# CEMENTLESS PLASTIC PAVING BLOCK INNOVATION FOR ENVIRONMENTALLY FRIENDLY PEDESTRIAN AREA UTILIZATION

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**Abstract.** *Urban infrastructure development demands sustainable solutions to address environmental challenges, particularly in pedestrian areas where conventional cement-based paving blocks contribute to high carbon emissions and resource consumption. This study aims to develop and evaluate cementless plastic paving blocks as an eco-friendly alternative by utilizing recycled plastic waste. The research focuses on assessing the compressive strength and water absorption of paving blocks containing 25% recycled plastic. An experimental approach was employed, involving the fabrication and testing of samples. Compressive strength was measured using a Universal Testing Machine (UTM), while water absorption. The results indicate that the paving blocks achieved a compressive strength of up to 20.27 MPa, surpassing the standard requirement of 12.5 MPa, making them suitable for pedestrian applications. The low water absorption rate (0.43% - 0.96%) enhances durability and reduces slipperiness, though it necessitates effective drainage solutions to manage runoff. This study contributes to sustainable construction by offering an innovative paving solution that minimizes cement use, reduces plastic waste, and supports urban sustainability.*

**Keywords**: *Cementless Paving, Compressive Strength, Pedestrian Areas, Plastic Waste, Sustainability.*

## 1. INTRODUCTION

Urbanization and rapid infrastructure development have significantly increased the demand for sustainable and environmentally friendly construction materials. Traditional paving blocks, primarily composed of cement-based materials, contribute to environmental degradation due to high carbon emissions and intensive resource consumption (Ashokan et al. 2024). The cement industry is a major contributor to global $CO_2$ emissions, accounting for approximately 8% of total emissions, which accelerates climate change and environmental pollution(Belaïd 2022).

Urban infrastructure is required to support the concept of sustainable development by paying attention to environmental aspects, including the design of environmentally friendly and sustainable pedestrian areas. Enhancing pedestrian infrastructure, such as better lighting, crosswalks, and sidewalks, is crucial for creating safe and walkable urban environments (Varsha et al. 2023). This infrastructure design needs to consider drainage efficiency, material durability, user comfort and environmental aesthetics in order to create functional public spaces and have a positive impact on the quality of life of urban communities.

One important aspect in the design of a pedestrian area is the selection of paving block material that supports effective surface drainage, minimizing puddles and enhancing pedestrian safety (Marchioni and Becciu 2015). Paving blocks made from recycled plastic are an innovative alternative to support sustainable urban infrastructure development (Prasath et al. 2023). Its use in pedestrian areas is an environmentally friendly solution that can replace conventional materials such as concrete, while helping to reduce plastic waste and carbon emissions.

Research on the utilization of recycled plastic materials in construction has been conducted extensively, highlighting their potential as sustainable alternatives to conventional materials. Studies by (Supit et al. 2022) evaluates the use of PET (Polyethylene Terephthalate) plastic waste as a substitute for sand in making pervious concrete paving blocks, which are designed for use on sidewalks and parking areas with light traffic. The research results show that the 5% PET mixture produces an optimal compressive strength of 11 MPa, which is sufficient to withstand pedestrian loads. In addition, paving blocks containing PET show increased porosity, which allows for better water absorption, which can help prevent puddles in pedestrian areas. However, the addition of excessive PET (>10%) tends to reduce the mechanical strength of the material due to reduced bonding between the plastic aggregate and cement.

Similarly, research by (Sastrawidana et al. 2022) evaluating the use of plastic waste as a sand substitute of up to 50% in making paving blocks with the addition of inorganic red stone pigment to improve aesthetics. The research results show that the paving blocks produced meet SNI 03-0691-1996 standards with compressive strength ranging from 18.06 MPa to 12.78 MPa, exceeding the minimum limit of 12.5 MPa, and low water absorption capacity (3.25%- 4.28%), which increases resistance to wet conditions and reduces the risk of slippage. The use of red stone pigment not only provides an attractive visual appearance but also maintains good mechanical quality, so this paving block is suitable for application in pedestrian areas such as sidewalks and city parks as an environmentally friendly solution to reduce plastic waste.

Other researchers also observed the use of PET (Polyethylene Terephthalate) plastic bottle waste as an alternative binding material in the production of paving blocks for pedestrian paths. The research results show that paving blocks containing 10% PET have a compressive strength of 23.64 $N/mm^2$ after 28 days, meeting standards for sidewalk applications with medium to high traffic. In addition, the highest skid resistance value was obtained for the 6% PET mixture, with a score of 85, which indicates better safety for pedestrians, especially in wet surface conditions. In terms of water resistance, paving blocks with 10% PET show a lower water absorption rate of 3.2%, compared to conventional paving blocks, so they are more resistant to moisture and degradation (Awolusi et al. 2023).

