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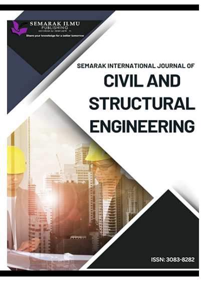

Performance Evaluation of Recycled EPS for Sustainable Lightweight Paving Blocks

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ABSTRACT

The accumulation of non-biodegradable expanded polystyrene (EPS) waste is a persistent environmental concern. This study examines the feasibility of using recycled EPS as a partial replacement for fine aggregate in the production of sustainable and lightweight paving blocks, thereby conserving natural resources and promoting green construction. Three mix designs were tested: a standard control mix with a cement-sand ratio of 1:6, and two EPS-incorporated mixes, Mix A (1:3:3) and Mix B (1:4:2) by volume. Six samples were tested using ASTM standards C936, C140, and C642 to assess dry density, water absorption, and compressive strength after 7 and 14 days of curing. The results showed a considerable drop in block weight, with a maximum reduction of 20% compared to the control. Water absorption was significantly reduced in EPS mixtures, from 4.47% in the control to only 0.8% in Mix A. Compressive strengths ranged from 4.15 MPa to 6.33 MPa, with Mix B reaching the maximum value of 6.33 MPa after 7 days. The 1:4:2 mix composition worked best, properly balancing lower density, increased water resistance, and acceptable mechanical strength. This study verifies recycled EPS as a technically suitable and environmentally beneficial material for producing non-structural lightweight paving blocks, providing a feasible pathway for waste valorisation and the advancement of circular economy concepts in the construction industry.

1. Introduction

The Recycling and reusing of Expanded Polystyrene (EPS) in engineering applications gained popularity in the late 1990s and early 2000s. This move was largely driven by increased awareness of plastic garbage's environmental impact, as well as the urgent need for more sustainable waste management options. During this time, researchers and engineers began to investigate the unique properties of EPS, including its low density, thermal insulation, and high compressibility. These qualities made it appropriate for a variety of geotechnical applications. Subgrade insulation, slope stabilization, and lightweight fill were among its most common applications in road embankments

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and retaining walls. These applications benefited from EPS's capacity to minimize load on poor subsoils while boosting thermal protection in civil infrastructure.

In addition to geotechnical applications, EPS began to be studied for new building materials, particularly lightweight concrete aggregates. Recycled EPS particles were mixed into cement-based composites to make non-structural concrete parts. These featured partition walls, roof insulation panels, and prefabricated blocks, all of which prioritized decreased weight and increased thermal insulation over mechanical strength. EPS has also been investigated as a component in modular construction systems, decorative architectural features, and pavement blocks, representing a viable alternative to virgin materials. These numerous applications demonstrate the rising understanding of EPS as a resource rather than a waste, which aligns with circular economy concepts and promotes sustainable development in the building and civil engineering industries.

Research into the use of recycled expanded polystyrene has since concentrated on its application in concrete technology, particularly for the development of lightweight and non-structural concrete mixes, expanding its role in sustainable engineering applications. Using EPS as a substitute for natural fine particles reduces concrete density and improves insulating performance, but also lowers compressive strength. According to recent studies Gyawali [1], EPS produced from thermocol waste can be included in mortar at varying percentages, with increased EPS content consistently producing lighter mixes with lower mechanical strength. Research comparing different mixing procedures shows that EPS-based composites are structurally viable only at lower replacement levels, whilst larger percentages are better suited for non-structural applications like infill and partition walls. Overall, these findings confirm that EPS-modified concrete and mortar are best suited for non-load-bearing components where lightweight characteristics and increased insulation are more important than strength.

The objective of this study is to investigate the potential of Expanded Polystyrene (EPS) as a recycled material for the production of environmentally friendly paving blocks. The study intends to convert EPS trash, which is normally non-biodegradable and difficult to manage, into a value-added construction material that contributes to sustainable infrastructure. Specifically, the study looks into the possibilities of using shredded or melted EPS in paving block mixtures to reduce reliance on traditional raw materials, reduce overall product weight, and potentially improve thermal or insulating qualities. The study's technique promotes circular economy concepts by removing plastic trash from landfills and reusing it into usable, low-cost solutions for non-structural civil engineering applications.

