

Compressive Strength Analysis of Glass and Plastic-Based Paving Blocks

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Abstract. Plastic waste is one of the major environmental pollutants due to its non-biodegradable nature. Utilizing it as an alternative material in construction is a promising solution, particularly as a binder in the production of paving blocks. This study aims to analyze the compressive strength of paving blocks made from a mixture of glass and plastic waste. The manufacturing process involved melting the plastic and mixing it with glass in various mix ratios M1 (1:1), M2 (1:2), M3 (1:3), and M4 (1:4). EPS was melted and mixed with glass powder in an electric furnace. After molding, the specimens were conditioned at room temperature for 24 hours before testing. Compressive strength testing was conducted in accordance with Indonesian National Standards (SNI). M1 and M4 reach low compressive strength (<10 MPa), may therefore only be considered for non-structural or decorative applications. M2 reach the highest compressive strength (13 MPa), thus acceptable for pedestrian zones and park pavements. M3 has lower compressive strength (11 MPa) but still in the same category with M2.

Keywords: compressive strength, paving block, plastic waste, sand, alternative binder.

1 Introduction

Paving blocks are widely used in the construction industry as one of the alternatives for surface pavement layers. This is due to their various advantages, such as ease of installation, cost-effectiveness, and affordability. Paving blocks, also known as concrete bricks, are building materials made from a mixture of Portland cement or similar hydraulic binders, water, and aggregates, with or without other additives, while maintaining the quality of the concrete brick.

Indonesia generated a total of 41,320,294.24 tons of waste in 2023. Of this amount, plastic waste accounted for 19.22%, equivalent to approximately 7,941,760.55 tons [3]. This figure highlights a highly concerning level of pollution, given that plastic is non-biodegradable and takes decades to centuries to decompose in the environment. The continuous increase in plastic waste poses a serious threat to ecosystems, contaminating soil, water, and oceans, while also having detrimental impacts on wildlife and human health. The percentage composition of waste can be seen in Figure 1.

Glass waste generated in 2023 reached 1,020,611.26 tons [3]. Although glass waste represents the smallest percentage compared to other types of waste, its amount remains significant and should not be overlooked. Glass waste, such as broken bottles and containers, requires a very long time to decompose in nature. Furthermore, if not properly managed, glass waste may cause injury risks, pollute the environment, and reduce the aesthetic value of public spaces.

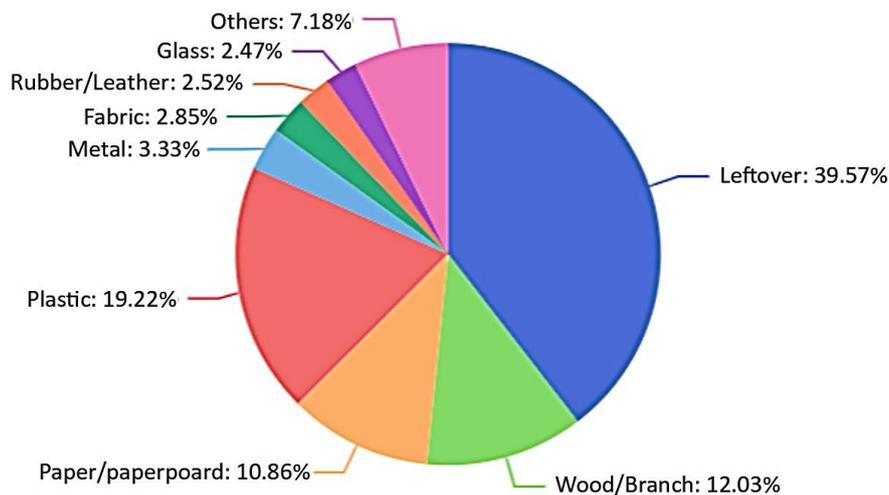


Figure 1. Composition of Waste in Indonesia in 2023
Source: sipsn.kemenlh.go.id

Indonesia, as a country committed to achieving the Sustainable Development Goals (SDGs), must take strategic measures to accelerate the attainment of these targets. The Ministry of National Development Planning/National Development Planning Agency has formulated the Sustainable Development Goals Roadmap. One of the government's targets is to reduce the per capita negative environmental impact of cities by 2030, with a particular focus on improving air quality and managing urban waste [4]. The SDG focus can be seen in Figure 2.