Advances in plastic recycling technology have further enabled the production of construction materials with improved mechanical properties and sustainability features. However, current research and industry applications largely focus on partial replacement of cement with plastic waste rather than full substitution. Most paving block innovations still rely on cementitious components, limiting their potential in achieving truly sustainable and carbon-neutral urban solutions. While some studies have explored the feasibility of plastic paving blocks, significant gaps remain in optimizing their design to meet urban requirements, load-bearing capacity, and aesthetic preferences.

This study aims to evaluate the performance of cement-free plastic paving blocks and their design for use in pedestrian areas. The evaluation was conducted to assess the mechanical durability, and aesthetic aspects of paving blocks to ensure their suitability for sustainable urban infrastructure needs. Through this approach, it is hoped that plastic paving blocks can be an innovative and environmentally friendly solution that supports urban water management, reduces carbon emissions, and improves visual appeal and functionality in urban environments.

## 2. LITERATURE REVIEW

The development of cementless plastic paving blocks for environmentally friendly pedestrian areas requires a comprehensive understanding of previous research and technological advancements in the fields of sustainable construction materials, plastic waste management, and urban infrastructure. This literature review explores key aspects related to the study, including the environmental impact of cement-based materials, the potential of plastic waste as an alternative construction material, performance characteristics of plastic paving blocks, and their practical applications in urban settings (Loganayagan et al. 2021). Studies indicate that cement manufacturing is responsible for approximately 8% of global $CO_2$ emissions, mainly due to the calcination of limestone and energy-intensive production processes (Thiam, Fall, and Diarra 2021). Moreover, the extraction of raw materials such as limestone and clay leads to land degradation and resource depletion.

Research by (Ryu, Lee, and Chang 2020) demonstrated that incorporating plastic waste into concrete mixtures can reduce weight while maintaining adequate mechanical properties. Furthermore, plastic-based paving blocks offer significant advantages in terms of durability, moisture resistance, and thermal insulation (Agrawal et al. 2023). Despite these advantages, challenges related to material compatibility, mechanical performance, and long-term degradation need further investigation to enhance the feasibility of plastic paving blocks as a viable alternative to cementitious products. The development of cementless plastic paving blocks necessitates an evaluation of their physical and mechanical properties, including permeability, compressive strength, and durability. Studies have shown that plastic-based paving blocks exhibit higher water permeability compared to conventional cement blocks, making them suitable for urban areas prone to flooding (Singh et al., 2021).

## 3. RESEARCH METHODS

This study was conducted using an experimental research approach, focusing on the development, testing, and evaluation of cementless plastic paving blocks for environmentally friendly pedestrian area utilization. The research methodology is divided into two main stages: (1) laboratory experimentation for sample fabrication and performance testing, and (2) design and evaluation of pedestrian area utilization scenarios based on the developed paving block characteristics. The methods used in this study were designed to ensure a comprehensive assessment of both technical performance and practical implementation feasibility.

### *3.1 Material and Mixing*

The materials used in this study consisted of recycled plastic (polyethylene terephthalate - PET), fine aggregate sand, and color pigments to enhance aesthetics. The PET plastic was sourced from local recycling facilities and processed into granules before being incorporated into the paving block mixture. Fine aggregate sand, in accordance with SNI 03-0691-1996, was used to ensure consistency in size distribution and support structural integrity. Different compositions of plastic and sand, such as 25% plastic content, were tested to identify the optimal mix that balances permeability and mechanical strength. The sample preparation process involved melting plastic granules at a controlled temperature of 250°C, mixing them with sand in a heated mechanical mixer, and molding the mixture into standard paving block(Karisma, Nursandah, and Tripriyatno 2024).

### *3.2 Testing*

To evaluate the performance of the paving blocks, laboratory tests were conducted on water absorption and compressive strength. The water absorption test, measured the weight difference before and after 24-hour water immersion, with results recorded as a percentage of dry weight. These values were compared with conventional paving blocks to assess drainage improvements and moisture resistance. The compressive strength test was conducted using a Universal Testing Machine (UTM), where blocks were subjected to a gradual load until failure, and the strength was recorded in MPa. Multiple samples were tested to ensure accuracy and compliance with standards such as SNI 03-0691-1996, which sets a minimum strength of 12.5 MPa for pedestrian use

## 4. RESULTS AND DISCUSSION

### *4.1 Compressive Strength*

Based on the compressive strength test results presented in Figure 1, the paving blocks with 25% plastic content exhibit a consistent increase in compressive strength across the tested samples. The results show a gradual improvement from 17.7 MPa in the first sample to 20.27 MPa in the fifth sample, indicating a positive trend in strength development. The average compressive strength recorded is around 18.82 MPa, which exceeds the minimum requirement of 12.5 MPa set by the SNI 03-0691-1996 standard for pedestrian paving applications. This suggests that paving blocks containing plastic waste as a partial replacement for conventional aggregates can still provide sufficient strength for pedestrian walkways.

