Circulizer
Journal of Circular Systems, Innovation, and Technology
E-ISSN: xxxx-xxxx | Volume 1, Number 1, February 2026

Original Research Article

Lightweight Hollow Block Production Using Recycled Expanded Polystyrene and Coconut Coir: An Experimental Assessment

Fahriza[1], Devi Satria Saputra[1]*, Mislina[1], Afdhal[1], Meraty Ramadhini[2]

[1] Industrial Engineering Department, Politeknik Aceh Selatan, Indonesia
[2] Institut Teknologi Sumatera, Indonesia
* Corresponding author's e-mail: devisatriasaputra@gmail.com

ABSTRACT

The increasing accumulation of expanded polystyrene (EPS) waste and the underutilization of agricultural residues have encouraged the development of alternative materials for lightweight construction products. This study experimentally investigates the feasibility of incorporating recycled EPS particles and coconut coir fiber into hollow concrete blocks as composite additives for reducing unit weight. Hollow blocks were produced using conventional cement–sand mixtures with partial volumetric substitution by EPS and the addition of coconut coir at controlled proportions. The specimens were cast in standard molds and cured under ambient conditions prior to testing. Unit weight was used as the primary performance indicator to evaluate the potential of the developed composites as lightweight masonry units for non-structural applications. The results show a consistent reduction in unit weight with increasing EPS content, while the inclusion of coconut coir improved the physical integrity of the specimens during demolding and handling. The combined use of EPS waste and coir fiber produced hollow blocks with lower density than the control mixture, indicating their potential for applications where reduced dead load and ease of handling are required. The findings demonstrate a practical approach for valorizing polymeric and lignocellulosic waste in cement-based products and support the development of lower-density masonry units within a circular construction framework. However, the study is limited to physical characterization, and further investigation of mechanical strength, durability, and long-term performance is required to assess suitability for practical construction use.

Keywords: *expanded polystyrene waste; coconut coir fiber; hollow concrete block; lightweight masonry unit; waste valorization.*

Received: 05-02-2026. **Accepted**: 23-02-2026. **Published**: 27-02-2026

INTRODUCTION

The construction sector is one of the largest consumers of natural resources and a major contributor to solid-waste generation, creating significant pressure on landfill capacity and environmental quality. The increasing demand for building materials has intensified the extraction of raw aggregates and the production of cement-based products, which are associated with high energy consumption and greenhouse-gas emissions (Scrivener, John, & Gartner, 2018; Pomponi & Moncaster, 2017). In parallel, the accumulation of non-biodegradable polymer waste such as expanded polystyrene (EPS) has become a persistent environmental problem because of its low density, high volume, and resistance to biological degradation, which complicate disposal and reduce recycling efficiency (Gu & Ozbakkaloglu, 2016; PlasticsEurope, 2021). These challenges have encouraged the exploration of alternative construction materials derived from waste streams in line with circular-economy and industrial-ecology principles that emphasize resource efficiency, waste valorization, and closed material loops (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Chertow, 2007).

Lightweight masonry units are increasingly used in non-structural building applications because they reduce the dead load of structures, improve handling during construction, and contribute to lower transportation energy due to their reduced mass (Neville, 2011; ACI Committee 213, 2014). The incorporation of low-density waste materials into cement-based composites has been widely investigated as a strategy to produce lightweight concrete and masonry products while simultaneously diverting waste from landfills (Meyer, 2009; Siddique, Khatib, & Kaur, 2008). Among polymeric wastes, recycled EPS particles have attracted attention because their cellular structure and extremely low specific gravity enable substantial density reduction when used as partial aggregate replacement in cementitious matrices (Babu & Babu, 2003; Gu & Ozbakkaloglu, 2016). However, the use of EPS alone may lead to reduced cohesion and poor interfacial bonding within the composite, which can affect the integrity of the molded product during demolding and handling.

In addition to polymeric waste, lignocellulosic agricultural by-products represent a renewable material source that can be used to enhance the performance of lightweight cement-based composites. Coconut coir fiber is an abundant natural fiber characterized by high toughness, low density, and good resistance to microbial degradation due to its high lignin content (Fiore, Scalici, Di Bella, & Valenza, 2015). Natural fibers have been widely used as reinforcement in cementitious materials because they improve crack resistance, increase post-cracking integrity, and enhance the overall toughness of otherwise brittle matrices (Li, 2007; Pacheco-Torgal & Jalali, 2011). The combined use of EPS particles as lightweight fillers and coconut coir as fibrous reinforcement, therefore, offers the potential to produce a composite material with reduced unit weight while maintaining sufficient integrity for handling and installation.

