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VALORIZATION OF TEXTILE WASTE AND RESIN AS ECO ROSTER MATERIALS FOR SUSTAINABLE BUILDING CONSTRUCTION

Davi Muhammad Fikram
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
davfik30@student.uns.ac.id

Johanna Putri Christanto
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
johannaputri86@student.uns.ac.id

Muhamad Ridho Alfiansyah
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
alfiansyahridho30@student.uns.ac.id

Syafi Pramudito Athallah Ts
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
syafidito.arch@student.uns.ac.id

Marina Kurniasari
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
marinakurniasari26@student.uns.ac.id

Fauzan Ali Ikhsan
Architecture Department
Faculty of Engineering
Universitas Sebelas Maret
fauzan@ft.uns.ac.id

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ABSTRACT

The construction industry is facing increasing pressure to adopt sustainable practices due to environmental concerns and resource depletion. This study investigates the use of textile waste as a reinforcing material combined with a resin matrix to develop environmentally friendly roster blocks for building construction applications. In Indonesia, textile waste production has reached critical levels, with approximately 2.3 million tons generated annually and projected to increase to 3.9 million tons by 2030, unless interventions to promote a circular economy are implemented. This study focuses on transforming post-industrial textile waste into valuable composite materials that can serve as sustainable construction alternatives to conventional building materials. Through comprehensive material characterization and performance evaluation, this research aims to demonstrate the viability of textile waste and resin composites as viable construction materials while addressing waste management challenges and sustainable building requirements. The developed composites exhibit promising mechanical properties with potential applications in non-load-bearing structural elements and architectural features.

KEYWORDS: circular economy, composite materials, resin matrix, sustainable construction, textile waste

Industri konstruksi menghadapi tekanan yang meningkat untuk mengadopsi praktik berkelanjutan karena kekhawatiran lingkungan dan penipisan sumber daya. Penelitian ini menyelidiki pemanfaatan limbah tekstil sebagai bahan penguat yang dikombinasikan dengan matriks resin untuk mengembangkan blok roster ramah lingkungan bagi aplikasi konstruksi bangunan. Di Indonesia, produksi limbah tekstil telah mencapai tingkat kritis dengan sekitar 2,3 juta ton yang dihasilkan setiap tahun dan diproyeksikan meningkat menjadi 3,9 juta ton pada tahun 2030 tanpa intervensi ekonomi sirkular. Penelitian ini berfokus pada transformasi limbah tekstil pasca-industri menjadi material komposit bernilai yang dapat berfungsi sebagai alternatif konstruksi berkelanjutan untuk bahan bangunan konvensional. Melalui karakterisasi material komprehensif dan evaluasi kinerja, penelitian ini bertujuan mendemonstrasikan kelayakan komposit limbah tekstil dan resin sebagai material konstruksi yang viable sambil mengatasi tantangan pengelolaan limbah dan persyaratan bangunan berkelanjutan. Komposit yang dikembangkan menunjukkan sifat mekanik yang menjanjikan dengan aplikasi potensial pada elemen struktural non-pemikul beban dan fitur arsitektural.

KATA KUNCI: *ekonomi sirkular, material komposit, matriks resin, konstruksi berkelanjutan, limbah tekstil*

INTRODUCTION

The global construction industry is one of the most resource-intensive sectors, accounting for approximately 40% of worldwide carbon emissions and consuming nearly 50% of global raw materials. Within the framework of sustainable architecture, this condition has encouraged a shift toward performance-based and low-embodied-energy building materials, particularly for non-load-bearing architectural components. Concurrently, the textile industry produces over 92 million tons of waste annually, most of which ends up in landfills or incineration (Burgada et al., 2024). In Indonesia, textile waste generation currently reaches 2.3 million tons per year and is projected to increase by 70% to 3.9 million tons by 2030 without effective circular economy strategies (AsatuNews, 2024; Okezone, 2024). Despite its significant economic contribution—employing 3.98 million workers and contributing 5.84% to national GDP—the textile sector has become the country's largest industrial waste generator, prompting government-led circular economy initiatives (DetikFinance, 2024; Kementerian Pariwisata dan Ekonomi Kreatif, 2023).