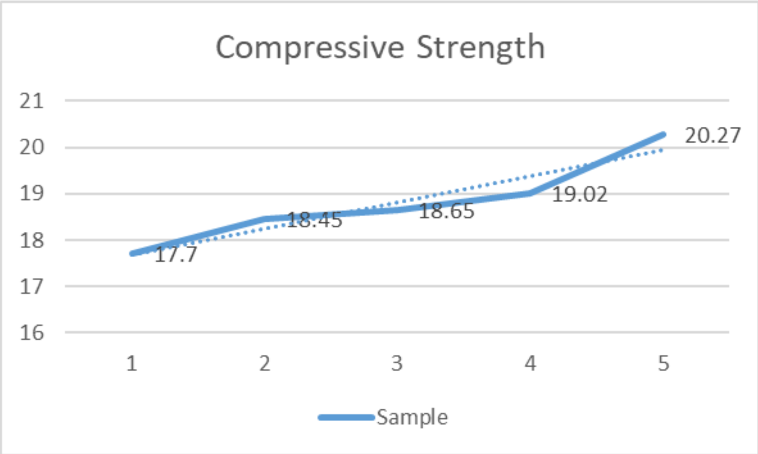


Figure 1. Compressive Strength Test Results

The results indicate that the incorporation of plastic waste in the paving block mixture does not significantly compromise the material's structural integrity. Instead, the blocks maintain adequate load-bearing capacity, making them suitable for low to medium pedestrian traffic areas. The observed increase in compressive strength across samples may be attributed to the uniform distribution of plastic particles, which enhances internal bonding and load distribution within the paving block matrix.

### *4.2 Permeability Analysis*

Based on the permeability test results presented in Table 1, plastic paving blocks with a 25% plastic content exhibited very low water absorption rates, ranging from 0.43% to 0.96%, with an average of approximately 0.682%. This value is well below the maximum limit set by SNI 03-0691-1996 for Class C paving blocks intended for pedestrian use, which allows up to 8% water absorption. Thus, these paving blocks possess high impermeability and strong resistance to water absorption, making them suitable for applications in environments with high humidity levels.

Table 2. Absorption of plastic paving blocks

| Sample | Wet | Dry | Absorption |
|---|---|---|---|
| 1 | 2381 | 2366 | 0,63% |
| 2 | 2397 | 2384 | 0,55% |
| 3 | 2398 | 2378 | 0,84% |
| 4 | 2337 | 2327 | 0,43% |
| 5 | 2316 | 2294 | 0,96% |

Figure 2. Water absorption test

Low water absorption offers several advantages, such as reducing the risk of slipperiness caused by surface water, enhancing durability in wet conditions, and extending service life by resisting weathering due to freeze-thaw cycles (Jesumanen, Chandrasekaran, and Aurtherson 2024). However, this impermeability also presents challenges, particularly in managing surface water. Since these paving blocks do not absorb significant amounts of water, additional drainage systems are required to prevent water pooling. Moreover, their application within green infrastructure concepts that emphasize water permeability must be carefully considered. Compared to traditional cement-based paving blocks with higher water absorption rates, plastic paving blocks function more as surface water drainage materials rather than infiltration media. Therefore, pedestrian area designs incorporating these paving blocks must account for effective drainage solutions, such as adopting joint spacing patterns to improve overall infiltration, using porous aggregate layers beneath the blocks, and combining them with permeable materials such as green pathways or porous paving in strategic locations.

*4.3 Design Considerations for Pedestrian Area Utilization*

Based on the experimental findings, a conceptual design for pedestrian area utilization was developed to optimize the performance and aesthetic appeal of the paving blocks.

Figure 3. Paving block application design

The paving blocks should be installed in areas with low to medium foot traffic, such as public parks, sidewalks, and recreational zones, to maximize their lifespan and minimize the risk of mechanical failure. Proper drainage planning is required to complement the high permeability of the paving blocks and prevent water accumulation in high-rainfall areas. The inclusion of color pigments and texture variations enhances the visual appeal of pedestrian walkways, aligning with urban landscape design principles. By diverting plastic waste from landfills and oceans, the utilization of plastic paving blocks contributes to the principles of the circular economy and reduces environmental pollution. Further research on the long-term performance of plastic paving blocks under various climatic conditions is necessary to ensure their widespread adoption.

## CONCLUSION

This study demonstrates that cementless plastic paving blocks offer a viable and sustainable alternative for pedestrian infrastructure. The experimental results indicate that paving blocks with 25% plastic content exhibit adequate compressive strength, exceeding the minimum standard requirement of 12.5 MPa, making them suitable for pedestrian applications. Additionally, the low water absorption rate (ranging from 0.43% to 0.96%) highlights their impermeability, reducing the risk of slipperiness and enhancing durability in wet conditions. However, their low permeability necessitates the integration of efficient drainage systems to prevent water accumulation. The inclusion of recycled plastic in the paving blocks not only provides environmental benefits by reducing plastic waste but also contributes to lowering carbon emissions by eliminating cement usage. Despite their promising mechanical and environmental performance, further research is recommended to evaluate long-term durability, aesthetic adaptability, and large-scale implementation feasibility. Proper design considerations, such as surface texture, joint spacing, and sub-surface drainage, will be essential to maximize their functional and aesthetic potential in urban environments.

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