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Partial Replacement of Coarse Aggregates with Plastic Waste in Paver Blocks

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Abstract: Plastics are widely used worldwide, but their non-biodegradable nature leads to significant waste generation. Improper management of plastic waste poses environmental hazards. Paver blocks made of concrete offer versatility, aesthetic appeal, and low maintenance when manufactured and placed correctly. Utilizing plastic as a building material aligns with Sustainable Development Goals. Concrete production contributes to the depletion of natural resources like aggregates. This study investigates the partial replacement of coarse aggregates with plastic waste in pavement blocks, using a mix ratio of 1:2:4. Coarse aggregates were replaced at volumes of 0%, 5%, 10%, and 15%. After batching and mixing, 54 cubes were produced and cured for 7, 14, and 28 days. Tests conducted included slump, compressive strength, and water absorption. The results indicate an optimal replacement of 10% of coarse aggregates with plastic waste which reduced water absorption. Plastic waste is recommended for use in low-load bearing walls and structures like pedestrian footpaths and water retaining structures, reducing costs and conserving natural resources. Effective utilization of plastic waste in the construction industry benefits the environment.

Keywords: *Interlocking, Pavement, PET, Plastics, Polyethylene terephthalate*

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1. Introduction

Polyethylene terephthalate (PET) is a type of polymer known as a polyester and is resistant to various chemicals such as acids, alkalis, alcohols, greases, and oils. PET also exhibits good weathering resistance, including resistance to sunlight, ozone, and ultraviolet light. In its molten state, plastic serves as an effective binding agent and is commonly used as a major matrix in the production of plastic-soil bricks. When PET is burned, the combustion products consist only of hydrogen, oxygen, and carbon, without the production of noxious gases (Gawande et al., 2012).

Paver blocks are highly versatile, visually appealing, functional, cost-effective, and require minimal maintenance when manufactured and installed correctly (Joel et al., 2015). As plastic is non-biodegradable, it can persist in the environment for many years without decomposing. The accumulation of non-degradable and low-biodegradable waste materials has led to a waste disposal crisis, with large quantities of plastic waste being generated in households. Effective management of plastic waste is a significant challenge faced by authorities worldwide. Recycling waste into useful products is a key solution to this problem. Utilizing waste plastic as a material for interlocking pavement blocks presents an ideal strategy to address waste disposal issues while optimizing the cost of building material production. The utilization of plastic waste materials offers a partial solution to environmental and ecological problems. Paver blocks produced from plastic waste have gained popularity in the building materials industry and find extensive application in areas where low strength is required. Revathi et al. (2015) highlighted that concrete paver blocks are particularly suitable for light traffic applications.

Several researchers, including Das et al. (2019), Neekhra et al. (2015), Arora and Dav. (2013), and Rai et al. (2012), have made significant contributions to the utilization of plastic waste in concrete production. Their studies focused on the partial replacement of binders or fine aggregates with plastic waste. However, this research aims to replace coarse aggregates in the production of lightweight paver blocks.

Figure 1: Types of paver blocks

While previous studies have investigated the use of plastic waste in concrete production, there is a research gap in the specific area of replacing coarse aggregates in the manufacturing of paver blocks. This research aims to address this gap by evaluating the effects of partial replacement of coarse aggregates with plastic waste on the properties of paver blocks. This research focuses on the partial replacement of coarse aggregates with plastic waste in the production of paver blocks. It builds upon previous studies on plastic waste utilization in concrete and aims to fill the research gap in this specific area. The research objectives include assessing the suitability of plastic waste, investigating its effects on paver block properties, optimizing the replacement percentage, and evaluating the feasibility and benefits of incorporating plastic waste in paver block production.

2. Materials and methods

The research methodology followed the British Standard for Concrete Paving Blocks (Standard, 2003) as a guideline for the experimental procedure. A standard mix ratio of 1:2:4 (cement: fine aggregate: coarse aggregate) was used to produce the paver blocks, and a water-cement ratio of 0.6 was maintained for proper hydration and strength development.

The materials used in the study included Dangote grade 42.5 cement as the ordinary Portland cement, river sand obtained from Bayara, Bauchi as the fine aggregate, and coarse aggregate purchased from a local supplier in Bauchi. The plastic waste used was sourced from waste PET bottles found in the surrounding area of Gwallameji, Bauchi. The PET bottles were stripped of labels and tags, thoroughly washed, dried, and cut into smaller pieces (flakes or strips). The plastic waste was then sized to match the coarse aggregate, passing through a 25mm sieve and retained on a 20mm sieve.

