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Recycling and Repurposing Plastic Waste in Ajayi Crowther as a Partial Replacement for Quarry Dust in Interlocking Block Production

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ABSTRACT: Plastic waste disposal remains a significant environmental challenge due to its non-degradable nature. Additionally, the rising cost of construction materials necessitates alternative sustainable solutions. This study evaluates the recycling and repurposing of plastic waste in Ajayi Crowther as a partial replacement for quarry dust in interlocking block production to determine its feasibility in sustainable construction.

Waste plastic bottles were collected, burnt, and milled into powder form. Specific gravity and sieve analysis tests were conducted on both quarry dust and milled waste plastic bottles (MWPB). The materials were batched by weight using a 1:6 cement-quarry dust mix ratio with a 0.45 water-cement ratio. A slump test was performed to assess workability, and interlocking paving blocks were cast with 0%, 10%, 20%, 30%, and 40% MWPB replacement and cured for 7, 14, 21, and 28 days. The mechanical properties of the paving stones were evaluated through compressive strength, splitting tensile strength, and flexural strength tests.

The results indicated that quarry dust exhibited a specific gravity of 2.39 and a well-graded particle distribution, while MWPB had a specific gravity of 1.08 and a gap-graded particle structure. The slump test showed increased workability with higher MWPB content. However, compressive strength values for 7-day curing decreased from 11.5 MPa (0% MWPB) to 4.24 MPa (40% MWPB). Similar declining trends were observed in splitting tensile and flexural strengths, highlighting a reduction in overall structural integrity with increased plastic content.

This research demonstrates that while incorporating MWPB enhances workability, it negatively impacts strength, limiting its application in high-load-bearing structures. However, interlocking blocks produced with up to 20% MWPB can be effectively used in low-traffic areas such as pedestrian pathways and recreational spaces. This study advances sustainable construction by providing an innovative approach to reducing plastic waste while maintaining construction quality.

KEYWORDS: Milled waste Plastic (MWP), Paving stones, Workability, Compressive Strength, Interlocking blocks.

1.0 INTRODUCTION

Many educational institutions in Nigeria, such as Ajayi Crowther University, face significant challenges related to plastic waste pollution. The improper disposal of plastic waste within academic environments contributes to environmental degradation and negatively affects the aesthetics of campuses. Ensuring cleanliness and sustainability through the adoption of eco-friendly materials, such as interlocking paving stones, is essential for maintaining a conducive learning atmosphere (Olaniyi et al., 2025). The production of interlocking paving stones traditionally involves a specific mix of cement and fine aggregates, mainly quarry dust. However, the rising cost of these conventional materials in Nigeria has led to increased construction expenses (Olaniyi et al., 2025). Given the abundance of plastic waste in educational areas, this study investigates the potential of incorporating milled plastic waste as a partial replacement for quarry dust. The aim is to promote environmental sustainability by reducing plastic waste pollution while also minimizing the cost of producing interlocking paving stones.

2.0 METHODOLOGY

2.1 Materials Used

The materials used for producing interlocking paving blocks with Milled Waste Plastic Bottle (MWPB) as partial replacement for quarry dust include Portland cement of grade 42.5, free from lumps and conforming to BS EN 197-1:2011, sourced from an open market in Oyo; quarry dust obtained from a quarry in Ibadan, meeting BS EN 12620:2013 standards and enhancing compactness; and MWPB derived from cleaned, dried, shredded, and milled plastic bottles collected within Ajayi Crowther University as shown in figure 1to ensure consistency in the mix.

Figure 1: plastic waste bottles collected within the Ajayi Crowther University premises

2.2 Production of Milled / Powdered Plastic

Plastic bottles were collected from various locations within the Ajayi Crowther University premises. They were thoroughly cleaned and sorted to remove foreign and non-plastic materials. The collected bottles were stored in clean containers, and the average weight of a single bottle was measured to be 20g. The plastic waste was then subjected to an open combustion process, where it was heated to a molten stage and allowed to solidify, as illustrated in Figure 2. The solidified plastic was broken into smaller pebbles before being milled into fine powder using a hammer mill machine and the powdered Milled plastics. The milled samples were then sieved using standard sieves to determine the particle size distribution.

