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Characterization of composite partition board using basalt rock and coir fibre

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ABSTRACT: The increasing global demand for housing and building materials is creating pressure for sustainable alternatives, driven by the massive generation of construction waste and the use of non-eco-friendly materials. The main purpose of this study was to analyse the characteristics of a composite partition board utilizing basalt rock offcuts with over 96 tons by 2019, and coir fibre waste, which reaches approximately 1.8 million tons annually, as alternative materials. The resulting composite boards were designed to substitute fine aggregate with basalt rock waste and utilized coir fibre as an additive. A key finding is the inverse relationship between coir fibre content and composite density, where the reduction of coir fibre significantly improved the physical properties. Analysis showed that all variations significantly exceeded the minimum requirements specified in the SNI 03-2104-1991 and JIS A 5417-1992 standards for density and dimensional stability. Specifically, the fibre free K2 composition achieved the highest density of 1.87 g/cm3, classifying it as a superior high quality cement board. Furthermore, all compositions demonstrated excellent durability, with impact resistance exceeding 99% mass retention and thermal stability up to 200°C, confirming the composite's potential as a sustainable, high-performance alternative to conventional partition materials. This study provides a practical contribution to green construction research by validating a localized dual-waste composite that meets international building codes, thereby operationalizing the objectives of SDG 9 and 12 through industrial and agricultural waste utilization.

KEYWORDS: alternative material; basalt rock; coir fibre; partition board.

1. INTRODUCTION

The increased global demand for housing is mainly because of the massive world population of 8.2 billion in 2025, projected to reach 9.7 billion by 2050 (Worldometer, 2025). Consequently, the construction industry faces an increasing demand for materials, despite already being responsible for approximately 40% of global natural resource consumption (Almeida et al., 2025). As raw material availability for concrete production decreases and environmental concerns rise, developing sustainable and eco-friendly alternatives becomes essential (Hamada et al., 2023).

Basalt rock, also known as basaltic scoria, is a type of volcanic igneous rock formed from cooling magma. This rock is characterized by its porous, lightweight, and rough surface, with a greyish-black colour. Basalt rock is typically processed by carving artisans and used as a material for traditional building ornaments in Bali (Aristyawan et al., 2021). During basalt rock processing by artisans, about 30% of the material is left as stone offcuts, resulting in more than 96 tons of waste by 2019 (Wijaya et al., 2019) with low economic value.

Coconut trees, the most important palm species in tropical and subtropical regions (Sanou et al., 2024), produce coir fibre as a natural byproduct of commercial processing. Recognized for its eco-friendly potential, coir combines high lignin content for rigidity with cellulose and hemicellulose components that enhance strength and flexibility (Bawono et al., 2025; Mulana et al., 2024). Global coconut production has shown a consistent upward trend, rising from 23.7 million tons in 1961 to 62.4 million tons by 2022 (Majd Rahimabadi & Arabani, 2025). Coir is readily available in regions with large coconut industries, such as Indonesia, where coconut processing largely focuses on food products like copra and coconut oil, leaving coir fibre largely underutilized (Bawono et al., 2025).

In response to these environmental and resource concerns, extensive research has focused on incorporating various alternative raw materials into construction composites. Arranged from Bamboo fibre (Yusra et al., 2020), Banana stem fibre (Ali et al., 2022), Coir fibre (Sivakumaresa Chockalingam & Rymond, 2022), to Basalt stone powder (Ramezani et al., 2024). While these efforts demonstrate the feasibility of waste-based concrete, their application in specific building components, particularly for concrete wall-filling or partition boards, is still rare (Yu & Sun, 2018). The characteristic porosity and mineral composition of basalt rock, rich in SiO_2 and Al_2O_3, along with coir fibre's high lignin and cellulose content, make both materials structurally viable for this composite application (Ahmed et al., 2025; Mahmud et al., 2021).

The novelty of this research lies in the engineered synergy of a dual-waste matrix, integrating inorganic basalt rock offcuts from the local artisan industry with organic coir fibre waste into a single composite partition board. While existing literature often focuses on singular waste streams, this study investigates the mechanical interaction between the silica-alumina rich porosity of basalt and the high-lignin flexibility of coir fibre. This research provides a practical contribution to green construction by operationalizing SDG 9 and 12, validating a localized dual-waste solution that not only meets but exceeds SNI 03-2104-1991 and JIS A 5417-1992 standards.

Building on this novelty, this study aims to quantitatively establish the relationship between coir fibre content and the key physical and mechanical properties of this novel composite. The objective is to identify an optimal formulation that maximizes performance while adhering to sustainable waste utilization principles, thereby providing a scientifically validated and practical alternative for partition boards.