From a circular-construction perspective, the integration of polymer waste and agricultural residues into masonry products represents a form of material valorization that extends the service life of secondary resources and reduces dependence on virgin raw materials. Such approaches are consistent with waste-to-resource frameworks in which construction materials are designed to incorporate recycled and renewable inputs while maintaining functional performance (Pomponi & Moncaster, 2017; Meyer, 2009). Despite the growing

body of research on lightweight concrete containing EPS and natural fibers, limited studies have focused specifically on their application in hollow concrete blocks and on the evaluation of unit weight as a primary performance indicator for non-structural masonry units.

Therefore, this study aims to experimentally investigate the effect of incorporating recycled EPS particles and coconut coir fiber on the unit weight of hollow concrete blocks. The research focuses on physical characterization as a preliminary assessment of lightweight material feasibility. By identifying the mixture composition that produces the greatest reduction in unit weight while maintaining adequate integrity during casting and demolding, this work provides an initial step toward the development of circular, lower-density masonry units for non-load-bearing construction applications.

LITERATURE REVIEW

The transition toward circular construction requires the development of building materials that incorporate recycled and renewable resources while maintaining functional performance. Circular-economy theory emphasizes the reduction of virgin material consumption through reuse, recycling, and material substitution, particularly in resource-intensive sectors such as construction (Geissdoerfer et al., 2017; Ghisellini et al., 2016). Within industrial-ecology frameworks, the utilization of waste as a secondary raw material in cement-based products represents a form of industrial symbiosis in which one sector's by-product becomes another sector's input, thereby reducing environmental burdens associated with both waste disposal and raw-material extraction (Chertow, 2007; Meyer, 2009). Lightweight masonry units produced from waste-derived materials therefore contribute not only to resource efficiency but also to the reduction of structural dead load and transportation energy.

2.1 Lightweight Cement-Based Composites

Lightweight concrete and masonry units are commonly produced by incorporating low-density aggregates or by introducing air voids into the matrix. The density of cement-based materials is a primary classification parameter that determines their structural and non-structural applications (Neville, 2011; ACI Committee 213, 2014). Previous studies have demonstrated that the inclusion of lightweight materials such as expanded clay, pumice, and polymeric particles significantly reduces the unit weight of concrete while altering its mechanical and durability properties (Bogas, Gomes, & Pereira, 2012). In non-structural applications, the reduction of density is often prioritized because it facilitates easier handling, lowers transportation costs, and improves thermal insulation performance (Meyer, 2009).

2.2 Recycled Expanded Polystyrene in Cementitious Materials

Expanded polystyrene has been widely investigated as a lightweight aggregate substitute due to its extremely low specific gravity and cellular structure. The incorporation of EPS beads into cementitious composites has been shown to produce significant density reductions, making the material suitable for lightweight panels, blocks, and non-load-bearing elements (Babu & Babu, 2003; Gu & Ozbakkaloglu, 2016). However, EPS particles exhibit weak interfacial bonding with the cement matrix because of their smooth surface and hydrophobic nature, which can reduce cohesion and mechanical strength if used in high proportions (Chen & Liu, 2004). To address this limitation, researchers have explored the use of supplementary materials and fibers to improve the integrity and crack resistance of EPS-based composites (Sabaa & Ravindrarajah, 1997). These findings indicate that EPS is effective for density reduction, but its performance depends on the overall composite formulation.

2.3 Natural Fiber Reinforcement in Cement-Based Materials

Natural fibers derived from agricultural residues have gained increasing attention as reinforcement in cementitious composites because they are renewable, low-density, and capable of improving post-cracking behavior. Coconut coir fiber, in particular, contains a high proportion of lignin, which contributes to its toughness, flexibility, and resistance to biological degradation compared with other plant fibers (Fiore et al., 2015). When incorporated into cement-based matrices, natural fibers can bridge microcracks, enhance ductility, and improve the integrity of molded products during demolding and handling (Li, 2007; Pacheco-Torgal & Jalali, 2011). The use of such fibers also aligns with sustainable-construction strategies that promote the utilization of renewable materials to reduce the environmental footprint of building products.