While traditional paving blocks are long-lasting and inexpensive surfacing options, they rely primarily on natural aggregates, which contribute to resource depletion and environmental pressure. Previous research using recycled EPS has shown significant reductions in density and benefits in thermal insulation, but frequently at the sacrifice of mechanical strength, especially at higher replacement levels. This study addresses these limitations by systematically evaluating optimized mix designs (1:3:3 and 1:4:2) that balance lightweight properties with adequate compressive strength and improved water resistance, resulting in a viable, sustainable alternative specifically designed for non-structural pavement applications.

2. Literature Review

Recycling plastic garbage into paving blocks has emerged as a feasible and sustainable approach to solve the growing issue of plastic pollution while producing long-lasting construction materials. Various types of plastic, such as polyethylene terephthalate (PET), high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS), have been successfully used in road construction via melting and moulding processes or by partially replacing sand or cement in concrete mixtures. Recycled plastic paving blocks offer a sustainable alternative to traditional concrete blocks, as they are generally lighter, more weather-resistant, and in some cases more flexible. According to a review by Bharadwaaj *et al*., [2], studies indicate that using optimized mix designs, such as replacing between 5% and 30% of sand with plastic waste, enables these blocks to achieve adequate compressive strength. This makes them suitable for non-structural applications like sidewalks, parking areas, and landscaping, supporting both waste reduction and sustainable construction practices.

Based on recent literature, several studies have expanded the role of recycled Expanded Polystyrene (EPS) in engineering, particularly in the context of sustainable concrete development and thermally efficient construction materials. For instance Hameed *et al*., [3], an investigation of lightweight concrete incorporating EPS as recycled aggregate, revealed that EPS significantly reduced the thermal conductivity of concrete while also lowering its density. Though compressive strength decreased, the study emphasised the optimisation of EPS content to maintain structural viability in non-load-bearing applications. This aligns with growing efforts to use EPS waste to address both construction efficiency and environmental impact by creating multifunctional concrete composites suitable for insulated wall panels or partitions in green buildings.

Based on the findings of Ahmed *et al*., [4], who concentrated on building lightweight structural concrete using nano-silica and expanded polystyrene (EPS) granules, it is clear that research on industrial by-product aggregates provides complementary insights relevant to EPS systems. Their research found that when EPS was coupled with nano-silica, it considerably lowered density and improved thermal insulation while maintaining adequate compressive strength for non-structural applications. These findings reflect the broader trend of using recycled materials to balance thermal efficiency and structural performance, demonstrating the importance of EPS recycling in sustainable and climate-resilient civil engineering practices.

The innovative use of Expanded Polystyrene (EPS) in this study by Shukri *et al*., [5] demonstrates its effectiveness as a partial replacement for coarse aggregates in lightweight concrete wall panels, offering solutions to both sustainability and performance challenges. Their research shows that incorporating EPS beads at 10%, 15%, and 20% by volume significantly reduces concrete density while maintaining compressive strength above the 17 MPa threshold required for lightweight concrete, particularly at 10% EPS replacement. The study also reveals that EPS enhances soundproofing performance, with 20% replacement providing optimal noise reduction across various frequencies. These findings position EPS as an eco-friendly construction material that reduces structural weight and improves energy efficiency in transportation and building processes. Furthermore, this application supports waste recycling initiatives, contributing to sustainable construction practices. While some mechanical properties are slightly compromised, the overall results confirm EPS's potential as an innovative material for modern construction needs, particularly in applications requiring lightweight and sound-insulating solutions.

The recycling of plastic waste, including materials such as Expanded Polystyrene (EPS), has shown increasing potential in engineering applications, particularly in the production of environmentally friendly paving blocks. As demonstrated in a community-based study at SMA 1 Seram Bagian Barat [6], plastic waste was successfully repurposed into paving block materials through a practical and low-cost process involving the melting of plastic (such as PET) and mixing it with sand and cement in a 45:55 ratio. This initiative not only provided a solution to reduce plastic pollution but also educated students and the community on sustainable waste management practices. Although EPS is not directly mentioned as the input material in the study, the recycling process and outcome are highly relevant to EPS reuse due to its similar thermal and physical behaviour when melted. The research supports the broader argument that plastic waste, including EPS, can be converted into useful engineering materials with acceptable mechanical properties for non-structural uses, while contributing positively to environmental conservation.

