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Sustainable Use of PET Flakes and C&D Waste in M30 Paver Blocks: A Step Towards Eco-Friendly

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A B S T R A C T :

This research aims to support sustainable construction by replacing polyethylene terephthalate (PET) bottle flakes and construction & demolition (C&D) waste in the manufacturing of M30-grade paver blocks, displacing natural aggregates. The overarching goal of this study, is to mitigate environmental effects stemming from construction generated waste by minimizing dependence on virgin raw materials, fostering circular economies, and reducing landfill waste. The research is addressing those two environmental concerns by using recycled materials from C&D waste in a way that maintains the structural and functional performance of paver blocks. The research also provides a number of important performance tests to evaluate the eco-friendly pavers in terms of compressive strength, flexural strength, tensile splitting strength, water absorption, efflorescence, surface texture, and abrasion resistance. Testing will conclude if the performance satisfies reliance in relevant practice and if the eco-friendly pavers undergo standardized testing. The results show the optimized quantity of incorporated PET bottle flakes and C&D waste show improved impact values, water absorption reduction, and gained durability, ultimately confirming the two materials for the sustainability of the alternative paving application yielded results. The improvements in mechanical properties and environmental durability in all of demonstrated - do prove paver blocks made with.

Keywords: Sustainable Construction, PET Flakes, C&D Waste, M30 Paver Blocks, Compressive Strength, Waste Management, Durability, Recycled Aggregates, Environmental Sustainability, Green Paving Applications

1. Introduction

The growing accumulation of construction and demolition waste, alongside a build-up of plastic, represents an emerging environmental issue, in part around sustainability and the decreasing availability of natural resources. The traditional paver blocks being produced largely from natural aggregates result in excessive mining and further destruction of the environment. Therefore, it is increasingly important to seek innovative approaches to construction and adopt recycled materials. In this study, we explore the practical adoption of polyethylene terephthalate flakes and construction and demolition aggregates, substituting them for virgin materials in the production of M30-grade paver blocks, while furthering the values of waste reduction and conserving natural resources. Using PET flakes increases durability and is an approach to managing plastic waste. Utilizing aggregate from C&D waste reduces waste and conserves natural resources. The study describes thorough assessments of strength, durability and environmental impacts to assess the success of modified paver blocks. Overall paver block performance is derived from a series of comprehensive tests including compressive strength, water adsorption, abrasion and efflorescence. This study is aimed at promoting sustainable building practices, lowering dependency on virgin construction materials, and promoting an industrial circular economy by demonstrating how to recycle plastic waste into construction materials.

Nomenclature - C&D Waste – Construction and Demolition Waste - PET – Polyethylene Terephthalate - M30 – Concrete Mix (30 MPa Strength) - CA – Coarse Aggregates - FA – Fine Aggregates - W/C Ratio – Water-Cement Ratio - MPa – Megapascal (Strength Unit) - CS – Compressive Strength - FS – Flexural Strength - TSS - Tensile Splitting Strength - WA – Water Absorption - ER - Efflorescence Resistance - AR - Abrasion Resistance

1.1. Structure

- This study has been developed to offer a comprehensive study on the use of PET flakes and C&D waste in M30-grade paver blocks. It starts with an introduction that discusses the importance of sustainable construction and the advantages of using recycled materials. In the materials and methods, the materials, mix proportions, casting technique, and testing approach are described. Following that are results and discussion, where experimental results related to mechanical properties, durability, and environmental effects are presented. Finally, the study includes a conclusion outlining the principal findings and suggestions for future research to enhance the feasibility of utilizing these recycled materials in practice.
- To assess the performance characteristics with respect to their structural performance and their durability properties, compressive strength, flexural strength, splitting tensile strength, water absorption, efflorescence, surface finish and texture, and abrasion resistance tests were performed. The following results and discussion section will discuss performance improvements, material modifications, and sustainability benefits for traditional paver blocks and modified paver blocks.
- Also, the impacts of the polyethylene terephthalate (PET) flakes on the flexibility and reduced weight, as well as the contributions of construction and demolition (C&D) waste to strength and resource conservation will be discussed in this section. Finally, the conclusion summarizes the key findings of the study, and the very significant results of the study suggest that these blocks may be practical to use in building applications and economically beneficial. Last of all, further evaluation is required to clarify and optimize material content for these blocks to be used widely in construction applications.