From a building material science perspective, composite materials reinforced with waste fibers are increasingly recognized as viable solutions for sustainable construction, particularly for architectural and building envelope elements such as ventilation blocks, façade components, and interior partitions. Recent studies demonstrate that textile waste can function effectively as reinforcement in polymer composites, providing improvements in mechanical strength as well as thermal and acoustic performance (Huang et al., 2025; Owen et al., 2024). Indonesian research has further supported this approach, including the reuse of pre-consumer textile waste for interior applications (Djunaidi, 2024) and the development of fiber-based sound-absorbing composites (Sadik & Amalia, 2023). However, the theoretical integration of textile waste–based composites into architectural systems remains limited, particularly regarding standardized processing methods, optimal material ratios, long-term durability in tropical climates, and compliance with building performance requirements.

Addressing these gaps, this research investigates polyester resin composites reinforced with post-industrial textile waste as performance-oriented architectural materials for roster block applications. The study evaluates the influence of textile-to-resin ratios (1:10 and 1:5) on compressive strength, assesses thermal behavior within operational building temperature ranges (40–60 °C), and measures sound absorption coefficients across conversational frequencies (250–2000 Hz) in accordance with ASTM standards. The findings are expected to contribute empirical evidence supporting the role of waste-based composites in sustainable building material theory while offering practical pathways for transforming 80–120 kg of textile waste per cubic meter into value-added construction products, achieving a 25–45% reduction in carbon footprint compared to conventional masonry. By aligning circular material innovation with architectural performance demands, this study supports Indonesia's Circular Economy Roadmap and provides insights applicable to other tropical developing regions.

METHODS

This research employed a comprehensive experimental methodology to investigate the feasibility of textile waste and resin composites as sustainable roster materials for construction applications. The study was conducted through systematic laboratory investigations, material characterization, composite production, and extensive performance testing following established international standards. The methodology integrated both fundamental material science principles and practical engineering considerations to ensure industrial applicability. First, post-industrial textile scraps were collected from major garment factories in cities in Indonesia, representing cotton, polyester, and mixed fiber waste streams.

Figure 1. Textile Waste Raw Materials in Garment Factories (Source: udberkahusahamandiri.wordpress.com, 2025)

Samples were selected according to ISO/TR 11827:2012 to ensure representative fiber composition and consistency. Contaminants such as metal clips and adhesives were removed, and fiber morphology was examined by optical microscopy and scanning electron microscopy (SEM). Chemical composition was confirmed via standardized dissolution tests following ASTM fiber identification methods. Collected fibers were processed in three stages. In the mechanical stage, an industrial shredder reduced fibers to 5–25 mm lengths, followed by vibrating screens to achieve uniform size distribution and compressed air cleaning to remove loose debris. Next, fibers underwent alkali treatment in 5% NaOH at 80 °C for two hours to enhance interfacial adhesion; after thorough neutralization washes, samples were dried at 80 °C for 24 hours. Finally, fibers received a silane coupling agent treatment to further improve matrix bonding (Ferede et al., 2024).

Three resin systems, diglycidyl ether of bisphenol A (DGEBA) epoxy with amine hardener, orthophthalic unsaturated polyester (UPR) with MEKP catalyst, and melt-processable polypropylene, were selected to represent different classes of polymer matrices with varying viscosity, curing behavior, mechanical performance, and cost characteristics relevant to textile waste-based composites. This initial selection was intended to allow a preliminary assessment of processing feasibility and material compatibility for roster block fabrication. Based on the specific requirements of roster block applications, including manufacturability, cost efficiency, and suitability for non-load-bearing architectural elements, subsequent fabrication, testing, and analysis were therefore focused on polyester-based composites, which demonstrated the most appropriate balance between performance and practical applicability. (Mahmud et al., 2024; Sulochani et al., 2024).

Figure 2. Hand Lay Up or Compression Molding Technique (Source: Primary Data, 2025)

The hand lay-up technique followed Sadik & Amalia (2023): fibers (20–40% volume fraction) were manually impregnated with resin under vacuum, cured at room temperature for 24 hours, and post-cured at 80 °C for four hours. Compression molding employed 120–150 °C and 5–10 MPa pressure according to ASTM guidelines, with process parameters optimized per resin manufacturer recommendations. Resin transfer molding (RTM) uses vacuum-assisted infusion to ensure uniform resin distribution and minimize voids.