In engineering applications, Expanded Polystyrene (EPS) can be used as a lightweight aggregate or partial binder in composite materials, similar to how polypropylene (PP) plastic waste was incorporated as a sand substitute in paving block production, as demonstrated in the research by Gungat *et al*., [7]. The current study by Vetryx *et al*., [8] shows that plastic-integrated paving blocks can have compressive strengths of up to 11.83 MPa, which is consistent with recognized quality standards for non-structural applications such as pedestrian walkways and landscaped areas. This research suggests that EPS, which has advantageous properties such as low density, thermal insulation, and impact resistance, could be efficiently included in lightweight concrete or paving compositions. Such integration would help to reduce overall material weight, improve thermal efficiency, and advance sustainable construction by valorizing plastic waste. Furthermore, the compression moulding method described by Gungat *et al*., [7], which involves thermally treating plastic and then combining it with granular aggregates, might be applied to EPS to create insulating pavement units or lightweight masonry parts. These advancements are consistent with current civil engineering aims that promote green building projects and the shift to a circular economy.

The appropriate ratio of Expanded Polystyrene (EPS) in concrete is crucial for striking a balance between low density and structural performance. Manikanta *et al*., [9] found that replacing coarse aggregates with 10-15% EPS reduces density by roughly 1,950-2,261 kg/m³ while retaining compressive strength above 17 MPa, making it suitable for lightweight structural concrete. At greater replacement levels, such as 20%, compressive strength may fall below this threshold, emphasizing the need for dosage control in mix design.

Based on the analysis of recent research, as shown in Table 1, the volumetric mix ratios of EPS-based construction materials vary significantly depending on the intended application and material composition. Petrella *et al*., [10] developed a mix with an EPS: Sand: Cement+Water ratio of 1:1:1.8, which is optimized for non-structural, indoor applications such as insulating panels, lightweight plasters, and acoustic elements. Similarly, Carvalho and Motta [11] proposed a ratio of 1:1.35:1.33 for recycled EPS concrete, emphasizing its suitability for thermal insulation in non-load-bearing walls and slabs in residential and low-rise commercial buildings. These mixes reflect a balanced approach where EPS content is comparable to sand and cementitious materials, prioritizing lightweight and insulating properties over structural strength.

In contrast, mixes designed for structural or semi-structural applications show different proportions. Assaad *et al*., [12] reported a ratio of 0.58:0.35:1 for structural lightweight concrete (LWC) incorporating recycled EPS, where the cement+water fraction dominates. This mix is reinforced with steel fibers to compensate for strength loss and is suitable for low- to medium-rise construction. Çelikten *et al*., [13] proposed an EPS-based screed mortar with a ratio of 1.5:1:0.6, which is rich in EPS and low in cement, making it ideal for indoor thermal and acoustic insulation in floors and walls. Rajan *et al*., [14] explored a plastic–foundry sand–aggregate paver block with a simplified ratio of 2:2:1, targeting sustainable, light-duty paving where environmental impact and cost are critical. At the extreme lightweight end, Shukri *et al*., [5] developed panels with a very low EPS content (0.003–0.01:2.2:1), achieving a balance between strength and insulation for lightweight panel applications.

Table 1
Summary of EPS-based concrete mix ratios and their application-specific properties

References	EPS: Sand: Cement+Water (by Volume)	Application / Key Properties
[11]	1: 1.35: 1.33	This recycled EPS concrete is ideal for thermal insulation applications in non-load-bearing walls and slabs, especially in residential and low-rise commercial construction.
[10]	1: 1: 1.8	This mix is designed for non-structural, indoor, lightweight construction elements, such as Insulating panels for walls and ceilings, Lightweight plaster/render, Acoustic panels, Void filling, and leveling compounds
[12]	0.58: 0.35: 1	Recycled EPS structural LWC is viable for low- to medium-rise construction when properly designed with steel fibers and quality-controlled RFA.
[13]	1.5: 1: 0.6	This EPS-based lightweight screed mortar is ideal for indoor, non-structural thermal and acoustic insulation applications in floors, walls, and roofs where weight reduction, waste reuse, and energy efficiency are priorities.
[14]	2:2:1	This plastic–foundry sand–aggregate paver block is ideal for sustainable, low-cost, light-duty paving projects where environmental impact and cost savings are priorities.
[5]	0.003–0.01: 2.2: 1	Lightweight panels, balanced strength-insulation