2. METHODS

2.1 Research Duration and Location

This research was conducted from June 3, 2025, to June 28, 2025, at the Material Technology Laboratory of the Civil Engineering Program at Udayana University.

2.2 Research Design and Approach

The study adopted an experimental laboratory approach to generate primary data through controlled testing of composite specimens with varying coir fibre composition of 0%, 0.5%, and 1%. The primary parameters investigated to evaluate the physical and mechanical performance include density, moisture content, water absorption, impact resistance, and heat resistance. This experimental data is complemented by secondary data derived from Indonesian National Standards (SNI), Japanese Industrial Standards (JIS), and peer-reviewed literature to contextualize findings and ensure compliance with international building codes.

2.3 Materials and Equipment Used

The materials used in this study include waste basalt stone from Surya Jaya Store, coconut coir fibre from Menanga village, along with 5% sodium hydroxide (NaOH), Portland Composite Cement (PCC) from UNUD JAYA BANGUNAN, and water. The equipment includes a hammer, glassware, an oven, callipers, measuring cups, buckets, aluminium moulds, sieves, trowels, and digital scales.

2.4 Material Preparation Process

Basalt stone was crushed into powder and sieved to obtain zone II fine aggregate according to SNI 03-2834-2000. Coir fibre was alkalinized with a 5% sodium hydroxide (NaOH) for optimal results (Ru et al., 2022). This process removes impurities such as waxes, oils, and lignin, and breaks down the fibre’s hemicellulose content (Mukesh & Godara, 2019). The raw materials were then measured based on the proportions specified in Table 1. Nine specimens were prepared, with three replicates for each composition.

Tabel 1. Mix design of the partition board

Material	Mass Percentage (%)		
	K2	K1	K0
Basalt Rock Powder	68.40%	67.90%	67.40%
Portland composite cement (PCC)	21.10%	21.10%	21.10%
Water	10.50%	10.50%	10.50%
Coir Fibre	0.00%	0.50%	1.00%

2.5 Partition Boards Making

The previously weighed basalt rock powder and PPC was dry-mixed in a container. Water was then added and mixed thoroughly, followed by adding coir fibre, which was stirred in until evenly blended. The resulting mixture was poured into moulds measuring 10 × 10 × 1 cm and allowed to set for 24 hours.

2.6 Data Analysis Techniques

The data analysis methodology involved calculating the physical and mechanical properties based on the established formulas (Equations 1-4). A comparative analysis was then conducted where the mean values for each property were systematically benchmarked against the minimum performance criteria stipulated in Indonesian National Standard (SNI) 03-2104-1991 and Japanese Industrial Standard (JIS) A 5417-1992 to determine the viability of each composite formulation. Secondary data from peer-reviewed literature was used primarily in the discussion section to contextualize and validate the experimental findings.

Density (ρ) is determined when the test piece is under dry air conditions. The mass of the test piece is recorded by weighing, and its dimensions (length, width, and thickness) are measured to ascertain its volume. The density can then be computed using Equation 1.

$$\text{Density}(\text{g/cm}^3) = \frac{\text{Mass(g)}}{\text{Volume(cm}^3)} \quad (1)$$

where Mass is the mass of the specimen in grams (g) and Volume is the volume of the specimen in cubic centimetres (cm³).

The moisture content (MC) is ascertained by comparing the initial mass (M1) of the specimen with its mass after being thoroughly dried in an oven (M2). The same specimen utilized for the density evaluation is used for this analysis. The specimen is first weighed to establish its initial mass (MI). It is then placed in an oven for 24 hours at a temperature of 103±2∘C. Once the oven-drying period is complete, the specimen is weighed again to determine its oven-dry mass (MOD). The moisture content percentage can be figured out using Equation 2.

$$\text{Moisture Content}(\%) = \frac{\text{M1(g)} - \text{M2(g)}}{\text{M2(g)}} \text{ x } 100\% \quad (2)$$

where M1 is the initial mass of the specimen in grams (g) and M2 is the oven-dry mass of the specimen in grams (g).

The water absorption capacity (WAC) is determined by noting the mass of the test specimen before it is submerged in water (MA) and its mass after a 24-hour immersion period (MB). Initially, the test specimen is weighed to get the value for MA, and it is weighed once more after the immersion to get the value for MB. The water absorption capacity is then calculated using Equation 3.

$$\text{Water Absorption }(\%) = \frac{\text{MA(g)} - \text{MB(g)}}{\text{MB(g)}} \text{ x } 100 \quad (3)$$

Where MA is the mass of the specimen after a 24-hour immersion period in grams (g) and MB is the oven-dry mass of the specimen before immersion in grams (g).