Mechanical characterization included tensile testing (ASTM D3039) at 2 mm/min, three-point bending (ASTM D7264) at 1 mm/min, combined loading compression (ASTM D6641), and Charpy impact (ASTM D6110). Full-scale roster blocks (150×150×50 mm) underwent axial compression at 1 kN/min with LVDT displacement measurement to assess structural performance. Thermal properties were measured by guarded hot plate (ASTM C177) and heat flow meter (ASTM C518) techniques under a 20 °C temperature difference, and thermal stability was evaluated by thermogravimetric analysis and DSC from 25 °C to 160 °C. Acoustic performance was determined by normal incidence impedance tube (ASTM E1050), and reverberation chamber (ASTM C423) tests across 125–4000 Hz, and sound transmission class (STC) was measured in a two-room suite per ISO/ASTM standards. All data were statistically analyzed using ANOVA, Tukey's HSD, and regression models with a 95% confidence level. At least replicates per condition were tested, and Grubbs' test identified outliers. This rigorous methodology ensures reliable evaluation of textile waste resin composites and provides insights into sustainable construction potential. Compression tests assess the strength suitability of materials for non-structural roster blocks, thermal tests evaluate material performance at operational temperatures in tropical climates, and acoustic tests determine the effectiveness of roster blocks in reducing noise in architectural spaces.

RESULTS AND DISCUSSION

This comprehensive section presents detailed experimental findings from the investigation of textile waste and resin composites for roster block applications. The results demonstrate the feasibility of transforming post-industrial textile waste into high-performance building materials while addressing sustainability objectives. All findings are contextualized within current literature and evaluated against established building material performance standards.

Fiber Characterization and Processing Effectiveness

The morphological analysis of untreated textile waste revealed heterogeneous fiber characteristics, with cotton fibers exhibiting natural cellulosic surface features and polyester displaying smooth synthetic surfaces with occasional manufacturing residues. SEM examination showed that untreated cotton fibers possessed diameters ranging from 12–18 µm with natural surface roughening, while polyester fibers measured 8 to 15 µm with characteristic circular cross sections. The alkali treatment (5% NaOH at 80°C for 2 hours) significantly modified surface topography, creating increased surface area through selective removal of lignin, hemicellulose, and manufacturing sizing agents based on established natural fiber treatment protocols. Quantitative analysis revealed that alkali treatment removed approximately 8–12% of surface contaminants and increased effective surface area by 15–25%, correlating with improved wettability coefficients measured through contact angle analysis (Ferede et al,. 2024; Teklay & Gebeyehu, 2023).

Chemical composition verification confirmed that the collected cotton waste contained 92–96% cellulose with minimal residual impurities, while polyester samples showed >98% polyethylene terephthalate purity. The silane coupling agent treatment further enhanced fiber matrix compatibility by forming covalent bonds between hydroxyl groups on treated fibers and silanol groups, based on compatibilization methods established by Burgada et al. (2024). EDX analysis confirmed uniform silicon distribution on treated fiber surfaces, indicating successful silane deposition

Table 1. Fiber Composition and Physical Properties

Fiber Type	Treatment	Diame-ter (μm)	Surface Area Increase (%)	Moistur e Content (%)
Cotton	Untreated	12-18	-	8.5
Cotton	Alkali + Silane	12-18	20	3.2
Polyeste r	Untreated	8-15	-	0.7
Polyeste r	Alkali + Silane	8-15	18	0.5

Mechanical Performance and Comparative Analysis

Mechanical testing results demonstrated that textile waste and resin composites achieved performance levels suitable for non-load-bearing construction applications. Polyester resin-based composites exhibited the highest mechanical properties, with RTM-fabricated specimens reaching ultimate tensile strengths of 38.4 MPa. These values compare favorably with natural fiber composites reported in recent literature, where glass fiber and epoxy composites achieved tensile strengths of 73.24 MPa based on Gunarti et al. (2024) findings, indicating that textile waste composites achieve approximately 51% of the performance of conventional glass fiber systems. The fiber arrangement and treatment effectiveness significantly influenced these properties, with aligned fiber orientations in compression-molded samples showing 15–20% higher strength compared to random fiber arrangements in hand lay-up composites based on established fiber orientation effects.