2.4 Combined Use of Polymeric Waste and Natural Fibers

The hybrid use of lightweight polymeric particles and natural fibers in cementitious composites has been proposed as a strategy to balance density reduction and material integrity. EPS contributes to lowering unit weight, while natural fibers improve cohesion and reduce brittleness in the composite matrix. Previous research on hybrid composites has shown that the combination of different waste-derived materials can produce synergistic effects in terms of physical and mechanical performance (Bogas et al., 2012; Sabaa & Ravindrarajah, 1997). Despite these advances, studies specifically addressing the application of EPS and coconut coir in hollow concrete blocks remain limited, particularly those focusing on unit weight as the primary performance indicator for non-structural masonry units.

2.5 Research Gap

Although extensive research has been conducted on lightweight concrete containing recycled polymeric materials and on natural fiber–reinforced cementitious composites, limited attention has been given to their combined application in hollow concrete blocks produced using conventional casting methods. Moreover, most existing studies emphasize compressive strength and durability, whereas unit weight remains the key parameter for classifying lightweight non-structural masonry units. Therefore, an experimental investigation that focuses on density reduction through the incorporation of EPS and coconut coir in hollow blocks provides a necessary preliminary step toward the development of circular, lightweight masonry products.

METHOD

3.1 Research Design

This study employed an experimental approach to evaluate the feasibility of producing lightweight hollow concrete blocks through the incorporation of recycled expanded polystyrene (EPS) particles and coconut coir fiber. The investigation focused on the effect of material composition on the unit weight of the blocks as the primary performance indicator for lightweight non-structural applications. Several mixture variations were prepared by introducing EPS as a partial volumetric substitute in the cement–sand matrix and adding coconut coir fiber in controlled proportions. A conventional hollow block mixture without waste-derived additives was used as the control. All specimens were fabricated using the same mold geometry and curing conditions to ensure comparability of results.

The overall experimental procedure is summarized in Figure 1, which illustrates the sequence from material preparation, mixture formulation, specimen casting, curing, and physical testing to data analysis

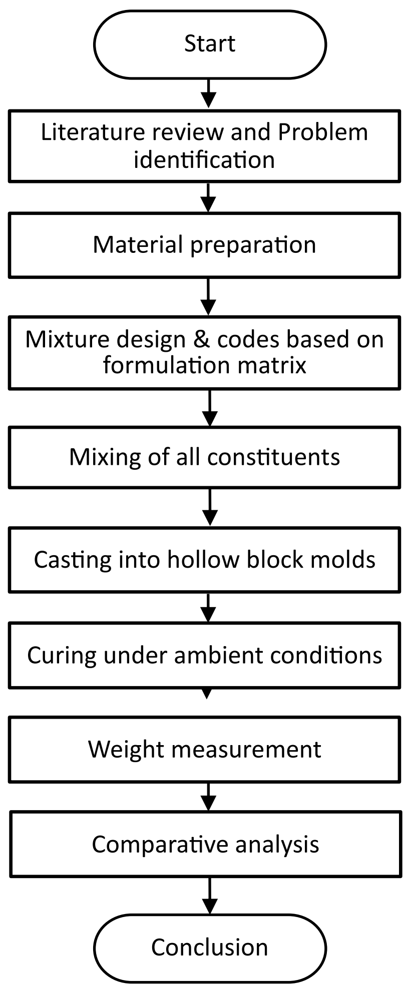

Figure 1. Research Flowchart diagram

3.2 Materials & Mixture Proportions

The primary materials used in this study consisted of ordinary Portland cement, natural river sand as fine aggregate, recycled expanded polystyrene (EPS) particles, and coconut coir fiber. The cement functioned as the main binding agent in the composite mixture. The use of Portland cement in masonry units is consistent with standard practice because of its hydraulic properties and its ability to form a rigid matrix through hydration reactions (Neville, 2011). Natural sand was used as the fine aggregate to provide dimensional stability and improve the packing density of the mixture.

Recycled EPS was obtained from post-consumer packaging waste and processed into small particles prior to mixing. The extremely low specific gravity and cellular structure of EPS make it suitable as a lightweight filler in cement-based composites because it significantly reduces the overall density of the material (Gu & Ozbakkaloglu, 2016). Coconut coir fiber was used as a natural reinforcing material due to its low density, high toughness, and high lignin content, which contributes to its durability and resistance to biological degradation (Fiore et al., 2015). Before use, the coir fibers were cleaned and cut into uniform lengths to ensure homogeneous distribution within the mixture. The physical characteristics and functional roles of the constituent materials are summarized in Table 1.