An impact resistance test (IRT) assesses the partition board's ability to withstand being dropped from a specified height. For this, the test specimen is dropped from a height of roughly 1 meter. Any alteration in its mass is recorded by reweighing the specimen after the drop. The impact strength percentage can be determined using Equation 4.

$$\text{Impact Resistance}(\%) = \frac{\text{M2(g)}}{\text{M1(g)}} \text{ x } 100\% \quad (4)$$

where M2 is the mass of the specimen after the drop in grams (g) and M1 is the initial mass of the specimen before the drop in grams (g).

The heat resistance test (HRT) involves incrementally raising the temperature of the partition board to levels between 100˚C and 200˚C. During this process, observations are made to see if any melting occurs on the partition board.

2.7 Research Limitations

This study was conducted on laboratory-scale specimens (10x10x1 cm), and the results may not fully reflect the performance of full-sized boards.

3. Result and Discussions

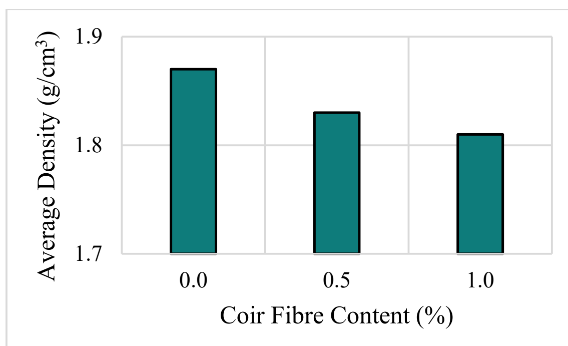
3.1 Density

Density is the ratio of the mass of an object to its volume. This physical property influences mechanical properties, specifically the strength of the resulting composite partition board.

Tabel 2. Density test result

Testing Composition	Sample	Mass (g)	Volume (cm3)	Density (g/cm3)	Average Density (g/cm3)
K0	S1	181.2	102.9	1.76	1.81
	S2	209.2	114	1.84	
	S3	184.4	99.75	1.85	
K1	S1	202.4	109.3	1.85	1.83
	S2	187.9	99.75	1.88	
	S3	182.3	104.5	1.74	
K2	S1	194.9	99.75	1.95	1.87
	S2	203.6	112.1	1.82	
	S3	215.8	117.6	1.84	

Based on Table 2, a clear relationship between coconut fibre content and material density is observed. The highest average density was 1.87 g/cm³, obtained from composition K2, which contained no coconut fibre. Conversely, the lowest average density was 1.81 g/cm³, recorded for composition K0, with the highest fibre content at 1%. Composition K1, with 0.5% coconut fibre, had an intermediate average density of 1.83 g/cm³. All compositions successfully surpassed the minimum density requirement of 0.57 g/cm³ and 0.8 g/cm³ specified by the SNI 03-2104-1991 and JIS A 5417-1992 standard, confirming the viability of the basalt rock fine aggregate substitution.



Gambar 1. Average density vs coir fibre content

This measured variation demonstrates a clear inverse relationship between coir fibre content and composite bulk density. The observed decrease in density is primarily attributed to the significantly lower specific gravity of the natural coir fibre compared to the dense basalt rock and cement matrix. The incorporation of a porous, lightweight organic material increases the overall volume without proportionally increasing the mass, thereby reducing the final unit density.

This result corroborates previous research on natural fibre-reinforced cement composites, which consistently reports a reduction in bulk density with the incorporation of organic fibres such as coir (Sivakumaresa Chockalingam & Rymond, 2022) and palm oil empty fruit bunch (Amna et al., 2014). The superior density exhibited by the fibre-free K2 composition aligns with the expected material behaviour when lightweight organic material is removed. This correlation strengthens the argument that basalt rock waste as an effective high-density replacement for fine aggregate in composite formulations.

3.2 Moisture Content

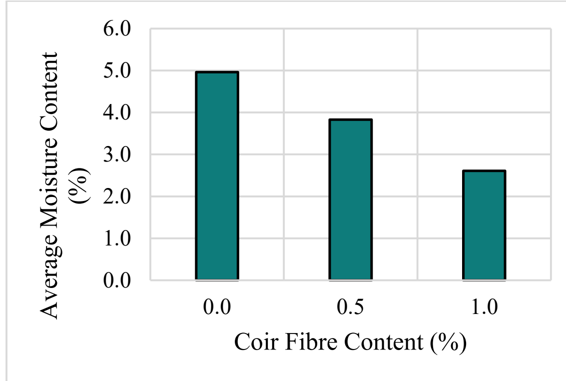
Moisture content is the ratio of the water mass to the partition board's oven-dry mass. The results of the moisture content test in this study are presented in Table 3.