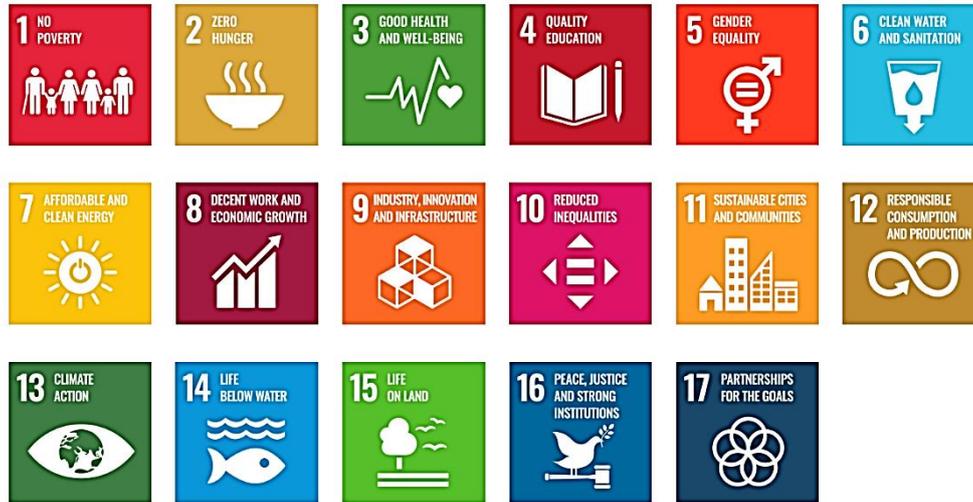


Figure 2. Focus of Sustainable Development Goals (SDGs)

Source: <https://www.un.org/sustainabledevelopment/news/communications-material/>.

Based on the above discussion, research is needed regarding the potential of new materials derived from plastic waste and glass waste. This serves as an effort to minimize the global waste issue.

2 Methodology

2.1 Preparation of Raw Materials

Prior to specimen production, both EPS (expanded polystyrene or styrofoam) and glass were subjected to pre-treatment. EPS fragments were stored in a dry environment to avoid moisture absorption, as moisture could cause bubbling during the heating process. Glass powder is processed by breaking glass waste and then prepared in sufficient quantities for all mixtures and stored in airtight containers.

2.2 Mixing and Heating Process

The production of paving block specimens was carried out through a thermal mixing process. EPS fragments were heated in an electric furnace at a controlled temperature of 150–200 °C until the material softened and became viscous. This temperature range was selected to soften the plastic without causing excessive degradation and release of harmful gases. Once the EPS reached a molten state, glass powder was gradually added while stirring continuously. The gradual addition and thorough mixing process aimed to ensure homogeneity and minimize voids within the composite matrix.

The molten mixture was then transferred into preheated stainless-steel molds. Manual compaction was applied immediately after pouring to eliminate entrapped air and improve

density. After compaction, the specimens were allowed to cool naturally at room temperature for 24 hours, after which they were carefully demolded.

2.3 Mix Proportions

Four variations of EPS-to-glass powder ratios were investigated, expressed by mass ratio, 1:1 (M1), 1:2 (M2), 1:3 (M3) and 1:4 (M4) as shown in Table 1.

Table 1. Mix Proportions of EPS and Glass Powder

Mix ID	EPS (%)	Glass Powder (%)	Ratio (EPS : Glass)
M1	50	50	1:1
M2	33.3	66.7	1:2
M3	25	75	1:3
M4	20	80	1:4

2.4 Specimen Preparation

The specimens were produced with a target depth 60 mm in hexagonal shape, following the standard size of paving blocks as specified in SNI 03-0691-1996. After demolding, the specimens were conditioned at ambient laboratory temperature (25–30 °C) for seven days prior to testing. This conditioning period was intended to stabilize the specimens and ensure that residual stresses due to thermal processing had dissipated.