This process ensured that the Milled Waste Plastic Bottle (MWPB) was adequately prepared for use as a partial replacement for quarry dust in the production of interlocking paving blocks.

Figure 2: Burning of waste plastic bottles

2.3 Specific Gravity Test

The specific gravity test was used to measure the strength and quality of quarry dust and milled waste plastic bottles (MWPB) used in the study of Recycling and Repurposing Plastic Waste in Ajayi Crowther as a Partial Replacement for Quarry Dust in Interlocking Block Production. Apparatus and materials for this test include a pycnometer bottle, a weighing balance sensitive to 0.01 grams, a vacuum pump, and distilled water. The specific gravity of the milled waste plastic bottles and the quarry dust was determined in accordance with BS standards.

2.4 Sieve Analysis

Sieve analysis was carried out on the quarry dust to determine the particle size distribution of quarry dust. This was done by shifting a weighed sample of quarry dust through a stack of wire mesh sieves on a mechanical sieve shaker, separating it into discrete size ranges. A sieve shaker was used to vibrate the sieve stack for a period of time, after which each sieve with retained quarry dust was weighed and recorded.

Sieve analysis was conducted on the quarry dust and milled plastic after oven drying for 24 hours in accordance with BS 1377-1979.

2.5 Casting and Curing of Paver Stones

The inner surface of the mould was lubricated with engine oil to facilitate the easy removal of the cast paver stone, after coating the moulds with engine oil, a mixture of cement, quarry dust, and milled waste plastic was batched by weight in a ratio of 1:6 (cement to quarry dust). A water-cement ratio of 0.45 was adopted to form a paste, which was poured into each mould using a hand trowel, with the surface leveled. The mixing of materials was done manually using shovels, head pans, and buckets.

For each mix, 15 specimens were produced, totaling 180 paving stone specimens, with 45 specimens crushed per curing age. The weight of the quarry dust was partially replaced with milled waste plastic at replacement levels of 10%, 20%, 30%, 40%, and 50%. After obtaining the weight of cement, milled waste plastic bottles, and quarry dust required, mixing was done manually by adding water to the constituents and thoroughly mixing. The mixed proportions were cast and placed into the moulds with the aid of a hand trowel. The cast products were then left for 24 hours to set properly before being removed from the mould as shown in figure 3

Figure 3: Cast Interlocks

2.6 Test on Fresh Concrete

The slump test was conducted to determine the workability of the fresh concrete.

Procedure:

1. The slump cone was greased and placed on a flat, non-absorbent surface.
2. Concrete was placed into the cone in three layers.
3. Each layer was tamped 25 times using a 16mm diameter rod.
4. The slump cone was carefully lifted vertically and placed upside down beside the concrete.
5. A tamping rod was placed across the top of the inverted cone, extending over the concrete.
6. The height difference between the rod and the displaced concrete was measured to determine the slump value.

This measurement helps assess the concrete's consistency and suitability for construction.

2.7 Comprehensive test on Hardened Concrete

Compressive strength test on the cured paving stone specimens was carried out in accordance with BS EN 12390-3:2019 at 7, 14, 21 and 28 days. The specimen was loaded up on the compression testing machine until failure occurs. The maximum load capacity of. Compressive strength machine used for this research is 2000 kN. The strength of each specimens was determined using equation 3.2.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Crushing}}{\text{Cross section area of paving stone}} \quad 3.2$$

2.8 Flexural Strength Test

Flexural strength test on the cured paving stone specimens was performed in accordance with BS EN 12390-3:2019 at 7, 14, 21 and 28 days. The specimen was loaded up in the universal testing machine until failure occurs. The maximum load capacity of the UTM machine used is 600KN. Flexural strength value of the specimen was determined using equation 3.3.

$$\text{Flexural strength} - \sigma\ (N/mm^2) = \frac{3PL}{2BH^2} \quad 3.3$$

Where P is the breaking load, L is the span of the simple support, B is the width and H is the thickness of the specimen.