The paver block specimens were produced by replacing coarse aggregates with plastic waste at varying percentages: 0%, 5%, 10%, and 15%. These specimens were cured for specific durations of 7, 14, and 28 days to allow for proper hydration and strength development.

Several tests were conducted on the specimens to evaluate their properties. The aggregate impact test was performed to assess the resistance of the aggregates to sudden impact. The aggregate crushing value test for plastic palates was conducted to determine the strength of the plastic aggregates. The compressive strength test measured the maximum load the specimens could bear before failure. The water absorption test assessed the amount of water absorbed by the specimens, while the slump test determined the workability and consistency of the concrete mix.

The mix design calculations were based on the specified mix ratio of 1:2:4 and the volume of the cube specimen, which was determined to be 0.1m3 using the formula (100mm/1000) x (100mm/1000) x (100mm/1000).

Overall, this research methodology adhered to the British Standard guidelines for concrete paving blocks. It encompassed the selection and preparation of materials, mix proportioning, specimen production with varying percentages of plastic waste replacement, curing, and conducting various tests to evaluate the properties of the paver block specimens.

3. Results and discussion

3.1. Physical test result

The physical properties of the plastic palate were evaluated, and the results showed a specific gravity of 1.29. The texture of the palate was predominantly smooth, and its color was greenish.

Table 2: Physical properties of plastic palate

Specific gravity	1.29
Texture	Predominantly smooth
Colour	Greenish

3.2. Aggregate crushing tests

Aggregate crushing tests were conducted to determine the crushing strength of the aggregates. The aggregate crushing value was calculated as the percentage of material passing through a 2.36 mm sieve compared to the total aggregate weight. The results, shown in Table 3, indicated an average aggregate impact value of 49.95%.

Table3: Aggregate impact value

Observation	**Sample1**	**Sample 2**
Total weight of the Aggregate filling the The cylindrical metal Measures W_1 g	122g	120g
Weight of aggregate Passing through 2.36 Mm sieve W_2 g	60	61
Aggregate impact value	49.1%	50.8%
Average Aggregate Impact Value	49.95%	

3.3. Slump test analysis

The slump test was performed to assess the workability and consistency of the concrete mix. The results, presented in Table 4, indicated that as the percentage of plastic waste in the mix increased, the slump decreased, indicating a lower degree of workability.

Table 4: Slump test results

%	**Slump (mm)**	Degree of Workability
0%	65	Medium
5%	5	Very Low
10%	5	Very Low
15%	5	Very Low

3.4. Compressive strength test result

The compressive strength of the paver block specimens was evaluated at different curing durations: 7, 14, and 28 days. The results, shown in Table 5, demonstrated the variation in compressive strength based on the percentage of PET waste replacement. It was observed that as the percentage of plastic waste increased, the compressive strength generally decreased.

Table 5: Result of compressive strength test

PET Waste %	**7days**	**14 days**	**28 days**
0%	14.5	15.1	16.9
5%	15.1	16.8	17.2
10%	12.5	16.6	16.8
15%	12.4	15	14.9

3.5. Water absorption test

The water absorption test was conducted to determine the ability of the paver blocks to absorb water. The results, presented in Table 6 and illustrated in Figure 2, revealed that as the percentage of plastic waste in the mix increased, the rate of water absorption decreased.

3.6. Density of specimen

The density of the paver block specimens was measured at different curing durations: 7, 14, and 28 days. The results, shown in Table 7 and depicted in Figure 3, demonstrated the density variation based on the percentage of PET waste replacement.

Das et al. (2019) demonstrated that plastic waste can be incorporated as a partial replacement for fine aggregate in grade M28 concrete. Replacement percentages up to 6% showed favorable results in terms of tensile strength, while higher percentages resulted in decreased compressive strength. Gaikwad et al. (2018) explored the use of plastic coarse aggregates and steel fibers as substitutes for natural coarse aggregates in M25 grade concrete. The findings indicated a decrease in split tensile strength, flexural strength, and compressive strength with an increase in plastic content, although the workability of the concrete improved. Shanmugavalli et al. (2017) investigated the complete replacement of cement with plastic waste and the substitution of aggregates with ceramic waste, revealing limitations in terms of heat resistance. Rai et al. (2012) examined the incorporation of waste plastic as a partial replacement for fine aggregate in grade M30 concrete, and Reddy et al. (2015) highlighted the positive impact of nylon fibers and rice husk ash on the compression strength of concrete paver blocks. These studies contribute to the understanding of the potential benefits and limitations of utilizing plastic waste in concrete applications.