The volumetric mix ratios in EPS-based materials generally correlate with their functional priorities. High EPS-to-cement ratios (e.g., ≥1:1) are typical in non-structural, insulating applications where lightweight and thermal performance are key. Lower EPS content (EPS ≤ sand or cement) is used in structural or semi-structural applications, often supplemented with fibers or quality-controlled recycled aggregates to maintain mechanical integrity. Cement-rich mixes (EPS < cement) are favored in load-bearing or durable outdoor elements, while EPS-dominated mixes are reserved for indoor, lightweight, and insulating components. Across all cases, the incorporation of EPS reduces density, improves thermal resistance, and contributes to sustainable construction by diverting plastic waste from landfills. These mixes collectively support a circular economy in construction, offering scalable solutions from interior finishes to structural members, depending on the engineered balance between EPS content, binder proportion, and performance requirements.

According to prior research, the compressive strength of recycled EPS in paving blocks frequently decreases with increasing EPS content, notably beyond 20% aggregate replacement [1,9]. To address this, future research should concentrate on optimizing the binder system by incorporating supplementary cementitious materials such as nano-silica, which has been shown to improve the interfacial transition zone between EPS and cement paste, thereby improving mechanical performance while maintaining lightweight benefits [4]. Furthermore, the inclusion of fiber reinforcement (e.g., polypropylene or steel fibers) may reduce brittleness and enhance post-cracking strength, making EPS composites more suitable for applications demanding better structural integrity [12].

Regarding density reduction, while EPS greatly reduces the total weight of paving blocks, uncontrolled substitution might result in weak zones and high porosity. Previous mixtures, such as 1:3:3 (EPS Mix A), achieved the lowest weight but at the expense of strength. Improved particle packing and gradation of EPS aggregates—combining different sizes of EPS beads—could increase matrix compactness and eliminate voids, resulting in a higher strength-to-weight ratio. Petrella *et al*., [10] and Çelikten *et al*., [13] found that optimizing EPS-sand-cement ratios and compaction processes can result in densities as low as 1,200-1,500 kg/m³ while preserving functional performance for non-structural purposes.

While the hydrophobic characteristic of EPS can reduce water absorption in cementitious composites, the long-term stability of such blends is uncertain due to probable interfacial debonding and microcracking at the EPS-cement interface. Studies show that the weak link between non-polar EPS surfaces and the cement matrix can produce preferred pathways for moisture infiltration, particularly under cyclic wetting and drying circumstances [11]. To improve water resistance, future studies should focus on surface modification strategies for EPS aggregates, such as coating with silica fume or employing silane-based coupling agents, which have been found to improve adhesion and reduce capillary porosity in polymer-cement composites. Furthermore, incorporating hydrophobic or pore-blocking admixtures into the mix design may reduce water absorption and improve freeze-thaw resistance, ensuring the long-term performance of EPS-based paving blocks in exposed locations.

Finally, the application-specific design of EPS-based blocks requires a clear distinction between structural and non-structural usage. While works by Shukri *et al*., [5] and Carvalho and. Motta [11] investigated EPS in lightweight structural panels, paving block research has primarily concentrated on non-structural uses. A performance-based classification system could be established to modify mix designs to meet specific specifications, such as ≥ 8 MPa for pedestrian pavements and ≥ 15 MPa for light traffic sectors, with variations in EPS content, binder type, and reinforcing. This strategy aligns with the circular economy's aims while maintaining technological feasibility, as demonstrated by community-based recycling projects [6,8].

3. Methodology

3.1 Research Design

The use of Expanded Polystyrene (EPS) as a lightweight aggregate substitute in the production of paver stones was examined utilizing an experimental research approach. The methodology used controlled mixing ratios, methodical material preparation, and standardized casting procedures to assess the samples' physical and mechanical qualities. The study adhered to key industry standards, particularly ASTM C936, which defines the parameters for solid concrete interlocking paving units and provides acceptable dimensional accuracy, durability, and minimum compressive performance for paver products.