2.9 Tensile Strength Test

Tensile strength test on the cured paving stone specimens was performed in accordance with BS EN 12390-3:2019 at 7, 14, 21 and 28 days. The specimen was loaded up in the universal testing machine until failure occurs. The maximum load capacity of the machine used is 600 kN. Flexural strength value of the specimen was determined using equation 3.4

$T=2P / \pi LD$ Equation 3.4

Where:

- T = Splitting tensile strength (MPa)
- P = Maximum applied load (kN)
- L = Length of specimen (m)
- D = Diameter of specimen (m)

The test was performed following the guidelines in BS EN 12390-6:2019

3.0 RESULTS AND DISCUSSION

3.1 Specific Gravity of Quarry dust and Milled Waste Plastic

The specific gravity results for quarry dust (Table 1) and milled waste plastic (MWP) powder shown in (Table 2) provide key insights into their density and suitability for use in interlocking paving stone production.

Specific Gravity of Quarry Dust

- The specific gravity of quarry dust was determined to be 2.39, which falls within the acceptable range for construction materials.
- The consistency of the results across multiple trials highlights minimal variability, confirming the reliability of the test.
- A higher specific gravity indicates that quarry dust is relatively dense and compact, which enhances strength and durability in paving stone production.
- This property ensures that quarry dust can effectively replace conventional fine aggregates, contributing to the structural integrity of the interlocking blocks.

Specific Gravity of Milled Waste Plastic (MWP) Powder

- The specific gravity of MWP powder was 1.08, which is significantly lower than quarry dust and other conventional materials (2.30–2.80).
- The results from this study align with findings by Samson Duna et al. (2017), who recorded a specific gravity of 1.06 for similar MWP materials.
- The low specific gravity indicates that MWP is a lighter material, which may affect the density, weight, and strength characteristics of the paving stones when used as a partial replacement for quarry dust.
- While some variations (0.81–1.21) were observed across trials, the average value of 1.08 provides a reliable benchmark for understanding the lightweight nature of MWP.

Impact on Interlocking Paving Stone Production

- The higher density of quarry dust ensures that paving stones maintain adequate strength and durability.
- The lower density of MWP suggests that replacing quarry dust with MWP will likely result in lighter paving stones, which could be beneficial for applications requiring reduced weight but may also impact compressive strength.
- To optimize performance, the replacement percentage of MWP should be carefully controlled to balance workability, strength, and sustainability in paving stone production.

These findings reinforce the potential of recycling plastic waste for sustainable construction while ensuring that the mechanical properties of interlocking paving stones are maintained within acceptable limits.

Table 1: The specific gravity results for quarry dust

S/N	**W1 (g)**	**W2 (g)**	**W3 (g)**	**W4 (g)**	**Gs**
1	562.51	814.26	1295.33	1115.52	2.39
2	562.51	814.26	1295.33	1115.52	2.39
3	562.51	814.26	1295.33	1115.52	2.39
Average Gs					**2.39**

Table 2: Specific gravity of MWPB

S/N	W1 (g)	W2 (g)	W3 (g)	W4 (g)	Gs
1	376	458	1450	1436	1.18
2	378	508	1450	1440	1.08
3	374	558	1290	1332	0.98
Average Gs					**1.08**

3.2 Sieve Analysis of Quarry Dust and Waste Plastic Bottle

The sieve analysis results for quarry dust and milled waste plastic (MWP) powder provide valuable insights into their particle size distributions, which are critical for their role in interlocking paving stone production.

Quarry Dust Analysis

- The quarry dust exhibited a well-graded distribution, indicating a mix of different particle sizes.
- As sieve size decreased, the percentage of mass retained increased, meaning that larger particles dominated the sample.
- A significant portion of quarry dust particles falls within the 600 µm to 1.18 mm range, with finer particles passing through smaller sieves.
- This gradation pattern is beneficial for concrete applications, as it enhances particle packing, reduces voids, and improves the strength and durability of interlocking paving stones.

Milled Waste Plastic (MWP) Powder Analysis

- The MWP powder also showed a graded distribution, but larger particle sizes were more prevalent compared to quarry dust.
- As sieve size decreased, the percentage mass retained increased, indicating that a significant portion of MWP particles remained in larger sieves.
- This implies that MWP particles may have coarser textures, affecting workability and bonding when mixed with cementitious materials.