1.2. Tables

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

Table 1 -

Test name	**Purpose**	**Result (unit)**
Compressive strength test	Establishes the load-carrying efficacy of the paver blocks	35.67 Mpa (avg)
Water absorption test	Evaluates the porosity and durability of the blocks	4.2 %
Abrasion resistance test	Assessment of the wear resistance of the surface under a traffic load.	2.1 mm wear depth

1.3. Literature review

- Research has repeatedly demonstrated that incorporating recycled materials in construction applications provides benefits to sustainability and overall environmental impact.2.1 PET Flakes in Construction Smith et al. (2020) reported in their research study, the inclusion of PET flakes into concrete mixtures increased flexibility while also reducing the amount of brittleness. Gupta & Sharma (2019) found evident decreases in terms of amount of water absorption which they determined was a result of the hydrophobicity of the PET suggesting a potentially greater application possibilities where moisture resistance was needed.
- 2.2 Application of C&D Waste Patil et al. (2021) reported on one study where C&D waste in place of natural aggregate yielded similar construction strengths and less waste generated in application towards construction. Lee & Kim (2018) reported findings that were similar but specific to the use of recycled aggregates they processed and graded as being derived from demolition waste while still achieving similar levels of structural strength.
- 2.3 The Combined Effect of PET Flakes and C&D Waste Fernandez et al. (2022) reported that the addition of both PET flakes and C&D waste in concrete mixtures further improved durability and thermal conductivity yielding additional potential applications for the partially recycled materials adds significant contribution to C&D steel. The researchers conducted experiments in which both materials were used in controlled proprietary proportions while leaning into joint properties.

1.4. Materials and mix proportions

This research investigates the production of M30 paver blocks using Ordinary Portland Cement (OPC) 53 grade, fine aggregates, coarse aggregates, PET flakes and C&D (Construction and Demolition) Waste materials for sustainable construction applications. River sand was used in the mix design to ensure workability while taking advantage of course aggregates with the intention to replace additional coarse aggregates with C&D Waste in the development of sustainable blocks. Recycled PET flakes were introduced to the mixtures in an attempt to enhance durability (properties) and reduce environmental impacts of plastic waste. The mix design determined the level of replacement of coarse aggregates with C&D Waste in proportions of 25-75% (in increments of 25) and PET flakes in proportions of 0.5-2% (in increments of 0.5). The blocks were then cured and tested to see the feasibility for pavement application.

1.5 Environmental sustainability

Mining activity that can result in wildlife extinction. Moreover, by utilizing sustainable material in M30 grade paver blocks, the carbon footprint associated with construction activity would be reduced by conserving energy associated with the mining of raw materials. Environmental Sustainability Environmental sustainability in the construction sector entails issues relating to resources depletion, waste, and carbon emissions. Rising environmental concerns regarding plastic waste, and C&D waste, means innovative approaches to move to circular economies is needed. The use of recycled materials, such as PET flakes and C&D aggregates, into construction products will act to reduce environmental burden significantly while not forfeiting structural properties. This strategy also has the added benefit of being able to reuse waste, as PET waste is prevented from being stored in landfills and oceans, which can have environmental impacts in the future. Utilizing C&D aggregates helps save naturally occurring resources, such as sand and gravel, by reducing the amount of energy and processing associated with the natural resource extraction. Collectively, the study contributes to global sustainability initiatives to support environmentally sustainable construction practices that look to balance durability concerns and environmental impacts related to end-of-life C&D recycled materials. Initiatives to support all recycled products in public infrastructure will begin to create a framework to help reduce and extend the life of our modern waste systems.