Table 1. Mixture formulation and specimen code

Material	Key characteristics	Function in the mixture	Expected influence on hollow block properties	Supporting references
Ordinary Portland cement (OPC)	Hydraulic binder; forms C–S–H gel during hydration	Primary binding phase that encapsulates aggregates and fibers and provides structural cohesion	Controls matrix formation and dimensional stability; enables comparison of density variation across mixtures	Neville (2011)
Natural river sand	Relatively high density; good particle packing; inert mineral material	Reference aggregate and volumetric baseline for EPS substitution	Provides baseline unit weight and shape stability during molding	Chen & Liu (2004); Neville (2011)
Recycled expanded polystyrene (EPS) particles	Very low density; closed-cell structure; hydrophobic surface; lightweight	Partial volumetric substitute for sand to reduce composite density	Decreases unit weight; improves handling due to lower mass; may reduce cohesiveness at high content	Chen & Liu (2004)
Coconut coir fiber	Rough surface texture; high lignin content; high elongation capacity; low density	Discrete fibrous stabilizing phase within cementitious matrix	Improves mixture integrity during demolding; reduces segregation; contributes to crack-bridging potential	Li et al. (2006)
Mixing water	Initiates cement hydration; controls workability	Enables hydration reaction and provides moldable consistency	Influences porosity and final unit weight when water content is controlled	Neville (2011)

The hollow concrete blocks were produced using a conventional cement–sand mixture as the control composition. In the modified mixtures, a portion of the sand volume was substituted with EPS particles, and coconut coir fiber was added in controlled proportions. The volumetric substitution method was adopted because EPS has a significantly lower density than mineral aggregates, and mass-based substitution would not reflect its actual contribution to the composite volume (Babu & Babu, 2003). The mixture proportions were selected to observe the effect of lightweight filler and natural fiber on the unit weight of the hollow blocks while maintaining sufficient cohesion for molding and demolding. Table 2 presents the formulation of each mixture and the specimen code used in the experiment.

Table 2. Mixture formulation and specimen code

Control Mix (Traditional Batako)				
Component	Proportion	Notes		
Cement	15%	Base reference		
Sand	80%	Standard aggregate		
Water	5%	Adjust for workability (w/c ratio ~0.5)		
Experimental Variations: EPS Factor (3 levels)				
Mix Code	EPS Content (%)	Cement (%)	Sand (%)	Adjustment Strategy
E-1	5%	15%	75%	EPS replaces sand volume
E-2	10%	15%	70%	Monitor density reduction
E-3	15%	15%	65%	Anticipate strength decrease
Experimental Variations: Coconut Coir Fiber Factor (3 levels)				
Mix Code	Coir Fiber (%)	Cement (%)	Sand (%)	Adjustment Strategy
C-1	2%	15%	78%	Coir replaces sand volume
C-2	4%	15%	76%	Monitor water absorption
C-3	6%	15%	74%	Anticipate high absorption
Combined Variations (EPS + Coir)				
Mix Code	EPS (%)	Coir (%)	Cement (%)	Sand (%)
EC-1	5%	2%	15%	73%
EC-2	10%	4%	15%	66%
EC-3	15%	6%	15%	59%

3.3 Specimen Preparation

All materials were mixed in dry conditions to achieve a uniform distribution prior to the addition of water. Water was then added gradually until a workable consistency suitable for molding was obtained. The fresh mixture was placed into hollow block molds and compacted manually to reduce entrapped air and improve matrix continuity. After demolding, the specimens were cured under ambient conditions for the designated curing period. Proper curing is essential in cement-based materials because it allows the hydration process to continue and contributes to the development of the composite microstructure (Scrivener et al., 2018).

3.4 Unit Weight Measurement

After the curing period, each hollow block was weighed using a calibrated digital scale. The external dimensions of the blocks were measured to determine their volume based on the mold geometry. Unit weight was calculated as the ratio between the measured mass and the corresponding volume. This parameter was selected because it directly represents the density of the masonry unit and is commonly used to classify lightweight cement-based materials (Neville, 2011).

Because the mixture design involved volumetric substitution of sand by EPS particles and coconut coir fiber, the unit weight was selected as the primary performance parameter to quantify the effectiveness of density reduction across mixture variations. The control mixture (CM) served as the baseline for comparison with the EPS series (E-1 to E-3), coir fiber series (C-1 to C-3), and combined EPS–coir series (EC-1 to EC-3).

To minimize moisture-related variability, all specimens were tested at the same curing age under identical environmental conditions, which were at days 7, 14, and 28. The measured unit weights were then grouped according to mixture code to enable direct evaluation of the influence of increasing EPS content, increasing coir fiber content, and their combined incorporation on density reduction.