Impact on Interlocking Paving Stone Production

- Quarry dust, being well-graded, contributes to good compaction and strength development in paving stones.
- MWP powder, when used as a partial replacement, may influence workability, density, and mechanical properties of the mix.
- The combined analysis shown in (Figure 4) will help in optimizing the blend proportions to achieve sustainable and structurally sound paving stones.

This analysis underscores the suitability of quarry dust and MWP powder in recycling and repurposing plastic waste as a partial replacement for quarry dust in interlocking block production, aligning with the study's objectives.

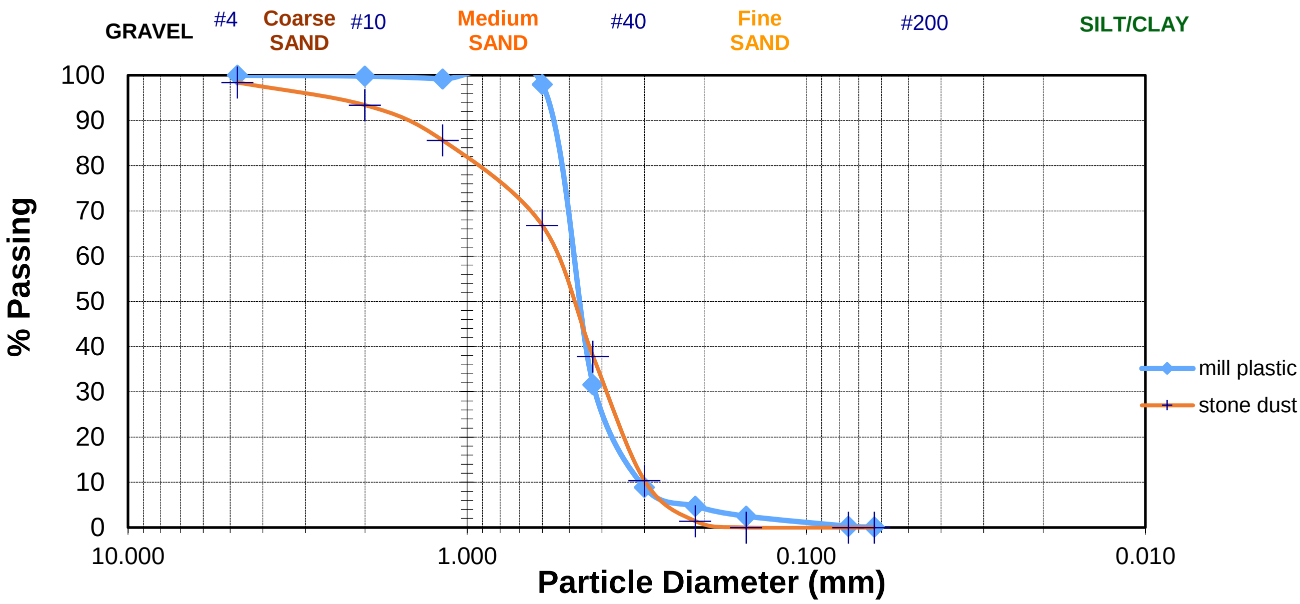

Figure 4: Gradation graph of quarry dust and milled waste plastic bottle

3.3 Compressive Strength on hardened Paving stones

Table 3 presents the compressive strength results of interlocking blocks at different curing periods (7, 14, 21, and 28 days) with varying percentages of recycled plastic waste as a partial replacement for quarry dust. The results show that as the percentage of recycled plastic waste increases from

10% to 40%, the compressive strength of the interlocking blocks decreases. However, the strength improves over time, with higher values recorded at 28 days compared to 21, 14, and 7 days.

This reduction in strength suggests that while replacing quarry dust with recycled plastic waste may contribute to sustainability, it negatively affects the load-bearing capacity of the interlocking blocks. Therefore, careful optimization of the replacement percentage is necessary to balance sustainability with structural performance. The detailed data is shown in the figure 5 below.