To ensure consistency and dependability in evaluating sample attributes, additional ASTM testing protocols were used throughout the experiment. ASTM C140 was utilized to calculate the compressive strength and density of the paving units, and ASTM C642 gave criteria for evaluating water absorption, permeability, and void content in hardened concrete. These standards assured that the testing results were accurate, comparable, and in line with standard concrete and paver performance requirements.

3.2 Materials and Equipment

Cement, sand, and Expanded Polystyrene (EPS) were the primary materials utilized in this investigation. Before being used, the EPS was cleaned and processed from recovered packaging trash. The EPS was baked in a drying oven at 200°C for ten minutes to eliminate any remaining moisture and consolidate its structure in order to guarantee material consistency. Additional tools and equipment included in Table 2:

Table 2
Equipment and tools

Polypropylene moulds (11 cm × 22 cm × 6 cm)
Mixing buckets and trowels for blending
Digital weighing scale for mass measurement
Drying oven for EPS processing
Compressive strength testing machine
Water immersion containers for absorption testing

This equipment and materials were chosen to enable precise assessment of performance characteristics and to ensure uniformity across all test samples.

3.3 Sample Preparation

Figure 1 shows a paver stone that has been finished according to the mold. As indicated in Table 3, three different kinds of paver stone combinations were made with different mix ratios. To achieve homogeneity, each mixture was carefully mixed. After pouring the new mixture into uniformly sized molds, it was allowed to solidify for a full day at room temperature before being demolded. In order to assess the impact of curing length on mechanical performance, a total of six samples were created, three of which were cured for seven days and three more for fourteen days in water.

Fig. 1. Paver stone that has been finished according to the mold

Table 3
Types of paver stone mixtures

Item	Substance	Ratio
Control sample	Cement: Sand	1:6
EPS Mix A	Cement: Sand: EPS	1:3:3
EPS Mix B	Cement: Sand: EPS	1:4:2

3.4 Experimental Procedure

3.4.1 Water absorption test

Each specimen's porosity and moisture resistance were assessed using water absorption testing. Following the curing period, the samples were dried in an oven, and their dry mass was measured. After being submerged in water for a full day, the samples were taken out, allowed to air dry, and then weighed again. The following formula was used to get the water absorption percentage:

$$\text{Water Absorption (\%)} = ((W_{wet} - W_{dry}) / W_{dry}) \times 100 \qquad (1)$$

where W_{wet} is the saturated weight, and W_{dry} is the dry weight.

3.4.2 Compressive strength test

Universal testing equipment was used for compressive strength testing to assess the paver stones' ability to support loads. A progressively increasing force was applied to each specimen until failure. The following formula was used to calculate the compressive strength (MPa):

$$\text{Compressive Strength (MPa)} = P / A \qquad (2)$$

where P is the maximum load applied (N) and A is the cross-sectional area (mm^2) of the specimen.

3.5 Data Analysis

To assess the mechanical and physical performance of various mix ratios and curing times, experimental data were statistically examined. To find trends in compressive strength, density, and water absorption, the results were displayed both graphically and tabularly. It was possible to assess EPS as a sustainable substitute for natural aggregates in the manufacturing of lightweight paver stones by comparing EPS-based mixtures with the control group.

3.6 Sustainability Considerations

By minimizing the need for natural aggregates and repurposing non-biodegradable plastic trash, the addition of EPS to the mixture promotes sustainable building practices. This strategy reduces landfill waste, helps protect the environment, and provides a practical route to the production of eco-friendly, lightweight building materials.

4. Result and Discussion

4.1 Overview

The findings from the experimental testing of lightweight paver stones made with varying amounts of Expanded Polystyrene (EPS) are shown in this section. Measurements of sample weight, water absorption, and compressive strength at two curing times—seven and fourteen days—are included in the results. To assess the impact of EPS content and curing time on the specimens' mechanical and physical performance, these results were examined.