3.5 Data Analysis

The measured unit weights of all specimens were tabulated and compared across mixture variations. The analysis was conducted using a comparative descriptive approach based on the predefined mixture formulation matrix. The control mix was used as the reference to determine the relative reduction in unit weight for each experimental variation. The results were interpreted as an initial material feasibility assessment for lightweight hollow block production rather than as a structural performance evaluation. Such an approach is commonly used in early-stage studies on lightweight cement-based composites to identify promising mixture compositions for further mechanical and durability testing (Meyer, 2009).

The evaluation followed three analytical stages:

1. Single-factor assessment: Effect of EPS content (E-1, E-2, E-3) on unit weight and Effect of coconut coir content (C-1, C-2, C-3) on unit weight.
2. Combined-material assessment: Comparison of EC-1, EC-2, and EC-3 to identify the cumulative influence of low-density polymer particles and lignocellulosic fiber.
3. Trend analysis: Identification of density-reduction patterns as a function of increasing volumetric substitution level.

Because water content was adjusted to maintain workability for each mixture, the interpretation of unit weight focused on the role of solid material composition rather than direct mass comparison of fresh mixtures.

The results were presented in tabular and graphical form to show absolute unit weight values, percentage reduction relative to the control mix, and performance ranking of mixture codes. This approach is consistent with preliminary feasibility studies of lightweight cement-based materials in which density is used as the primary classification parameter prior to mechanical testing (Neville, 2011).

3.6 Methodological Limitations

This study was designed as a physical feasibility assessment based on a mixture matrix that varied the volumetric substitution of sand with EPS and coconut coir. Consequently, several limitations should be acknowledged. First, the experimental program focused exclusively on unit weight as the performance indicator. Mechanical strength, water absorption, durability, and thermal behavior were not evaluated. Therefore, the developed mixtures cannot yet be classified for structural or load-bearing applications. Second, the study did not include statistical modeling or replicate-based variance analysis. The results should therefore be interpreted as trend-based material feasibility rather than as predictive performance data.

RESULT

4.1 Unit Weight of Hollow Concrete Blocks

The measured unit weights of the hollow concrete blocks for all mixture variations at different curing ages are shown in Table 3. The results show a consistent reduction in density for the hollow concrete blocks containing recycled EPS compared with the control mixture. This trend confirms the effectiveness of EPS as a lightweight filler, primarily due to its very low specific gravity and closed-cell structure, which introduces a high volume of internal voids into the composite matrix (Babu & Babu, 2003; Gu & Ozbakkaloglu, 2016). The decrease in unit weight observed in the modified mixtures is consistent with previous studies on EPS-incorporated cementitious composites, where density reduction is directly proportional to the volume fraction of polymeric particles replacing mineral aggregates (Sabaa & Ravindrarajah, 1997).

Table 3. Unit weight of hollow concrete blocks at different curing ages

Mix Code	Composition	Weight (kg)		
		At day 7th	At day 14th	At day 28th
CM	15% cement, 80% sand	8.06	7.87	7.71
E-1	5% EPS	6.67	6.52	6.43
E-2	10% EPS	5.89	5.81	5.69
E-3	15% EPS	5.16	5.09	4.96
C-1	2% coir fiber	7.33	7.15	6.98
C-2	4% coir fiber	6.88	6.72	6.61
C-3	6% coir fiber	6.49	6.46	6.24
EC-1	5% EPS + 2% coir	6.31	6.18	6.06
EC-2	10% EPS + 4% coir	5.54	5.43	5.32
EC-3	15% EPS + 6% coir	4.75	4.66	4.59

The addition of coconut coir fiber further influenced the unit weight of the hollow blocks. Although natural fibers have a higher density than EPS, their overall effect on the composite remained relatively small due to their low volume fraction and low specific gravity compared with conventional aggregates. Instead of significantly increasing density, the presence of coir contributed to improved physical integrity during demolding and handling. This behavior can be associated with the crack-bridging ability of natural fibers, which enhances the cohesiveness of the cement matrix and reduces the likelihood of edge breakage in lightweight composites (Li, 2007; Pacheco-Torgal & Jalali, 2011).

The combined use of EPS and coconut coir produced hollow blocks with lower unit weight than the control specimens while maintaining adequate dimensional stability. From a materials-classification perspective, the reduction in density indicates the potential of these composites to be categorized as lightweight masonry units for non-structural applications, where the primary performance requirement is reduced dead load rather than high compressive strength (ACI Committee 213, 2014; Neville, 2011). Lightweight blocks are advantageous in such applications because they facilitate manual handling, reduce transportation energy, and contribute to improved construction efficiency (Meyer, 2009).

