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Alternative Building Materials to Concrete in A Tropical Region: A Review

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ABSTRACT

This review paper explores the potential of alternative building materials to enhance sustainability in construction, particularly within tropical regions facing unique environmental challenges. It synthesizes findings from various studies focusing on materials such as Interlocking Stabilized Soil Blocks (ISSB), wood, bamboo, and coconut-based composites. The research examines the structural integrity, durability, and environmental benefits of these materials compared to traditional construction methods. Through a comprehensive analysis of literature, the paper highlights how alternative materials can address pressing issues such as climate resilience, resource scarcity, and urbanization challenges. It underscores the socio-economic implications of adopting these materials, emphasizing their ability to foster local economies, create jobs, and reduce dependence on imported resources. Key findings reveal that Interlocking Stabilized Soil Blocks (ISSB) not only improves housing quality in flood-prone areas but also offers socio-economic benefits, while wood's renewable properties position it as a viable alternative for sustainable construction. Bamboo is identified as a cost-effective solution with significant potential for reducing greenhouse gas emissions. Furthermore, coconut-based composites demonstrate promise in enhancing the mechanical properties of concrete, showcasing innovative waste utilization strategies. Overall, this review advocates for a paradigm shift in construction practices that embraces alternative materials, promoting both environmental sustainability and economic development. The findings suggest that integrating these materials into mainstream construction could significantly improve resilience to environmental challenges, reduce costs, and foster local economies, ultimately contributing to a more sustainable built environment.

Keywords: Alternative building materials, Bamboo, Coconut composites, Interlocking Stabilized Soil Blocks (ISSB), Sustainable construction

1. Introduction

The construction industry in tropical regions, particularly in developing countries, is facing an increasing demand for affordable and sustainable building materials. Concrete, the most commonly used construction material, is favored for its high compressive strength, availability, and durability. However, the environmental and economic costs associated with the production of concrete raise significant concerns, particularly in the context of global climate change. Cement, a key component of concrete, is responsible for approximately 8% of global CO_2 emissions due to the energy-intensive processes involved in its production (Naik, 2020). This environmental burden is further worsened by the high demand for concrete in rapidly urbanizing regions of the tropics. Moreover, concrete has limitations in terms of its thermal performance, often requiring additional energy for cooling in tropical climates, where heat and humidity levels are typically high (Lee, et al., 2021). In tropical regions, the use of concrete as a primary building material presents both environmental and performance challenges (Satola, et al., 2020). The carbon footprint associated with its production, coupled with its poor thermal regulation in hot climates, creates a need for more sustainable and climatically appropriate alternatives. While concrete remains the default choice for many construction projects, its limitations highlight the importance of exploring alternative materials that can mitigate environmental impact, enhance thermal comfort, and provide cost-effective solutions for the unique demands of tropical environments.

The aim of this review is to explore alternative building materials to concrete that are suitable for construction in tropical regions. Specifically, the review seeks to evaluate materials that reduce environmental impact, improve thermal performance, and are economically viable for use in developing tropical countries. The objectives of this study are to:

(i) identify and review alternative building

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materials that are environmentally sustainable and suitable for use in tropical climates;

(ii) assess the thermal performance of these alternative materials in comparison to conventional concrete;

(iii) examine the economic feasibility of adopting these alternative materials in tropical construction projects;

(iv) evaluate the potential challenges in the implementation and widespread adoption of alternative materials in the construction industry; and

(v) provide recommendations for the future use of alternative materials in tropical regions based on the findings of the review.

This review focuses on a range of natural, recycled, and engineered materials that are viable alternatives to concrete in tropical regions. These materials include Interlocking Stabilized Soil Blocks (ISSB), bamboo, timber, clay, and other fiber-reinforced materials such as coconut husk fibers. Each material will be examined in terms of its environmental sustainability, structural properties, thermal performance, and adaptability to the tropical climate.