2.5 Testing Procedure

The primary mechanical property evaluated in this research was the compressive strength. Testing was conducted using a Universal Testing Machine (UTM) with a constant loading rate of 0.2 MPa/s, in accordance with SNI 03-0691-1996. Each specimen was placed centrally on the loading platen, and load was applied until failure occurred. The maximum load at failure was recorded, and compressive strength was calculated using equation:

$$\sigma_c = \frac{P}{A}$$

Where:

σ_c = compressive strength (Mpa)

P = maximum load at failure (N)

A = loaded surface area (mm²)

2.6 Data Analysis

The compressive strength values obtained from three specimens per mix variation were averaged to minimize experimental error. The results were compared with the minimum

compressive strength requirements specified by SNI 03-0691-1996, which classifies paving blocks into several categories based on application as shown in Table 2.

Table 2. Classification of Paving Block

Category	Minimum Strength (Mpa)	Application
D	10	pedestrian
C	15	gardens and parking areas
B	20	medium traffic roads
A	30	heavy traffic roads



Figure 3. Plastic Paving Block

In addition to quantitative strength values, qualitative observations such as surface texture, density, presence of voids, and overall homogeneity of the specimens were also documented to provide supporting insights into the performance of the developed composite paving blocks.

3 Result And Discussion

The compressive strength test was conducted on four paving block specimens composed of varying ratios of expanded polystyrene (EPS) and waste glass powder. The average compressive strength values obtained from the tests are presented in Table 3.

Table 3. Average Compressive Strength of EPS–Glass Powder Paving Blocks

Mix ID	Average Compressive Strength (MPa)	Classification of Use
M1	9.1 MPa	Below Category D – Not suitable for structural paving
M2	12.7 MPa	Category D – Suitable for pedestrian and light-load areas
M3	10.6 MPa	Category D – Suitable for pedestrian walkways
M4	5.6 MPa	Below Category D – Decorative or non-structural use only

3.1 Effect of EPS–Glass Ratio on Compressive Strength

The results indicate that the ratio between EPS and glass powder significantly influences the compressive strength of the produced paving blocks. The mixture with a ratio of 1:2 (EPS : Glass) achieved the highest compressive strength of 12.7 MPa, meeting the Category D requirement for pedestrian applications.

This composition exhibits an optimal balance between the binding capability of melted EPS and the rigidity of the glass powder filler. At this ratio, sufficient EPS is available to coat and bond the glass particles, ensuring effective load transfer under compression.

When the EPS proportion was increased (M1, 1:1), the resulting matrix became more ductile, reducing stiffness and compressive resistance to 9.1 MPa. In contrast, when the glass content was increased excessively (M4, 1:4), the binder became insufficient to encapsulate the glass particles, resulting in weak inter-particle bonding, higher porosity, and the lowest compressive strength of 5.6 MPa.

The mixture with a 1:3 ratio (M3) showed moderate strength (10.6 MPa), which still satisfies Category D requirements but slightly lower than the 1:2 mix. This suggests that beyond a certain glass content, the reduction in binder continuity outweighs the benefit of filler rigidity.

3.2 Material Behavior and Structural Observation

The visual inspection of failed specimens revealed that mixtures with higher EPS content (M1) tended to deform plastically before failure, while those with higher glass content (M4) failed in a brittle manner with noticeable surface cracks. The 1:2 mix (M2) showed a more uniform crack pattern and less fragmentation, indicating balanced toughness and rigidity.

The fine glass powder (with size comparable to flour) contributed to dense packing and improved interfacial contact between the binder and filler. However, adequate melting temperature control was crucial to avoid EPS degradation, which could reduce binding efficiency and release volatile organic compounds (VOCs).

4 Conclusion

Based on the experimental results and analysis, the following conclusions can be drawn:

1. The combination of expanded polystyrene (EPS) waste and finely ground waste glass powder successfully produced paving blocks with measurable compressive strength suitable for light-duty applications.
2. The optimal composition was found at a ratio of 1:2 (EPS : Glass), yielding the highest average compressive strength of 12.7 MPa, which meets the requirements of Category D paving blocks under SNI classification, suitable for pedestrian and garden path use.
3. The compressive strength decreased when the EPS proportion was either too high (1:1, 9.1 MPa) or when the binder was insufficient due to excessive glass content (1:4, 5.6 MPa).
4. The results confirm that the strength of EPS–glass composite paving blocks strongly depends on the balance between binder continuity and filler rigidity.

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