4.2 Trend of Weight Reduction

The percentage reduction relative to the control mixture is illustrated in Figure 2. The EPS series showed a higher rate of reduction than the coir series, while the combined mixtures produced the greatest overall decrease in unit weight. Based on the unit weight measured at 28 days, the mixtures can be ranked from highest to lowest density as follows: CM → C-series → E-series → EC-series. The trend demonstrates that density reduction is directly related to the volumetric substitution level defined in the formulation matrix.

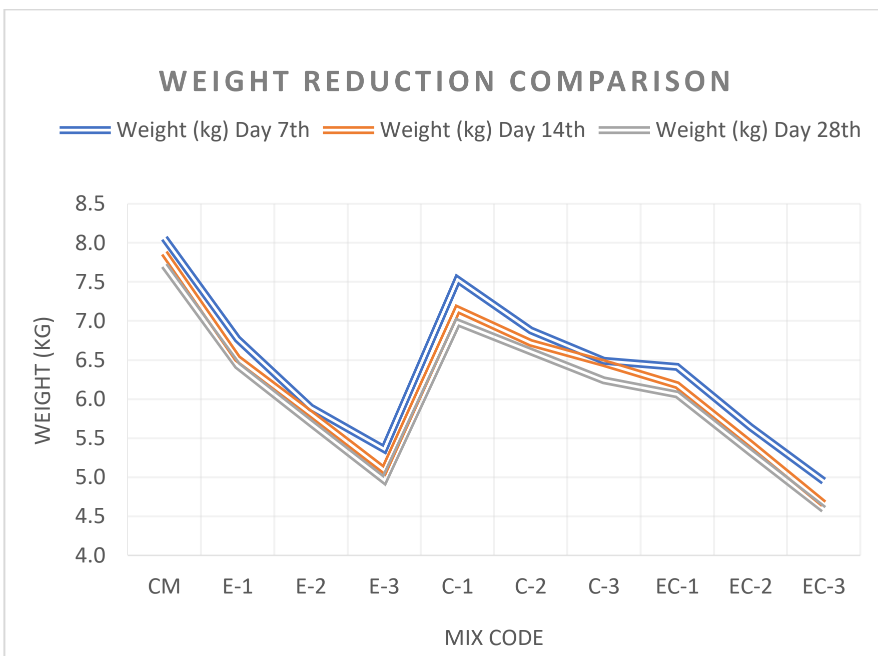

Figure 2. The weight reduction of the samples relative to the control mixture

4.3 Lightweight Material Feasibility

The primary objective of this study was to evaluate the feasibility of producing lightweight hollow concrete blocks through the incorporation of recycled EPS and coconut coir fiber. The unit weight reduction achieved in the modified mixtures demonstrates that waste-derived polymeric and lignocellulosic materials can be used to produce lower-density masonry units. In the context of circular construction, this finding supports the concept of material substitution in which secondary resources replace conventional aggregates without compromising the basic functional requirements for non-load-bearing applications (Pomponi & Moncaster, 2017; Meyer, 2009).

It should be noted that the present results are limited to physical characterization, and no mechanical or durability properties were evaluated. Therefore, the lightweight classification of the produced blocks should be interpreted as a preliminary indication based solely on density. Further studies are required to assess compressive strength, water absorption, and long-term performance to determine their suitability for practical construction applications.

DISCUSSION

The experimental results demonstrate that the incorporation of recycled EPS as a partial volumetric substitute for fine aggregate is the primary factor responsible for the reduction in unit weight of the hollow concrete blocks. This behavior is consistent with the fundamental principle of lightweight composite design, in which density is controlled by replacing mineral aggregates with low-specific-gravity materials that introduce a higher internal void ratio into the matrix (Neville, 2011). The cellular structure of EPS contributes to this effect by creating discontinuities within the cementitious phase, thereby lowering the overall mass per unit volume of the hardened composite (Gu & Ozbakkaloglu, 2016). Similar trends have been reported in previous studies on EPS-modified concrete, where density reduction is directly associated with the volume fraction of polymeric particles and their distribution within the matrix (Babu & Babu, 2003; Sabaa & Ravindrarajah, 1997).