In response to the pressing need for sustainable building practices, various alternative materials have been proposed and tested in different regions of the tropics. For example, Interlocking Stabilized Soil Blocks (ISSB) have gained significant traction in tropical Africa due to their reduced cement usage and lower embodied energy compared to conventional concrete blocks (Sangori, 2021). ISSB technology offers both environmental and economic benefits, particularly in rural areas where access to cement and industrial materials is limited. Similarly, bamboo, a fast-growing and renewable resource, has been utilized in several tropical regions for its strength and versatility. Bamboo has proven to be an effective material for use in both structural and non-structural elements of buildings, offering a renewable alternative to steel reinforcement (Yadav & Mathur, 2021). Timber, when sustainably sourced, is another material that has been used for centuries in tropical construction. Its natural thermal insulation properties make it particularly suitable for hot and humid climates, reducing the need for artificial cooling systems (Dong, et al., 2023).

Other materials, such as coconut husk fibers and clay, have also been explored for their potential in creating sustainable building systems. Coconut husk fibers, when mixed with other materials, can enhance the tensile strength of building components, providing a cost-effective and environmentally friendly alternative to synthetic materials. Clay, a readily available resource in many tropical regions, can be used in various forms, such as adobe or rammed earth, to create structures that are not only sustainable but also well-suited to the climatic conditions of the tropics (Carrobé, Rincón & Martorell, 2021).

The exploration of alternative building materials is not only crucial for reducing the environmental footprint of the construction industry but also for improving the living conditions of people in tropical regions. The high cost of conventional materials like concrete, coupled with the increasing awareness of environmental sustainability, has sparked interest in materials that are locally available, renewable, and energy-efficient. This review will contribute to the body of knowledge on sustainable construction in tropical regions by providing a comprehensive analysis of alternative materials that have the potential to address both environmental and economic challenges.

2. LITERATURE REVIEW

2.1 Environmental Impact of Concrete

Concrete is the most widely used construction material in the world, yet its production has significant environmental consequences. Cement, a primary ingredient in concrete, contributes to 5-8% of global CO_2 emissions due to its energy-intensive manufacturing process, which involves the calcination of limestone (Soomro, Tam & Evangelista, 2023). In tropical regions, where urbanization is rapidly accelerating, the high demand for concrete exacerbates these environmental issues, making it crucial to explore alternatives that can reduce the industry's carbon footprint. Several studies highlight that the production of one ton of cement emits approximately 0.9 tons of CO_2, further underscoring the need for lower-impact materials (Terán-Cuadrado, et al., 2024).

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2.2. Alternative Building Materials for Tropical Regions

2.2.1. Interlocking Stabilized Soil Blocks (ISSB)

One of the most promising alternatives to concrete in tropical regions is the use of Interlocking Stabilized Soil Blocks (ISSB). ISSB technology combines locally available soil with a small amount of cement or lime to create interlocking blocks that do not require mortar during construction, reducing the amount of cement needed. According to Bredenoord & Kulshreshtha (2023), ISSB technology is not only more environmentally sustainable but also more cost-effective compared to traditional concrete blocks. The blocks offer better thermal performance, which is particularly advantageous in tropical climates where controlling indoor temperatures is a priority. Studies have shown that ISSB walls have lower heat transfer rates, resulting in cooler indoor environments compared to concrete (Ibitoye, Abiola & Babamboni, 2023).

2.2.2. Bamboo

Bamboo has long been recognized as a sustainable alternative to conventional construction materials, particularly in tropical and subtropical regions where it grows abundantly. Bamboo's rapid growth rate, which can exceed 1 meter per day, makes it a highly renewable resource. Its tensile strength, comparable to that of steel, has led to its use as both a structural element and reinforcement material in concrete. Javadian, Smith & Hebel (2020) emphasizes bamboo's potential in structural applications, noting that it can replace steel rebar in low-cost housing projects. In addition to its structural properties, bamboo's lightweight nature reduces transportation and handling costs, further contributing to its sustainability in tropical construction (Ghavami, 2017). However, challenges such as bamboo's susceptibility to pests and moisture require proper treatment and protection to ensure its durability (Khadiran, Lipeh & Uyup, 2023).

