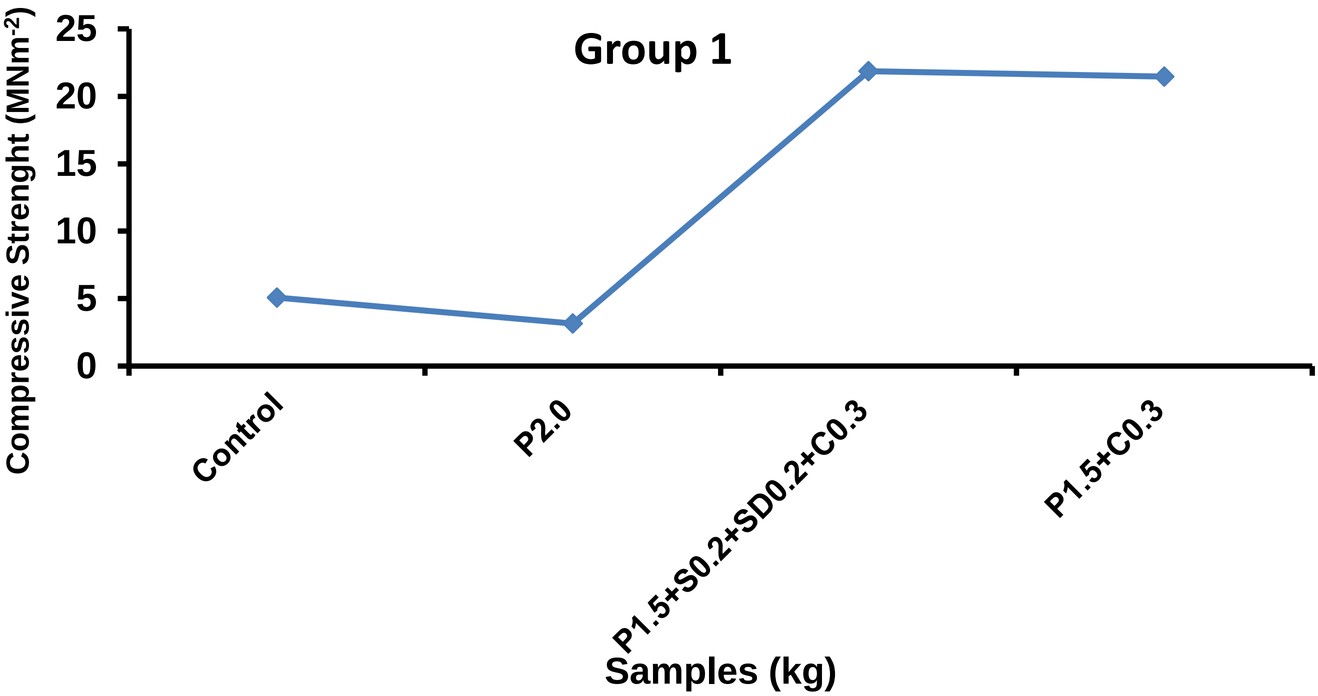

**Figure 6:** Compressive strength test of group 1

From figure 6, the compressive strength test results for group 1 show significant enhancements with hybrid composites. The control sample exhibited 5.08N/mm² compressive strength with a 2.3kN max load, while the plastic block alone showed (3.15N/mm²) strength with 1.3kN max load. However, adding sand and cement improved strength. Sample 3 (plastic 1.5kg, sand 0.2kg, cement 0.3kg) reached 21.86N/mm² with 8.8kN max load, and sample 4 (plastic 1.5kg, cement 0.3kg) reached 21.45N/mm² with 8.2kN max load. This 4-fold increase is attributed to cement's binding properties[3], sand's rigidity[4], and plastic's flexible matrix[5]. These hybrid composites demonstrate potential for structural applications, offering improved compressive strength and durability[7], and suggest optimization of material ratios and composition for further enhanced performance[9].