Tabel 2. Moisture content test result

Testing Composition	Sample	Mass (g)	Oven dry mass (g)	Moisture content (%)	Average moisture content (%)
	S1	181.2	176.5	2.66	
K0	S2	209.2	204	2.55	2.61
	S3	184.4	179.7	2.62	
	S1	202.4	195	3.79	
K1	S2	187.9	180.8	3.93	3.83
	S3	182.3	175.7	3.76	
	S1	194.9	187.1	4.17	
K2	S2	203.6	196.7	3.51	4.96
	S3	215.8	201.3	7.2	

Moisture content is the ratio of the water mass to the partition board's oven-dry mass. The results of the moisture content test in this study are presented in Table 3.

The measured moisture content for all specimens ranged from 2.55% to 7.20%. The average moisture content for the composition with 1% coir fibre (K0) was 2.61%, for 0.5% coir fibre (K1) it was 3.83%, and for the fibre-free composition (K2) it was 4.96%. These results show an unexpected trend where moisture content increased as fibre content decreased, which is visualized in Figure 2. Despite these variations, all tested compositions successfully satisfied the maximum moisture content limit of 14% as mandated by the SNI 03-2104-1991 standard and 16% as specified by the JIS A 5417-1992 standard.



Gambar 2. Average moisture content vs coir fibre content

The analysis of moisture content reveals an unexpected relationship where the fibre-free composition (K2) exhibited the highest moisture retention. This finding contradicts the general expectation that the inclusion of hygroscopic materials like coir fibre, with its cellulose and hemicellulose components that readily bond with water, would lead to higher moisture content (Adeniyi et al., 2019; Yan et al., 2016). A possible explanation for this anomaly could be related to the curing process and the final micro-structure of the matrix. The K2 composition may have developed a different internal pore structure that trapped more residual water from the initial mixing process compared to the more densely packed fibre-reinforced composites. While natural fibres are inherently hygroscopic, the chemical treatment and the high-density basalt-cement matrix in all compositions proved effective. The fact that all compositions remained well below the SNI and JIS thresholds validates the material's fitness for use in internal partition applications where moisture fluctuations must be minimized.

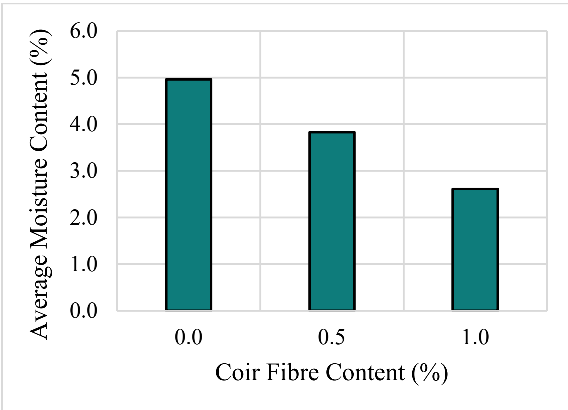
3.3 Water Absorbtion

The water absorption test indicates the ability of the composite partition board to absorb water over a specific period of time. The results of the water absorption test in this study are presented in Table 4.

Tabel 3. Water absorbtion test result

Testing	Initial mass (g)	Final mass (g)	Water absorption (%)	Average water absorption (%)
	176.5	203.7	15.41	
K0	204	233	14.22	14.55
	179.7	204.9	14.02	
	195	221.4	13.54	
K1	180.8	207.8	14.93	14.35
	175.7	201.3	14.57	
	187.1	209.4	11.92	
K2	196.7	221.2	12.46	13.51
	201.3	233.8	16.15	

The highest average water absorption of 14.55% was recorded for composition K0 (1% coir fibre), while the lowest, 13.51%, was observed in the fibre-free composition K2. Composition K1 (0.5% coir fibre) had an intermediate value of 14.35%. All compositions successfully met the requirements of the SNI 03-2104-1991 standard, which specifies a water absorption range of 10%-30%.



Gambar 3. Average water absorbtion vs coir fibre content

The results demonstrate a clear and direct relationship between coir fibre content and water absorption. The increase in water uptake with higher fibre content is attributed to two primary factors. First, the addition of fibres introduces a more porous structure within the dense cement matrix, creating more voids and pathways for water ingress. Second, the inherent hygroscopic nature of coir fibre's cellulose and hemicellulose components actively attracts and holds water molecules, a well-documented characteristic of natural fibres.