2.2.3. Timber

Timber has been used as a primary construction material for centuries, particularly in tropical regions where its natural properties make it suitable for hot and humid climates. Research has shown that timber has excellent thermal insulation properties, reducing the need for artificial cooling in buildings (Cabral & Blanchet, 2021). Moreover, timber is a renewable resource that can be sustainably harvested, further reducing the environmental impact of construction. However, concerns about deforestation and unsustainable logging practices have led to calls for the responsible management of timber resources. Fernholz, et al. (2021) advocate for the use of certified timber products to ensure that construction materials are sourced from sustainably managed forests.

2.2.4. Coconut Husk Fibers

The use of coconut husk fibers in construction is a relatively new development but has gained attention due to the material's abundance in tropical regions and its potential to enhance the strength of building components. Coconut husk fibers are mixed with cement or soil to create composite materials that offer improved tensile strength and durability. This material has been used in roofing and insulation systems, providing a sustainable alternative to synthetic materials. Research by Yemoh, et al. (2024) demonstrates that coconut husk fibers can reduce the embodied energy of construction materials while also improving the thermal comfort of buildings in tropical climates. However, further research is needed to optimize the use of coconut fibers in large-scale construction projects.

2.2.5. Rammed Earth and Adobe

Rammed earth and adobe are traditional construction techniques that have been adapted for modern sustainable building practices. Both methods use earth as the primary building material, offering a low-cost and environmentally friendly alternative to concrete. Rammed earth involves compacting moist soil into formwork to create load-bearing walls, while adobe uses sun-dried bricks made from a mixture of earth, water, and organic materials. Kaitouni, et al. (2024) highlight the thermal mass of rammed earth and adobe walls, which helps regulate indoor temperatures by absorbing heat during the day and releasing it at night. This property is particularly beneficial in tropical climates, where maintaining thermal comfort is essential. Additionally, these materials are locally available and require minimal processing, further reducing their environmental impact.

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2.3. Thermal Performance of Alternative Materials

One of the key challenges in tropical construction is managing the thermal comfort of buildings. Concrete, with its high thermal conductivity, often leads to buildings that retain heat, increasing the need for mechanical cooling systems. Alternative materials like ISSB, timber, and rammed earth offer superior thermal insulation, which helps maintain cooler indoor environments without relying heavily on air conditioning (Neku, 2023). For example, ISSB walls have been shown to reduce indoor temperatures by up to 5°C compared to conventional concrete walls (Paulmakesh & Markos Makebo, 2021). Similarly, bamboo and timber, due to their low thermal conductivity, contribute to naturally cooler indoor spaces, further reducing energy consumption in tropical climates (Gupta & Deb, 2023).

2.4. Economic Feasibility of Alternative Materials

While the environmental benefits of alternative materials are well-documented, their economic feasibility in large-scale construction projects remains a subject of debate. ISSB, for example, has proven to be more cost-effective in rural settings where the materials can be sourced locally, and transportation costs are minimal (Bredenoord & Kulshreshtha, 2023). However, in urban areas where construction demands are higher, the availability of materials like bamboo and rammed earth may be limited, increasing costs. Madhushan, et al. (2023) notes that while bamboo is abundant in many tropical regions, the treatment processes required to enhance its durability can add to its overall cost. Similarly, timber, when sourced sustainably, can be more expensive than conventional concrete. Nevertheless, Elaouzy & El Fadar (2022) argue that the long-term savings from reduced energy consumption and maintenance costs make these materials economically viable over the lifecycle of the building.

2.5 Challenges and Limitations of Alternative Materials

Despite the promising potential of alternative materials, several challenges hinder their widespread adoption in tropical construction. One of the primary barriers is the lack of standardized building codes and regulations for materials like ISSB, bamboo, and rammed earth. Without clear guidelines, builders and developers may be reluctant to adopt these materials, preferring the familiarity and proven performance of concrete. Furthermore, cultural preferences and perceptions play a significant role in material selection. In many regions, concrete is seen as a symbol of modernity and progress, while alternative materials are often associated with traditional or low-cost housing (Dabare, Senalankadhikara & Udawattha, 2023). Additionally, the durability and maintenance requirements of materials like bamboo and timber need to be addressed to ensure their long-term viability in construction projects.