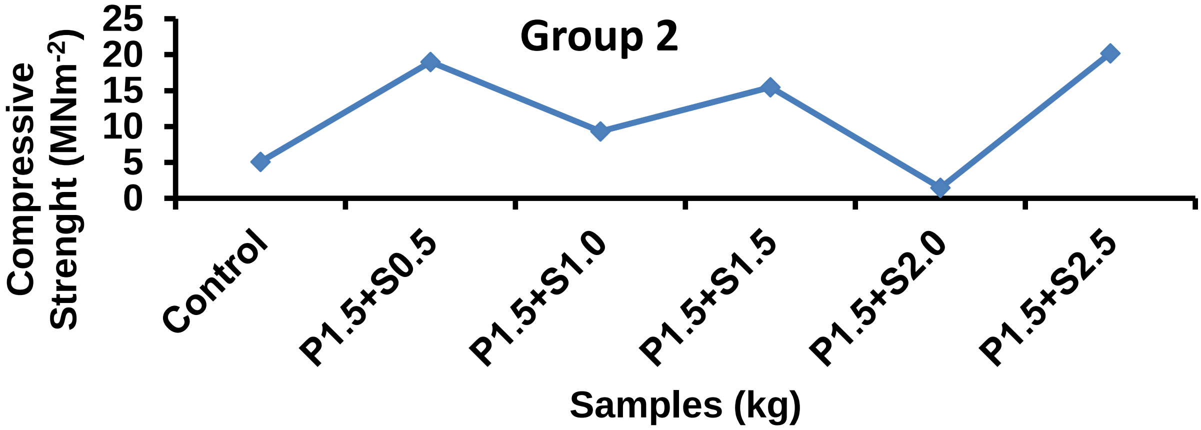

**Figure 7:** Compressive strength test of group 2

From figure 7, the Group 2 compressive results show varying strengths with different sand-plastic ratios. The control sample exhibited (5.08N/mm²) strength with 2.3kN max load, while samples with sand additions showed increased strength, except sample 5. Sample 2 (plastic 1.5kg, sand 1.5 kg) achieved 18.99N/mm² with 6.2kN max load, Sample 4 (plastic 1.5kg, sand 1.5 kg) reached 15.49N/mm² with 5.5kN max load, and sample 6 (plastic 1.5kg, sand 2.5kg) attained 20.21N/mm² with 7.6kN max load. Sample 5 (plastic 1.5kg, sand 2.0kg) showed an anomalously low compressive strength 1.46N/mm² with 0.6kN max load. Sample 5's lower compressive strength (1.46N/mm²) compared to sample 6 (20.21N/mm²) may be due to factors such as suboptimal sand-plastic ratio, inconsistent aggregate distribution, inadequate mixing[14], or oversaturation[12]. Testing variability could also contribute to the difference.