4.2 Weight and Density Analysis

The average weight of paver stone samples with varying EPS mix percentages following 7 and 14 days of curing is shown in Table 4. As anticipated, the total density of the paver stones was considerably decreased by the use of EPS. Because of the increased concentration of dense mineral aggregates, the control sample—which just contained cement and sand—recorded the highest mass. On the other hand, EPS-based examples had a mass reduction of up to 20%, making them lighter. Continued cement hydration and the decrease of internal voids during curing are responsible for the minor weight gain seen in all mixes between 7 and 14 days. The lightest structure was produced by the (1:3:3) combination, demonstrating that EPS is a successful material for creating lightweight, energy-efficient paving that may be used for landscaping or non-structural purposes.

Table 4
The average weight of paver stone samples with different EPS mix ratios

Mix	7-Day Weight (kg)	14-Day Weight (kg)
Cement: Sand (Control)	2.309	2.402
Cement: Sand: EPS	1.833	1.836
Cement: Sand: EPS	1.889	1.894

4.3 Water Absorption Test

The proportion of water absorption for each sample at various curing times is shown in Figure 2. According to the findings, samples with EPS showed reduced rates of water absorption when contrasted with the control mixture. This decrease results from EPS's hydrophobic properties, which restrict water's ability to pass through the mortar matrix. The mixture with the highest moisture resistance, 1:3:3, had the least amount of absorption. Despite a minor increase in absorption at day 14, this is consistent with pore expansion brought on by extended curing. The maximum absorption was seen in the control mix (1:6), indicating that a more porous microstructure resulted from the lack of EPS. These results imply that adding EPS increases water resistance and reduces density, which makes it perfect for outdoor paving that is subjected to humidity and precipitation.

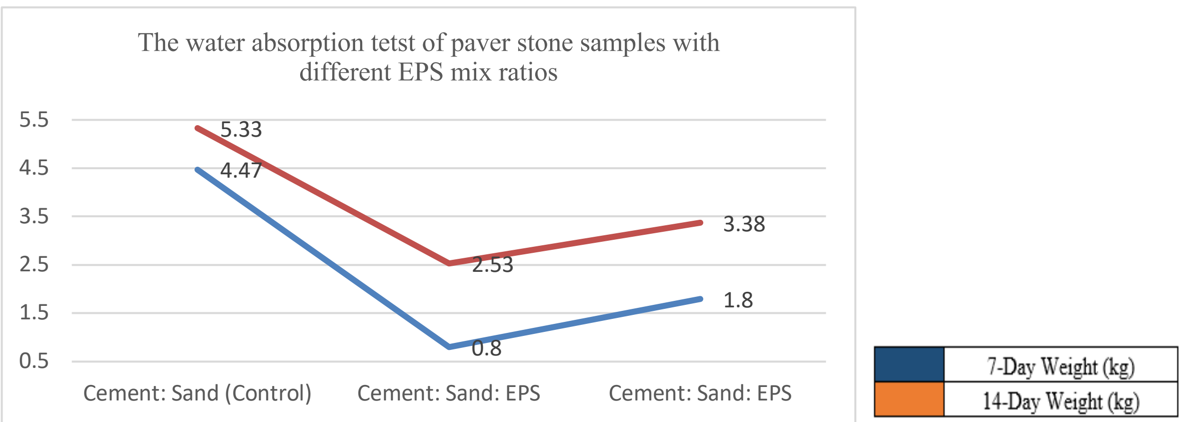

Fig. 2. The water absorption test of paver stone samples

4.4 Compressive Strength Test

The samples' compressive strengths after 7 and 14 days of curing are displayed in Table 6. After seven days, the 1:4:2 combination showed the highest compressive strength (6.33 MPa), suggesting that the cement paste and EPS content were optimally balanced. Even though the EPS-filled samples contained light particles, their strength was on par with or better than that of the control. Because EPS is thermally stable and has a low bonding affinity with cement paste, microstructural voids may be the cause of the drop in compressive strength after 14 days. For pedestrian pavement applications, which normally call for compressive strength between 4 and 8 MPa (ASTM C936), all results, however, stayed within acceptable bounds. This suggests that the incorporation of EPS does not substantially impair mechanical strength, especially when combined in moderate ratios like 1:4:2.