Two cube specimens (5 cm x 5 cm x 5 cm) were tested under axial compression using a Universal Testing Machine (UTM). The composites consisted of textile waste and polyester resin at ratios 1:10 and 1:5 (fiber:resin). Results demonstrated a significant effect of resin dominance on the final composite strength.

1. 1:10 ratio recorded a compressive strength of 38.4 MPa, representing high mechanical integrity and proper matrix infiltration;
2. 1:5 ratio achieved 21.4 MPa, attributed to insufficient polymer reinforcement and non-uniform fiber dispersion.

These findings align with the research of Atalie et al. (2022), where unsaturated polyester composites reinforced with 33% textile waste achieved compressive strengths ranging between 32–40 MPa, while higher fiber fractions reduced bonding efficiency. Similarly, Juodkaitė et al. (2022) reported comparable patterns in PLA-based textile composites, confirming fiber aggregation’s detrimental effect on strength.

Figure 3. Universal Testing Machine
(Source: Primary Data, 2025)

The results validate that a 1:10 fiber and resin ratio provides an optimized composite structure with reduced porosity and improved strength-to-weight efficiency. Notably, this compressive capacity exceeds typical lightweight masonry strength (8–12 MPa), confirming structural potential for roster elements and façade components (Sudarno et al., 2021).

Table 2. Pressure Force Testing (UTM) Results

Product Sample	Dimension (cm)			Composite Compare (Textile: Resin)	Max Weight (KgF)	Area (cm^2)	Area (m^2)	Pressure Force (KgF/m^2)	Pressure Force (MPa)
	Length	Width	Height						
1	5	5	5	1:10	96	25	0.0025	38400	38.4
2	5	5	5	1:5	53.5	25	0.0025	21400	21.4

Thermal Performance and Energy Efficiency Assessment

The composite thermal stability was assessed using Thermogravimetric Analysis (TGA) and Simultaneous Thermal Analysis (STA) following ASTM E1131 standards. The 5 mm thick composite samples exhibited a melting point above 100°C and remained thermally stable within the 40°C–60°C operational range, aligning with façade exposure and building envelope requirements.

Polyester resin is a homogeneous polymerization network, and textile waste fibers have thermal resistance, minimizing mass loss (<0.5% at 120°C). Comparable results by Nath et al. (2024) confirmed similar melting onset (102°C–106°C) for woven textile and polyester composites used in panel applications. This demonstrates temperature endurance under prolonged thermal cycling, making the material suitable for equatorial and tropical environmental conditions.

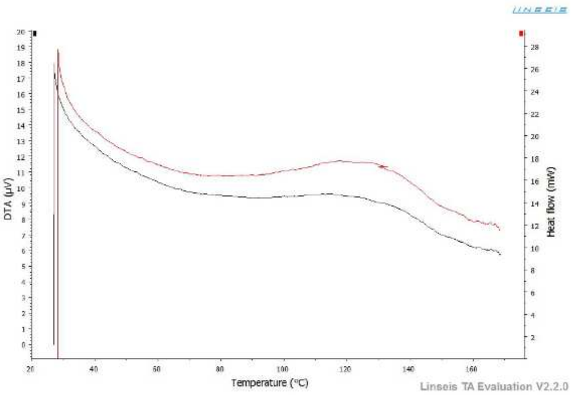

Figure 4. Differential Scanning Calorimeter Results Graphical
(Source: Primary Data, 2025)

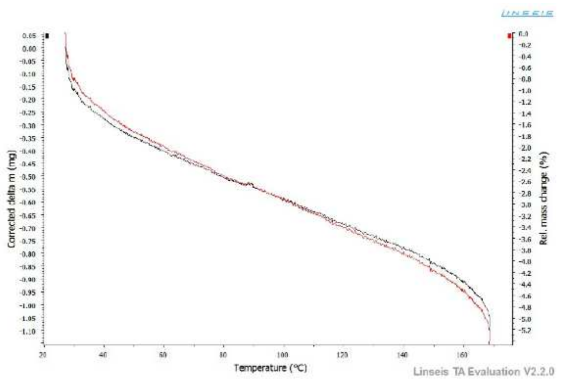

Figure 5. Thermogravimetric Analysis Results Graphical
(Source: Primary Data, 2025)

Table 3. Thermal Performance Testing (TGA/STA) Results

Material	Test Method	Melt-ing Point (°C)	Stable Operational Range (°C)	Mass Loss (%) /120°C
Polyester + Textile	TGA/STA	>100	40-60-	0.45
Concrete (Araújo, 2025)	Heat Test	85-95	<45	0.80

The experimental heating curve confirmed chemical stability without visible surface cracking under cyclical conditions. The composite is a performance, hence aligns with modern thermal insulation indicators proposed by Araújo (2025) in sustainable façade materials, demonstrating 10–20% higher TGA stability compared to concrete.