Table 3: Compressive strength result table

Percentage Replacement (%)	7 Days	14 Days	21 Days	28 Days
0	16.45	17.63	17.69	18.15
10	14.94	17.37	17.52	17.47
20	9.25	14.34	14.93	14.93
30	8.19	12.17	12.80	13.69
40	6.06	7.04	11.35	11.47

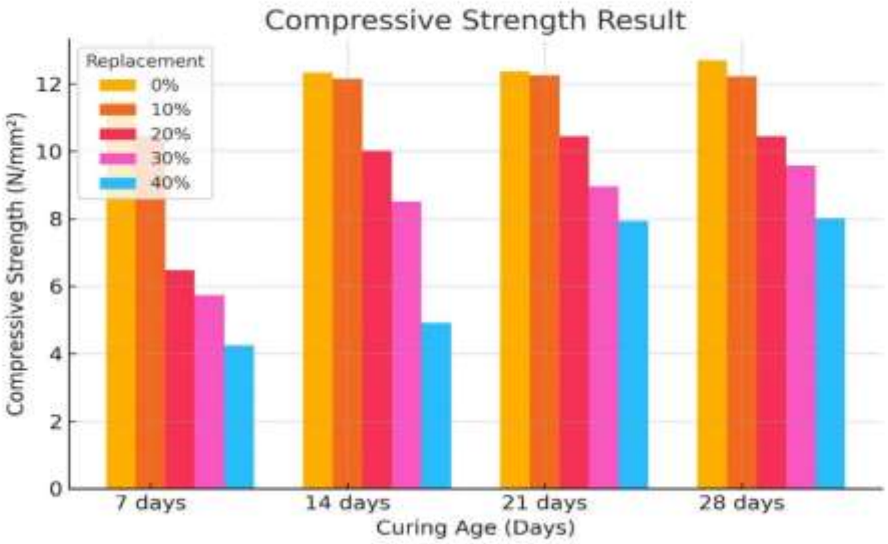

Figure 5 Compressive Strength Result with MWPB Replacement

3.4 Splitting tensile test on hardened Paving stones with MWPB Replacement

Table 4 presents the splitting tensile strength results for interlocking blocks with different percentages of recycled plastic waste as a partial replacement for quarry dust at various curing periods (7, 14, 21, and 28 days). The results indicate a consistent decline in tensile strength as the percentage of recycled plastic waste increases. At 7 days, the control sample (0% replacement) exhibits the highest strength, followed by the 10% replacement, with further reductions as the replacement level increases.

Despite the overall decrease in tensile strength, the results also show that strength improves with curing time, with 28-day values exceeding those of 21, 14, and 7 days. This suggests that while recycled plastic waste may enhance sustainability, its inclusion reduces the tensile capacity of the interlocking blocks, potentially affecting their long-term durability. The detailed figure is provided below in figure 6.

Table 4: Splitting tensile test on hardened Paving stones with MWPB Replacement

Percentage Replacement	7 Days	14 Days	21 Days	28 Days
0%	2.64	3.18	3.48	3.92
10%	2.27	2.72	3.19	3.48
20%	1.98	2.20	2.39	2.78
30%	1.39	1.68	2.04	2.38
40%	1.44	1.79	1.85	1.94