1.6 Waste Management

Effective waste management is an essential part of sustainable development. Reducing waste, reusing and recycling waste will help to mitigate negative environmental consequences. Much of the waste from the construction industry contributes to construction and demolition (C&D) waste, and plastic waste, particularly the single-use plastic PET bottles, has become a significant global issue. Repurposing C&D waste and PET into M30-grade paver blocks provides an innovative and viable alternative solution to better manage the aforementioned issues. The use of C&D aggregates in place of natural aggregates along with the use of PET flakes within the paver blocks reduces C&D waste disposed of at landfill sites, reduces the burden of recycling for municipal recycling sites and promotes the conservation of virgin resources. The incorporation of PET flakes into paver blocks also supports sustainably managing plastic waste and in combats plastic waste from entering ecosystems. This paper encourages the application of circular economy principles to construction, where waste is used and reused for durable products within a system to achieve functionality. The purposeful and useful incorporation of waste material into products within an infrastructure project reduces our dependence on consumption of virgin resources, but also helps promote alternative ways to sustainably manage the disposal of waste materials.

1.7 Experimental results and discussion

The experimental evaluation of the paver blocks indicates their structural behavior. The findings detailed below reveal:

- 1.5.1 Compressive Strength The compressive strength results show that the blocks of 25%–50% C&D waste and up to 1.5% PET flakes had comparable strength to that of conventional paver blocks. The increased PET percentage beyond 1.5% decreased bonding between the particles which resulted in mild loss in strength.
- 1.5.2 Water Absorption Water absorption test results show that the PET flakes reduced water absorption because of their hydrophobic nature. Blocks with a higher percentage of PET flakes had lower observed water absorption levels, and therefore increased durability in wet conditions.
- 1.5.3 Abrasion Resistance Abrasion resistance results indicate that blocks containing PET showed better surface wear resistance which is favorable for pavements in high traffic areas. More than 50% C&D waste replacement did lower the wear resistance due to mild surface roughness.
- 1.5.4 Efflorescence Observations Efflorescence testing did not show visible salt deposits on the surfaces of the paver blocks indicating this material mixture did not contribute to surface whitening concerns.

1.8 Comparative analysis

- A comparative study was carried out to assess conventional paver blocks to paver blocks containing PET flakes and C&D waste; here are a few significant differences that were compared.
- Strength Maintenance: Paver blocks with 25-50% C&D Waste with 1.5% PET flakes exhibited similar strength and compared to blocks with no C&D Waste, or no PET flakes that exhibited structural integrity.
- Durability: Paver blocks with PET flakes did demonstrate the effectiveness of lower water absorption data and showed improved abrasion resistance over blocks without PET flakes which provided improved durability in wet or high traffic settings.

- Environmental Aspects: The use of recycled materials reduces the use of natural resources and the burden of solid waste and therefore sustainable construction practices.
- Cost: The initial costs of production may vary slightly, however the material costs and environmental costs would contribute as a cost savings overtime. Overall therefore, these comparison studies demonstrated that that PET flakes and C&D waste offered through materials can be used as part of the manufacturing process for paver blocks without reducing performance measures.