Although the addition of EPS effectively reduced unit weight, the physical integrity of the specimens during demolding indicated the importance of supplementary reinforcement to maintain composite cohesion. The inclusion of coconut coir fiber contributed to improved handling performance, which can be attributed to the crack-bridging mechanism commonly observed in fiber-reinforced cementitious materials. Natural fibers provide resistance against microcrack propagation and enhance post-cracking integrity by transferring tensile stresses across discontinuities in the matrix (Li, 2007; Pacheco-Torgal & Jalali, 2011). This mechanism is particularly important in lightweight composites, where the reduction of mineral aggregate content tends to increase brittleness and reduce the continuity of the cementitious phase.

From a material-design perspective, the hybrid use of EPS particles and coconut coir fiber represents a complementary system in which each component performs a distinct function. EPS acts as a lightweight filler that controls density, while coir fiber serves as a reinforcing element that improves cohesion and reduces the susceptibility of the composite to physical damage during handling. The combined effect observed in this study is consistent with the concept of multi-phase composite optimization, in which lightweight fillers and fibrous reinforcements are used simultaneously to balance density reduction and structural integrity (Bogas et al., 2012; Sabaa & Ravindrarajah, 1997). Although mechanical properties were not evaluated in the present work, the improved demolding behavior suggests that the fiber addition partially compensates for the reduced matrix continuity associated with high EPS content.

In the context of non-structural masonry applications, the reduction in unit weight achieved in the modified mixtures is particularly relevant. Lightweight masonry units are widely used in partition walls and other non-load-bearing components because they reduce dead load, facilitate manual installation, and lower transportation and handling energy (ACI Committee 213, 2014; Meyer, 2009). The results, therefore, indicate that the use of waste-derived EPS and renewable coir fiber can contribute to the development of lower-density building elements that meet the primary functional requirement for such applications, which is weight reduction rather than high compressive strength.

From a circular-construction perspective, the incorporation of polymeric waste and agricultural residues into hollow concrete blocks represents a form of material valorization that extends the service life of secondary resources and reduces dependence on virgin aggregates. The substitution of natural sand with EPS waste contributes to landfill diversion, while the use of coconut coir provides a productive application for an abundant lignocellulosic by-product. Such material substitutions are consistent with waste-to-resource strategies in which construction materials are designed to integrate recycled and renewable inputs without compromising their intended function (Pomponi & Moncaster, 2017; Geissdoerfer et al., 2017). By reducing the unit weight of masonry units, the proposed composite also offers indirect environmental benefits through lower transportation energy and reduced structural dead load, which can contribute to improved resource efficiency at the building scale (Meyer, 2009).

It is important to note that the present discussion is limited to physical characterization based on unit weight and observed handling performance. No mechanical strength, water absorption, or durability tests were conducted, and therefore, no conclusions can be drawn regarding the structural performance or long-term behavior of the developed composite. Previous studies have shown that the incorporation of EPS generally leads to a reduction in compressive strength due to weak interfacial bonding with the cement matrix (Chen & Liu, 2004), while natural fibers may improve toughness but can also introduce variability if not properly treated (Pacheco-Torgal & Jalali, 2011). Consequently, further investigation is required to evaluate the mechanical and durability properties of the proposed material before its practical implementation in construction.

CONCLUSION

This study experimentally evaluated the feasibility of producing lightweight hollow concrete blocks through the incorporation of recycled expanded polystyrene (EPS) particles and coconut coir fiber as partial substitutes for conventional fine aggregate in cement-based mixtures. The results demonstrate a consistent reduction in unit weight in the modified specimens compared with the control mixture, confirming the effectiveness of EPS as a low-specific-gravity filler for density reduction in cementitious composites. This finding is consistent with the established principle that the replacement of mineral aggregates with lightweight materials significantly decreases the mass per unit volume of hardened concrete (Neville, 2011).

The inclusion of coconut coir fiber contributed to improved physical integrity during demolding and handling, indicating its role as a reinforcing element in the lightweight composite system. The observed behavior can be associated with the crack-bridging mechanism of natural fibers, which enhances matrix continuity and reduces the brittleness typically associated with lightweight cement-based materials containing high volumes of low-density fillers (Li, 2007; Pacheco-Torgal & Jalali, 2011). The hybrid use of EPS and coir, therefore, represents a complementary material strategy in which density reduction and composite integrity are achieved simultaneously.