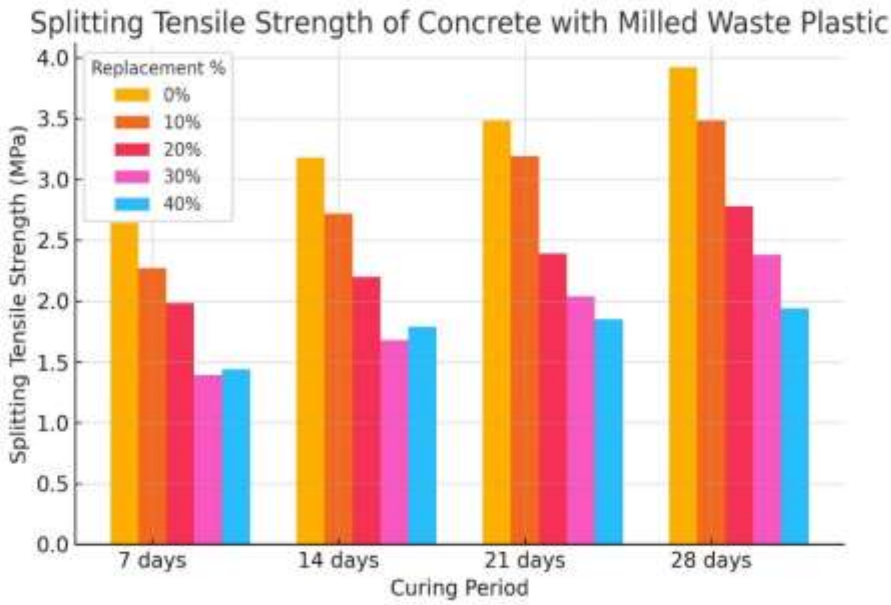

Figure 6Splitting Tensile Result with MWPB Replacement

3.5 Flexural Strength on hardened Paving stones with MWPB Replacement

The flexural strength results presented in table 5 illustrate the performance of interlocking paving stones produced with varying percentages of recycled plastic waste as a partial replacement for quarry dust at different curing periods (7, 14, 21, and 28 days). A clear trend is observed: as the percentage of recycled plastic waste increases, the flexural strength consistently decreases across all curing durations. This suggests that higher concentrations of recycled plastic waste reduce the paving stones’ resistance to bending stresses. Consequently, replacing quarry dust with recycled plastic waste negatively impacts the structural integrity and load-bearing capacity of the interlocking paving stones, which is critical for their long-term performance in construction applications.

Table 5: Flexural Strength on hardened Paving stones with MWPB Replacement

Percentage Replacement	7 days	14 days	21 days	28 days
0%	8.65	9.04	10.14	11.05
10%	7.89	8.74	9.23	9.62
20%	6.62	8.10	8.32	8.71
30%	5.64	6.71	6.83	7.22
40%	4.42	5.07	5.72	6.93

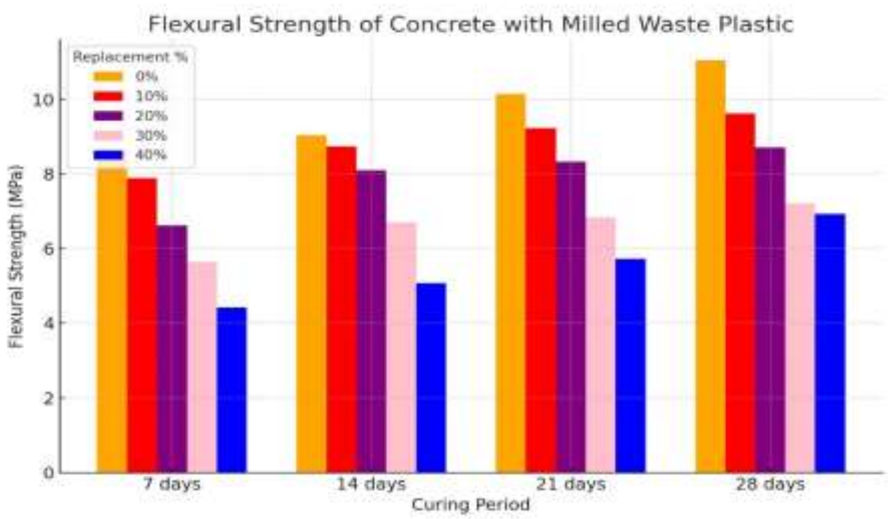

Figure 4.5: Flexural Strength on hardened Paving stones with MWPB Replacement

4.0 CONCLUSION AND RECOMMENDATION

In conclusion, the recycling and repurposing of plastic waste in Ajayi Crowther for interlocking block production can contribute to sustainability efforts by reducing plastic waste accumulation. However, its application should be carefully considered, as higher replacement levels negatively impact strength properties. For non-structural applications where workability is a priority, this method may be viable. However, for load-bearing and high-strength uses, its incorporation should be limited to avoid compromising performance.

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