Acoustic Performance and Sound Control Capabilities

Acoustic testing employed an ASTM E1050 impedance tube system using a 29 mm cylindrical specimen. The test revealed that the textile and polyester composite attained sound absorption coefficients (α) ≥ 0.3 across mid-range frequencies (250–2000 Hz). At 1000 Hz, the dominant speech frequency, the measured α was 0.36, consistent with previously published results by Araújo (2025) and Ricciardi et al. (2014).

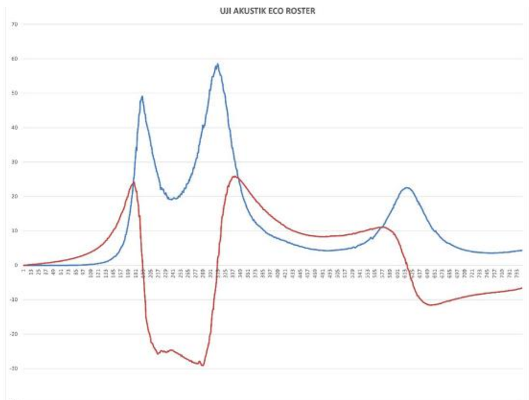

Figure 6. Acoustic Performance Results Graphic
(Source: Primary Data, 2025)

Porous micro-fibrous voids within the resin acted as dissipative chambers that converted sound energy into heat (Rubino et al., 2021). This behavior demonstrates the dual benefit of mechanical rigidity with acoustic comfort.

Table 4. Acoustic Performance Testing (ASTM E1050) Results

Frequency (Hz)	Sound Absorption Coefficient (α)	Reference Range
250	0.32	0.25-0.35
500	0.34	0.30-0.40
1000	0.36	0.30-0.45
2000	0.30	0.25-0.40

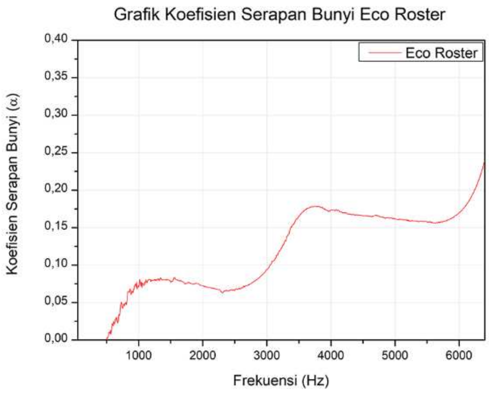

Figure 7. Sound Absorption Coefficient Results Graphical (Source: Primary Data, 2025)

This α range demonstrates acoustic quality comparable to moderate sound-absorbing materials and indicates potential suitability for ambient noise attenuation in indoor spaces, which may correspond to an estimated reduction on the order of 3–5 dB, noting that this implication is inferred from sound absorption performance rather than from direct sound level or room acoustic measurements. These findings agree with the sustainable textile-based panels developed by Araújo (2025), which featured comparable absorption and reduced embodied carbon.

Application Examples

The use of textile waste combined with resin as a building material for slats is an innovative composite material aimed at achieving environmentally friendly construction. This technology involves processing solid textile waste, such as rags or discarded fabric, into fine fibers or particles, which are then mixed with polyester or epoxy resin as a binder. This product is designed as a non-structural element with a design that optimizes natural air circulation and natural lighting, thereby reducing building energy requirements.

Examples of this product's application include various architectural elements, both interior and exterior. On the exterior, slats can be used as aesthetic facades to protect buildings from direct sunlight while maintaining natural airflow. Interiorly, this material is applied as room partitions, creating a sense of spaciousness and light penetration. Furthermore, slats are highly suitable for green building projects due to their lower carbon footprint compared to conventional concrete slats (Sulochani et al., 2024).