Table 6
The compressive strength of paver stone samples

Mix	7-Day Weight (kg)	14-Day Weight (kg)
Cement: Sand (Control)	4.64	4.15
Cement: Sand: EPS	5.3	4.44
Cement: Sand: EPS	6.33	5.66

4.5 Correlation between EPS Content, Density, and Strength

To contextualize the performance of the ideal mix (1:4:2) within the broader research environment, Table 7 shows a comparison analysis of key features between this study's findings and selected EPS-based mixes from the literature, classified by their application.

Table 7
Comparative performance of EPS-based mixes from literature versus the optimal mix (1:4:2) from this study

Source	Mix Ratio (EPS:Sand: Cement+Water)	Density (kg/m³) or Weight	Water Absorption (%)	Compressive Strength (MPa)
This Study (Mix B)	1:4:2	~1.89 kg/sample (est. ~1300–1600 kg/m³)	1.8% (7-day); 3.38% (14-day)	6.33 (7-day); 5.66 (14-day)
[11]	1:1.35:1.33	~600–800 kg/m³ (estimated)	Not specified	< 5 MPa (non-structural)
[10]	1:1.8	~400–600 kg/m³ (lightweight indoor)	Not specified	Very low (< 3 MPa)
[12]	0.58:0.35:1	~1600–1800 kg/m³ (structural LWC)	Not reported	> 17 MPa (with steel fibers)
[13]	1.5:1:0.6	~800–1000 kg/m³ (lightweight mortar)	Not reported	~2–4 MPa (non-structural)
[14]	2:2:1 (plastic–foundry sand–aggregate)	Not quantified	Not reported	Not reported (sustainability focus)
[5]	0.003–0.01:2.2:1	~1800–2000 kg/m³ (lightweight panels)	Not reported	> 17 MPa (lightweight structural)

Both density and strength showed a pronounced negative correlation with EPS content. By decreasing the mass of the paver stone, an increase in EPS percentage helps to make it lighter and simpler to handle. On the other hand, a decrease in compressive strength and decreased inter-particle bonding could result from an overabundance of EPS replacement, as in the 1:3:3

combination. As a result, the 1:4:2 ratio strikes the ideal balance between weight reduction, moisture resistance, and mechanical integrity.

This optimal balance is further contextualized by comparing it to other EPS-based mixes in the literature (Table 7). While high-EPS mixtures (e.g., 1:1.35:1.33, Carvalho et al., 2019) have extremely low densities, their compressive strengths are less than 5 MPa, restricting their applicability for paving. Conversely, structural mixtures with lower EPS content Assaad *et al*., [12] provide strong strength (>17 MPa) but at substantially higher densities. The 1:4:2 mix used in this study falls somewhere in the middle, providing compressive strength (6.33 MPa) that exceeds that of conventional non-structural EPS composites while keeping a reasonable density acceptable for handling and installation. This comparative study reveals that the 1:4:2 formulation well balances lightness and strength, making it especially suitable for non-structural paving applications where both attributes are crucial.

4.6 Implications for Sustainable Construction

The results provide credence to the viability of replacing natural aggregates with recovered EPS waste from an environmental standpoint. There are two primary benefits to this approach. It creates pavement units that are lightweight, water-resistant, and thermally efficient while also assisting in the reduction of non-biodegradable plastic trash that is dumped in landfills. The findings show that EPS-based paver stones are a viable and environmentally benign substitute for traditional concrete in non-load-bearing applications such as landscape pavements, garden walks, and pedestrian walkways.

5. Conclusion

Investigating the viability of employing recycled Expanded Polystyrene (EPS) as a substitute material in the manufacturing of lightweight paving stones was one of the study's objectives, and it was accomplished. While retaining sufficient compressive strength for non-load-bearing applications that include landscaping, pavements, and pedestrian walkways, the addition of EPS successfully decreased the blocks' overall density and enhanced their water resistance. The cement–sand–EPS ratio of 1:4:2 showed the best balance between mechanical integrity, durability, and weight reduction among the combinations evaluated.

The full accomplishment of the objectives of this research would make EPS a sustainable and feasible alternative to natural aggregates in the building sector. In addition to keeping non-biodegradable plastic trash out of landfills, this invention creates paving pieces that are lightweight, water-resistant, and thermally efficient, making them ideal for environmentally friendly infrastructure. Essentially, by combining waste management strategies with sustainable material creation, the effective use of this strategy promotes the global shift toward a circular economy.

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