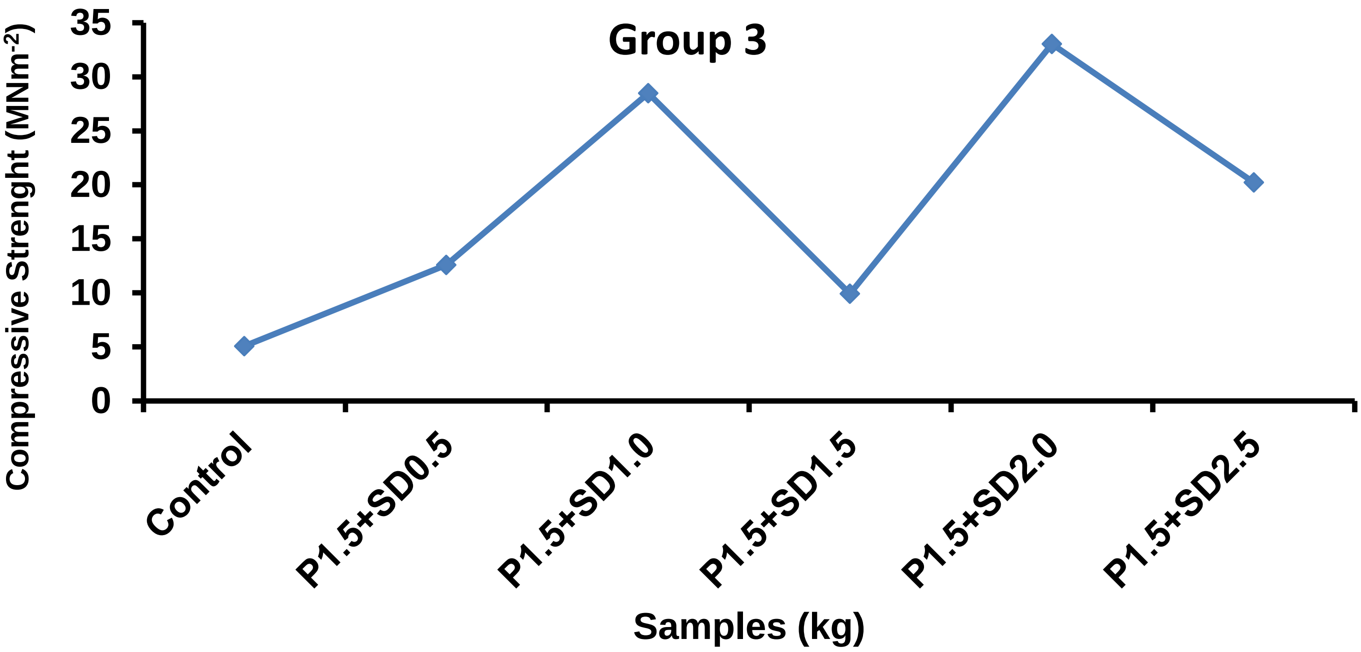

**Figure 8:** Compressive strength test of group 3

To understand sample 5'ss performance, re-testing, microstructure analysis, and adjusting the sand-plastic ratio or mixing procedures may be necessary. Despite this, sample 5 still exceeds the control sample's strength (5.08N/mm²) indicating the potential for optimization within the (0.5-1.5 kg) sand-plastic ratio range for enhanced compressive strength, suitable for construction material[13].

From figure 8, the Group 3 compressive results show varying strengths with different stone dust-plastic ratios. The control sample exhibited (5.08N/mm²) strength with 2.3kN max load, sample 2 (plastic 1.5 kg, stone dust 0.5 kg) achieved 12.59 N/mm² with 4.3kN max load, sample 3 (plastic 1.5kg, stone dust 1.0kg) reached 28.49N/mm² with 9.2kN max load, and sample 5 (plastic 1.5kg, stone dust 2.0kg) attained 33.03N/mm² with 10.7kN max load. Sample 4 (plastic 1.5kg, stone dust 1.5kg) showed a relatively low 9.92 N/mm² with 8.2kN max load, likely due to an optimal ratio disruption, causing aggregate settlement[15] and reduced interfacial bonding[16]. Sample 6 (plastic 1.5kg, stone dust 2.5kg) returned to 20.21 N/mm² with 7.6kN max load. Optimal stone dust-plastic ratios enhance compressive strength, suitable for construction materials[13], infrastructure components, and other structural applications, highlighting the importance of ratio optimization for developing strong, durable composite materials[17]. The current study's pavement blocks (1.5 kg plastic, 1.0 kg stone dust) 1.5:1 ratio achieved 28.49 N/mm² compressive strength, surpassing [5] (1.5:1 with 24.5 N/mm²), [18] (1.5:1 ratio achieved 22.1 N/mm²), and [19] (1.5:1 ratio achieved 20.08 N/mm²). Similarly, Sample 4 of the current study (1.5 kg plastic + 2.0 kg stone dust) with 1.5:2 resulted in 33.03 N/mm², exceeding [5] (1.5:2 resulted in 29.2 N/mm²), [18] (1.5:2 with ratio achieved 26.5 N/mm²), and [19] (1.5:2 achieved 24.8 N/mm²).

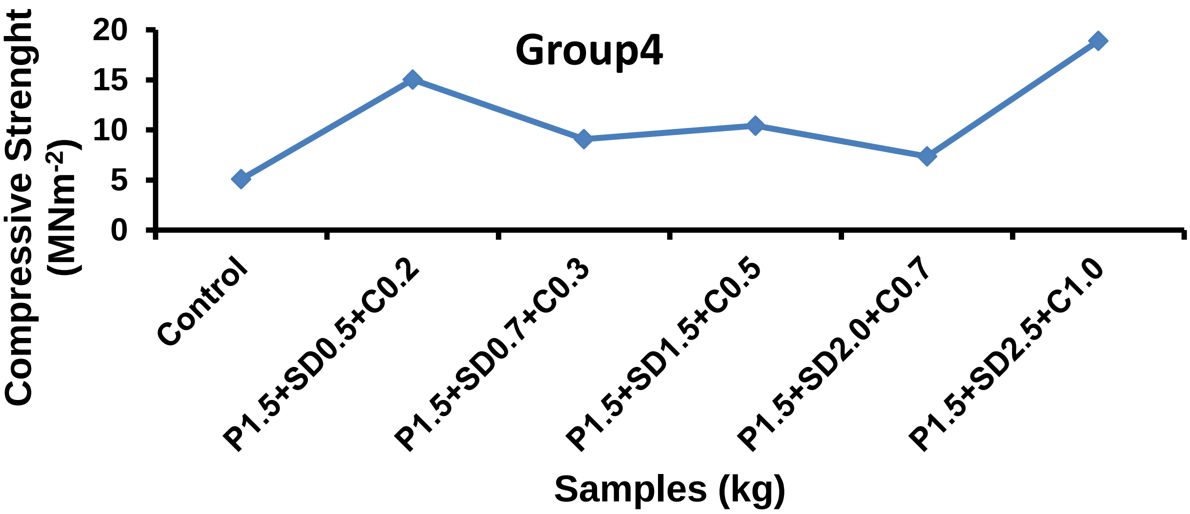

**Figure 9:** Compressive strength test of group 4

From figure 9, the Group 4 compressive results demonstrate the impact of cement addition on plastic and stone dust composites, with sample 2 (plastic 1.5kg, stone dust 0.5kg, cement 0.2kg) achieving (15.03N/mm²) strength due to cement's binding properties[12]. Increasing cement content didn't consistently enhance strength, suggesting optimal ratios[23].