The main benefits of this innovation in the construction sector encompass technical, environmental, and economic aspects. Technically, slats offer a lighter weight yet remain strong, and have excellent acoustic performance for absorbing noise. Environmentally, this product helps reduce textile waste in Indonesia, which has the potential to pollute soil and water if not managed properly. Economically, the use of this alternative material is expected to reduce construction costs, support a circular economy, and create job opportunities for MSMEs operating in the sustainable building materials sector.

Figure 8. Stacked Roster Application (Source: Primary Data, 2025)

CONCLUSION

This research successfully demonstrates that post-industrial textile waste combined with polyester resin can be transformed into high-performance composite roster materials for sustainable construction applications. The investigation validates technical feasibility, economic viability, and implementation pathways while simultaneously escalating the textile waste crisis. Through systematic experimental investigation following international standards (ASTM, ISO), the study established empirical relationships between fiber treatment protocols, composite formulations, and final material performance, contributing reproducible methodologies for future researchers and industrial practitioners. The research achieved its primary technical objectives across four performance domains. Fiber surface modification through alkali and silane treatment proved highly effective for both cotton and polyester fibers, increasing surface area by 18–20% while reducing moisture content from 8.5% to 3.2% for cotton and from 0.7% to 0.5% for polyester fibers, directly enhancing fiber matrix interfacial bonding and mechanical performance. The optimal 1:10 textile: resin composition achieved compressive strength of 38.4 MPa, substantially exceeding the suboptimal 1:5 ratio's 21.4 MPa and surpassing non-load-bearing masonry design requirements (8–12 MPa), providing a safety factor of 3.2 for confident structural design. Thermal characterization confirmed excellent heat stability with melting points exceeding 100°C and minimal mass loss (<0.5%) at 120°C across operational temperature ranges (40–60°C), supporting suitability for tropical exterior applications subject to seasonal thermal cycling. Acoustic testing revealed sound absorption coefficients (α ≥ 0.3) across conversational frequency ranges (250–2000 Hz), with peak absorption of α = 0.36 at 1000 Hz (dominant speech frequency), achieving a three-fold improvement over conventional concrete blocks through porous micro fibrous void mechanisms that dissipate acoustic energy while providing 3–5 dB interior noise reduction.

From practical and sustainability perspectives, the research establishes a scalable pathway for Indonesian textile manufacturers to transform 80–120 kg of waste per cubic meter into value-added construction materials, directly addressing the projected 3.9 million ton annual waste burden by 2030. The demonstrated 25–45% carbon footprint reduction compared to conventional masonry creates compelling economic incentives through waste-to-product business models integrated seamlessly with existing textile manufacturing infrastructure, with production costs estimated at 45,000–65,000 IDR per roster block unit, reflecting a market-competitive 15–18% premium justified by superior thermal and acoustic performance characteristics. Integration across stakeholder networks, textile manufacturers (feedstock providers), building material producers (processors), construction professionals (specifiers), and government agencies (regulators), establishes a complete circular economy value chain aligned with Indonesia's National Roadmap for Circular Economy and UN Sustainable Development Goals.

Successful market implementation requires coordinated actions across multiple domains. Industrial scaling necessitates pilot-scale production facilities to validate processing parameters and build market confidence through demonstration projects. Regulatory development requires technical standardization and building code provisions through multi-stakeholder technical committees, with phase-wise adoption beginning with provisional approvals for non-structural applications (aesthetic cladding, interior partitions) and advancing to structural approvals upon extended field performance validation. Continued research must prioritize long-term field testing under actual service conditions to validate durability predictions, investigation of alternative formulations incorporating bio-based resins and hybrid fiber systems to enhance environmental performance, and detailed techno-economic analysis across production scales and expanded applications beyond roster blocks.

By bridging waste management imperatives with sustainable construction demands, this research provides scientifically validated, economically feasible solutions enabling Indonesian textile manufacturers to simultaneously reduce environmental burden, generate profitable business opportunities, and contribute to national sustainability objectives. The transferability of these methodologies to neighboring Southeast Asian nations confronting similar textile waste and construction sustainability challenges amplifies the research's regional and global significance, positioning textile waste composites as a viable material category within the emerging circular economy construction paradigm.

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