This trend is consistent with findings from studies on natural fibre-reinforced composites, which consistently report increased water absorption with higher fibre content due to the hydrophilic nature of the fibres (Sanjeevi et al., 2021). The superior performance of the K2 composition in resisting water absorption, coupled with its higher density, reinforces its suitability for applications where dimensional stability and moisture resistance are critical. This finding also underscores the effectiveness of a dense basalt-cement matrix in creating a less permeable final product.

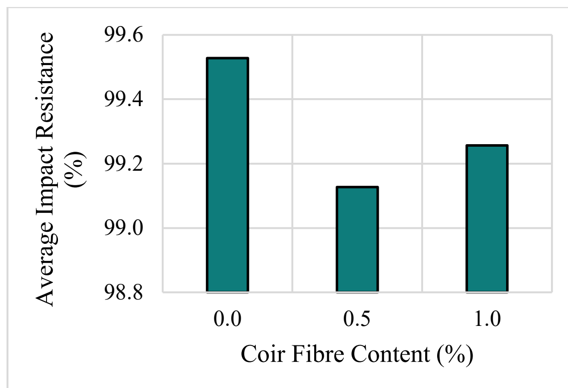
3.4 Impact Resistance

The impact resistance test is conducted to determine the resilience of the test specimens when subjected to external forces. The results of the impact resistance test in this study are presented in Table 5.

Tabel 4. Impact resistance test result

Testing	Initial mass (g)	Final mass (g)	Impact resistance (%)	Average impact resistance (%)
	182.1	180.9	99.34	
K0	224.5	223.6	99.60	99.53
	195.3	194.6	99.64	
	208.5	206.7	99.14	
K1	194.2	193.1	99.43	99.13
	193.6	191.3	98.81	
	206.7	204.3	98.84	
K2	219.3	218.1	99.45	99.26
	229.4	228.2	99.48	

The results show excellent performance, with average mass retention values exceeding 99%. The composition with 1% coir fibre (K0) exhibited the highest average impact resistance at 99.53%. The fibre-free composition (K2) and the 0.5% fibre composition (K1) also showed high durability, with values of 99.26% and 99.13%, respectively. The minimal mass loss across all specimens indicates a high level of structural integrity.



Gambar 4. Average impact resistance vs coir fibre content

The outstanding impact resistance across all formulations is a key finding, confirming the material's robustness. Although the differences are marginal, the slightly superior performance of the fibre-reinforced composition (K0) is noteworthy. This enhanced resistance is attributed to the fundamental role of fibres in a brittle cementitious matrix. The coir fibres act as a crack-arresting mechanism upon impact, they bridge micro-cracks as they form, absorbing and dissipating energy. This reinforcement directly aligns with previous research which has demonstrated that coir fibres significantly improve the durability and toughness characteristics of cementitious composites (Varghese & Unnikrishnan, 2023).

3.5 Heat Resistance

The exceptional thermal stability demonstrated by the composite is confirmed by minimal mass loss (less than 1%) and no visible structural damage across all compositions. The basalt rock aggregate, an igneous volcanic rock, and the Portland cement matrix are both inherently non-combustible and stable at temperatures well beyond the 200°C test limit. This finding is supported by (Han et al., 2024), which has also shown the positive contribution of basalt's inherent properties to a material's heat resistance, even when used in different forms such as a fibre substitute. While coir fibre is an organic material, its low percentage and encapsulation within the dense, inorganic matrix appear to have protected it from thermal degradation at this temperature. This high level of thermal durability is a critical finding, as it suggests the material may offer enhanced fire resistance, a significant advantage for its application in building safety.

4. CONCLUSION

This study successfully characterized a composite partition board made from basalt rock and coir fibre waste, achieving its objective of identifying a sustainable and high-performance formulation. The results revealed an inverse relationship between coir fibre content and the board's physical performance, with the fibre-free composition (K2) emerging as the optimal formulation, exhibiting superior density (1.87 g/cm³) and moisture resistance while maintaining excellent impact and thermal resilience across all variants. The study's primary contribution lies in validating a dual-waste utilization strategy that provides a practical pathway to support Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure) and Goal 12 (Responsible Consumption and Production) by transforming regional waste streams into viable construction materials. Although the findings confirm the composite's potential, its reliance on short-term evaluations underscores the need for future studies focused on long-term durability and creep behaviour to assess service life under environmental stressors. Furthermore, comprehensive flexural strength testing is recommended to fully characterize the board's mechanical performance and evaluate its suitability for semi-structural applications.

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