Overall, the results of the physical, aggregate crushing, slump, compressive strength, water absorption, and density tests provided insights into the properties of the paver block specimens. It was observed that the inclusion of plastic waste in the mix affected various properties, such as workability, strength, and water absorption. These findings contribute to the understanding of the behavior and performance of paver blocks produced with partial replacement of coarse aggregates by plastic waste.

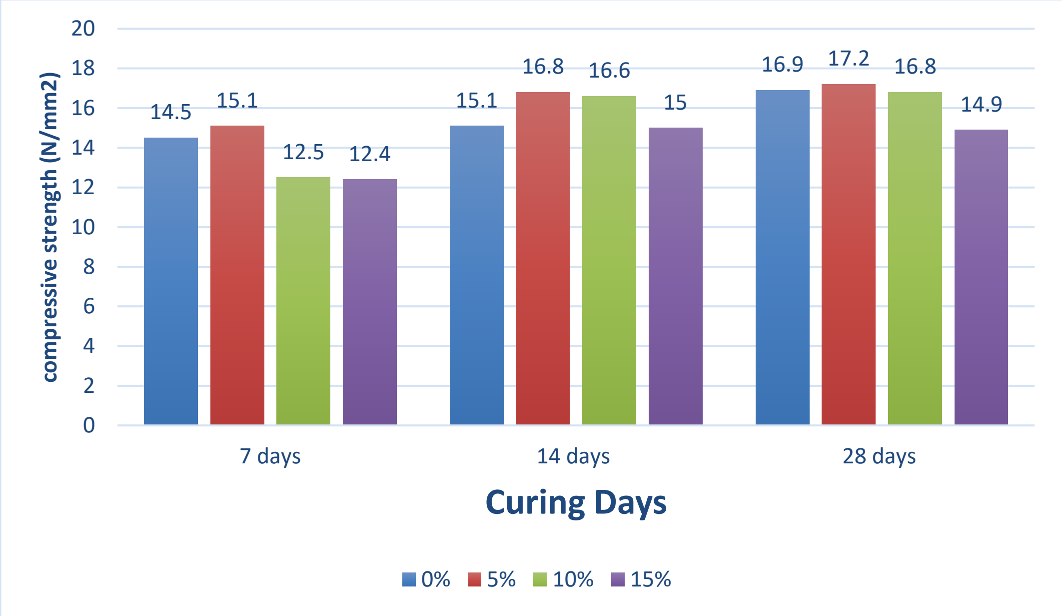

Figure 1: Graph showing variation of all compressive strengths after 28 days

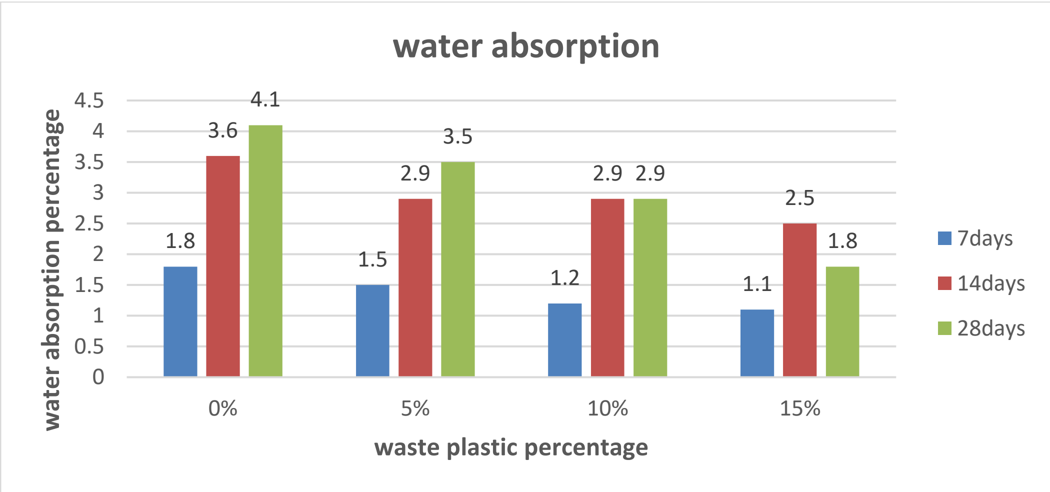

Figure 2: Graph showing variation of all water absorption after 28 days

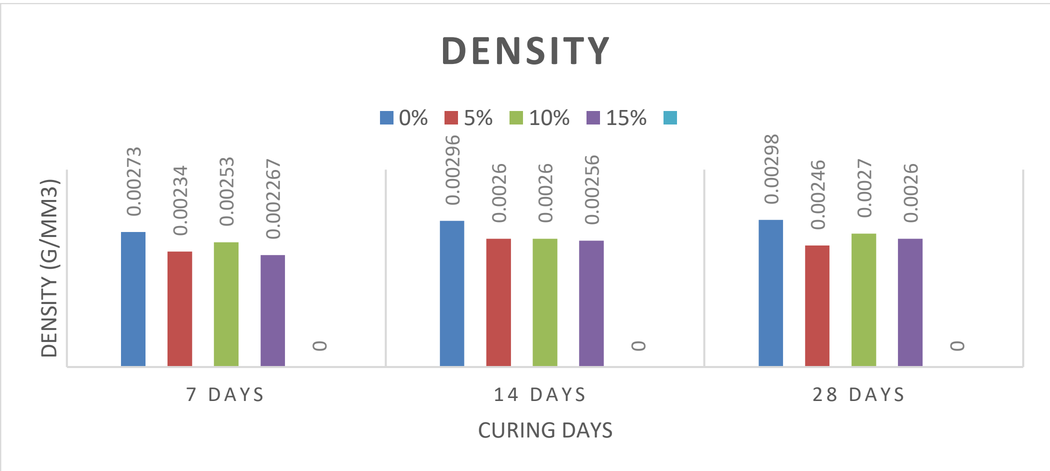

Figure 3: Graph showing density of specimen

Table 6: Water absorption test results

PET waste % replacement	Curing Days	Av. Wet Weight (kg)	Ave. Dry Weight(kg)	Water Absorption	Water Absorption %
0 %	7days	2.8	2.75	0.018	1.8%
	14 days	2.87	2.77	0.036	3.6%
	28 days	3.0	2.88	0.041	4.1%
5 %	7days	2.7	2.67	0.011	1.5%
	14 days	2.8	2.72	0.029	2.9%
	28 days	2.9	2.8	0.035	3.5%
10 %	7 days	2.6	2.56	0.015	1.2%
	14 days	2.75	2.67	0.029	2.9%
	28 days	2.78	2.70	0.029	2.5%
15 %	7 days	2.41	2.38	0.012	1.1%
	14 days	2.52	2.46	0.024	2.4%
	28 days	2.61	2.56	0.019	1.8%

Table 7: Result of density of specimen

Days	0% (g/mm^3)	5%(g/mm^3)	10%(g/mm^3)	15% (g/mm^3)
7days	0.00273	0.00234	0.00253	0.002267
14 days	0.00296	0.0026	0.0026	0.00256
28 days	0.00298	0.00246	0.27	0.0026

4. Conclusion

The study demonstrated that the inclusion of plastic waste in the production of paver blocks has an impact on various properties. The physical test results showed that the plastic palate had a specific gravity of 1.29 and a predominantly smooth texture. The aggregate crushing tests revealed an average aggregate impact value of 49.95%. The slump test indicated a decrease in workability as the percentage of plastic waste increased. The compressive strength test results showed a decrease in strength with higher percentages of plastic waste, with 10% replacement recommended for concrete production. The water absorption test demonstrated a reduction in water absorption rate as the percentage of plastic increased. Additionally, the density of the specimens varied based on the curing duration and percentage of PET waste replacement.

Based on these findings, it is recommended to utilize 10% plastic waste as a replacement for coarse aggregates in concrete production, as it provides a good balance between strength and workability. This approach can be applied in the construction of structures such as gardens, pedestrian footways, car parks, buildings, and road shoulders. Incorporating PET plastic waste in concrete not only helps in the management of plastic waste but also contributes to the production of lightweight concrete, thereby reducing construction costs. The results of this study offer valuable insights for sustainable waste management and the utilization of plastic waste in the construction industry.

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