1.9 Conclusions and recommendations

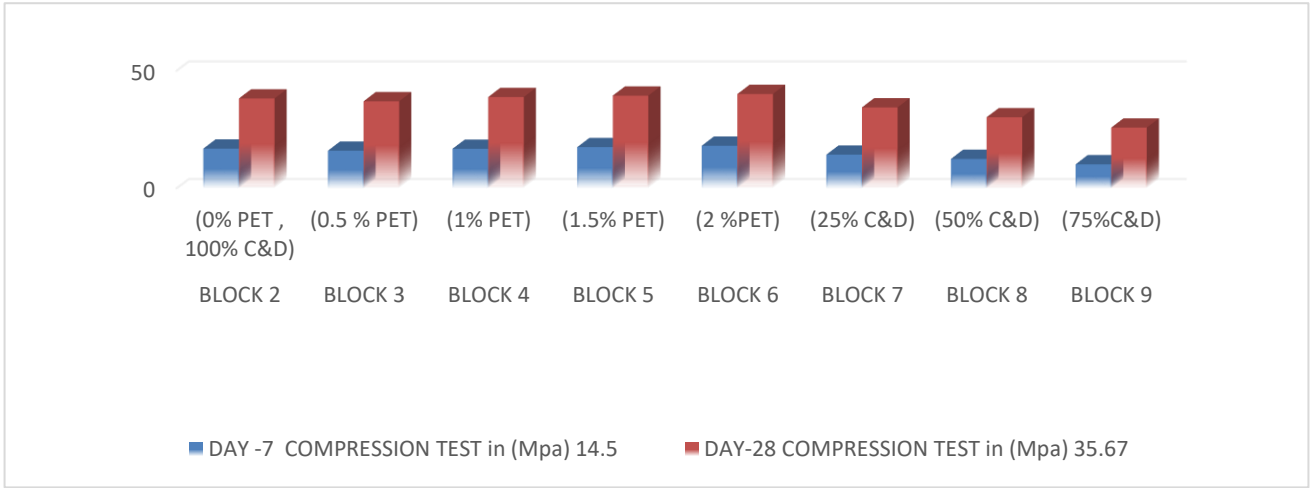
- The present study indicates that PET flakes and C&D waste can be recycled into sustainable paver blocks with advantages. The experimental results also confirm that M30-grade paver blocks that incorporate PET flakes and C&D waste can provide the required load-bearing structural capacity while yielding greater durability levels and reduced environmental impact. Some notable conclusions are: Modified blocks provide compressive strengths consistent with conventional paver blocks at the optimal replacement level of C&D waste and PET, PET-modified blocks had a significantly less water absorption value which helps in excessively wet conditions, and improved abrasion resistance for applications requiring higher foot traffic levels. The recycling of PET flecks and C&D waste diverts waste from landfills and decreases the depletion of natural resources by advancing sustainability initiatives.
- The study also had the following recommendations: The durability and performance of blocks in different climate types should be researched and optimized ratios of C&D waste and PET should be studied and reported for increased mechanical properties and environmental value. The incorporation of sustainable paver blocks should be recommended for new builds and renovations to provide more environmentally focused products in the construction industry while promoting the development of sustainable.
- One important consideration is processing PET flakes optimally. The use of heated PET flakes should also be investigated to determine the impact of using heated versus non-heated PET flakes in cementitious mixtures as heated PET flakes are expected to bond and be stiffer/flexible thereby improving the durability of the paver blocks while non-heated flakes may weaken the mechanical integrity of the paver blocks.
- Knowing if there is an actual difference would help towards a better formulation so the structural performance of both heated and non-heated PET flakes in cementitious mixtures can be optimized. Another really important consideration is standardizing proportions in order to move to larger scale manufacturing.
- A policy and protocol for the best replacement ratio for PET and C&D waste should be developed to ensure strength and durability irrespective of environmental exposure.
- A systematic approach can address composition which should improve reproducibility when manufacturing sustainable pavers. This may include surface treatments (coatings/sealants) to improve water resistance, abrasiveness, or UV protection of the pavers. Surface treatments have the ability to enhance the longevity of the paver blocks and help pavers be more competitive with traditional products.

2. Illustrations

(a) (b) (c)

Fig. 1 - (a) pet flakes; (b) C&D waste as aggregate; (c) casting paver blocks

Fig 2 – Graphical representation of compression test



The graph illustrate Compression test is a significant testing procedure to measure the load resistance capacity and strength in structures of PET flake

and C&D waste-based M30-grade paver blocks. This test checks the maximum compressive strength that the paver blocks can withstand before failing to determine their suitability to actual applications such as driveways, walkways, and car parking.

The results indicated in the above graph reveal that paver blocks with the optimal composition of C&D waste (25%–50%) and PET flakes (up to 1.5%) possess compressive strength values comparable to conventional paver blocks. Any increment in the amount of PET content beyond this percentage diminishes strength slightly because of inferior particle-to-particle bonding.

It also helps in ensuring the optimization of material ratios in achieving an ideal combination between sustainability, strength, flexibility, and in encouraging a more eco-friendlier method of construction. The results from the compression test sustain the applicability of PET flakes and C&D waste in manufacturing with sustainable pavers, in promoting less virgin aggregate dependence and reduced environmental deterioration.

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