From a materials-classification perspective, the reduced unit weight obtained in the modified mixtures indicates their potential application as lightweight masonry units for non-structural building components, where the primary performance requirement is the reduction of dead load rather than the achievement of high compressive strength (ACI Committee 213, 2014; Meyer, 2009). The use of lower-density masonry units can contribute to improved construction efficiency, easier handling, and reduced transportation energy, which are recognized advantages of lightweight building materials.

In the context of circular construction and waste-to-resource strategies, this study demonstrates a practical pathway for the valorization of polymeric waste and lignocellulosic agricultural residues in cement-based products. The substitution of natural sand with recycled EPS reduces the demand for virgin aggregates and diverts non-biodegradable waste from landfill, while the utilization of coconut coir provides a productive application for a renewable by-product. Such material substitutions are consistent with circular-economy principles that promote resource efficiency, material reuse, and the extension of product life cycles in the built environment (Geissdoerfer et al., 2017; Pomponi & Moncaster, 2017).

However, the scope of the present study is limited to physical characterization based on unit weight and qualitative observation of specimen integrity. No mechanical strength, water absorption, thermal performance, or durability testing was conducted. Therefore, the classification of the developed blocks as lightweight materials should be interpreted as a preliminary indication, and further experimental investigations are required to evaluate their structural performance and long-term behavior. Future research should focus on compressive strength, flexural performance, water absorption, and microstructural analysis in order to determine the suitability of the proposed composite for practical construction applications.

REFERENCES

ACI Committee 213. (2014). *Guide for structural lightweight-aggregate concrete (ACI 213R-14)*. American Concrete Institute.

Babu, K., & Babu, D. (2003). Behaviour of lightweight expanded polystyrene concrete containing silica fume. *Cement and Concrete Research*, *33*(5), 755–762. https://doi.org/10.1016/s0008-8846(02)01055-4

Bogas, J. A., Gomes, A., & Pereira, M. (2012). Self-compacting lightweight concrete produced with expanded clay aggregate. *Construction and Building Materials*, *35*, 1013–1022. https://doi.org/10.1016/j.conbuildmat.2012.04.111

Chen, B., & Liu, J. (2004). Properties of lightweight expanded polystyrene concrete reinforced with steel fiber. *Cement and Concrete Research*, *34*(7), 1259–1263. https://doi.org/10.1016/j.cemconres.2003.12.014

Chertow, M. R. (2007). “Uncovering” industrial symbiosis. *Journal of Industrial Ecology*, *11*(1), 11–30. https://doi.org/10.1162/jiec.2007.1110

Fiore, V., Scalici, T., Di Bella, G., & Valenza, A. (2015). A review on basalt fibre and its composites. *Composites Part B Engineering*, *74*, 74–94. https://doi.org/10.1016/j.compositesb.2014.12.034

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy – A new sustainability paradigm? *Journal of Cleaner Production, 143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production, 114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Gu, L., & Ozbakkaloglu, T. (2016). Use of recycled plastics in concrete: A critical review. *Waste Management*, *51*, 19–42. https://doi.org/10.1016/j.wasman.2016.03.005

Li, V. C. (2007). Engineered cementitious composites (ECC): Material, structural, and durability performance. In *Concrete construction engineering handbook*. CRC Press.

Meyer, C. (2009). The greening of the concrete industry. *Cement and Concrete Composites*, *31*(8), 601–605. https://doi.org/10.1016/j.cemconcomp.2008.12.010

Neville, A.M. (2011). Properties of Concrete. Pearson Education Limited, Essex.

Pacheco-Torgal, F., & Jalali, S. (2011). Cementitious building materials reinforced with vegetable fibres: A review. *Construction and Building Materials, 25*(2), 575–581. https://doi.org/10.1016/j.conbuildmat.2010.07.024

PlasticsEurope. (2021). *Plastics – the Facts 2021: An analysis of European plastics production, demand and waste data*. https://plasticseurope.org/knowledge-hub/plastics-the-facts-2021/

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential, economically viable solutions for a low-CO_2 cement-based materials industry. *Cement and Concrete Research, 114*, 2–26. https://doi.org/10.1016/j.cemconres.2018.03.015

Siddique, R., Khatib, J., & Kaur, I. (2008). Use of recycled plastic in concrete: A review. *Waste Management, 28*(10), 1835–1852. https://doi.org/10.1016/j.wasman.2007.09.011

Sabaa, B., & Ravindrarajah, R. S. (1997, December). Engineering properties of lightweight concrete containing crushed expanded polystyrene waste. In *Proceedings of the symposium MM: advances in materials for cementitious composites, Boston, MA, USA* (pp. 1-3).