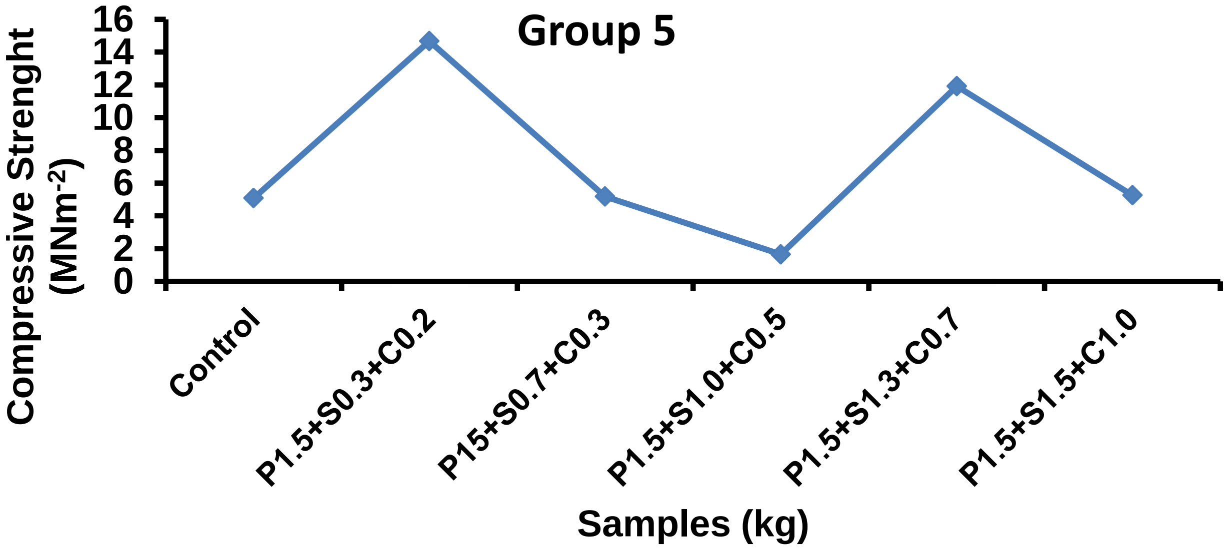

**Figure 10:** Compressive strength test of group 5

Samples 3 and 4 showed lower strength (9.08N/mm² and 7.35N/mm²) due to excess cement, sample 5's low strength may be attributed to over-saturation or aggregate settlement[15], while sample 6 regained strength (18.9 N/mm²) with optimal cement ratio (1.0 kg cement to 2.5 kg stone dust) and enhanced interfacial bonding[23]. The control sample exhibited (5.4N/mm²) strength with 2.3kN maximum load.

From figure 10, the Group 5 results demonstrate varying compressive strengths with different sand-plastic-cement additions. Sample 2 (plastic 1.5 kg, sand 0.5 kg, cement 0.2 kg) achieved the highest strength (14.67 N/mm²) due to optimal ratios[20]. Increasing sand content decreased strength, suggesting excess sand disrupts optimal ratios[22]. Sample 4 regained strength (11.92N/mm²) with optimal sand-cement ratio and improved mixing[24]. Key applications include construction materials[13].

## CONCLUSION

In conclusion, this study presents a novel approach to addressing plastic waste by transforming high-density polyethylene (HDPE), polypropylene (PP), and polyethylene terephthalate (PET) into high-performance pavement blocks. Through innovative methods of shredding, melting, and mixing with traditional materials, remarkable improvements was achieved in terms of mechanical properties, such as zero water absorption, enhanced hardness, and satisfactory compressive strength compared to conventional blocks. This research not only highlights the feasibility of utilizing plastic waste in construction but also underscores its potential to contribute to sustainable waste management practices. By demonstrating the economic viability and superior performance of plastic-based blocks, this study paves the way for environmentally friendly infrastructure development, showcasing a promising solution to both plastic pollution and the demand for durable building materials.

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