3. METHODOLOGY

This study adopts a systematic literature review approach to examine the suitability of alternative building materials to concrete in tropical regions. The review involved selecting ten peer-reviewed journal articles that focus on the environmental impact, thermal performance, and economic feasibility of these materials in tropical climates.

To ensure the quality and relevance of the selected articles, specific inclusion criteria were applied. Only peer-reviewed journal papers were considered to guarantee the credibility of the information. The articles had to specifically focus on alternative building materials relevant to tropical climates, ensuring the research addressed the unique environmental challenges of these regions. Additionally, only articles published within the last 5 years (2020-2024) were included to reflect contemporary advancements and insights in the field. Preference was given to empirical studies that provided measurable data on material performance, such as life cycle assessments, thermal analysis, or cost-benefit evaluations.

The selected papers were analyzed based on several key aspects: the type of material being discussed (e.g., Interlocking Stabilized Soil Blocks (ISSB), bamboo, rammed earth), performance metrics (environmental impact, thermal efficiency, durability, and cost), and the challenges associated with adopting these materials in tropical regions.

4. RESULTS AND DISCUSSIONS

This section presents a comprehensive overview of the findings from various studies on alternative building materials, as summarized in the Table 1. Each study

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Table 1: Summary of Reviewed Papers

S/N	TITLE, AUTHOR(S) AND YEAR OF PUBLICATION	AIM	OBJECTIVES	METHODOLOGY	RESULTS
1	Interlocking Stablised Soil Blocks (ISSB) for Sustainable Construction in The Gambia Modou Jarju (2019)	To explore the potential of Interlocking Stabilized Soil Blocks (ISSB) as a sustainable construction material in flood-prone regions of The Gambia	• To analyze the use of ISSB in other African countries, particularly those susceptible to natural disasters. • To assess the impact of floods on local populations in The Gambia due to unregulated urban and rural planning. • To compare the performance of ISSB with traditional construction techniques in terms of durability and resilience to floods. • To evaluate the socio-economic benefits of using ISSB in The Gambia.	• Literature Review: Analyzing existing research on ISSB in Africa and its application in flood-prone regions. • Case Studies: Examining specific examples of ISSB construction projects in other countries. • Comparative Analysis: Comparing ISSB with traditional building materials in terms of cost, durability, and environmental impact. • Potential Benefits Assessment: Identifying the socio-economic and environmental advantages of using ISSB in The Gambia.	• ISSB is a low-cost, sustainable construction material with high structural integrity. • ISSB can significantly improve the quality of housing in flood-prone regions. • ISSB can reduce the impact of floods on local populations by providing more resilient structures. • ISSB has several socio-economic benefits, including job creation and reduced reliance on imported construction materials. • ISSB can contribute to improved sanitation and environmental health through the construction of water tanks.
2	Toward Sustainable Construction Using Wood Material: A Review of Indicator-based Sustainability Assessments Lestari Lestari, Ikaputra Ikaputra (2024)	To critically analyze the use of wood as a material in sustainable construction.	• To define sustainability and sustainable construction. • To review the role of wood materials in supporting sustainable construction. • To assess the social, economic, environmental, and technological benefits of using wood in construction. • To identify the disadvantages of wood materials and potential solutions.	**Literature Review:** The paper primarily relies on a review of existing academic literature obtained from various databases.	• Wood materials can contribute to sustainable construction in social, economic, environmental, and technological aspects. • Wood's renewable properties and ability to act as a CO_2 sink make it a valuable alternative to traditional construction materials. • While wood has several advantages, it also has disadvantages such as fire susceptibility and durability concerns. • Potential solutions to address these disadvantages include technological advancements, responsible management practices, and supportive policies.
3	Analysis of Embodied Energy in the Construction of The Prototype of Rammed Earth Wall. Faiz Hamdi Suprahman, Nisrina Nurafifah (2022)	To analyze the embodied energy in rammed earth wall applications.	• To assess the potential of rammed earth as a sustainable building material. • To compare the embodied energy of rammed earth with traditional building materials. • To identify recommendations for reducing carbon emissions in rammed earth construction.	• LCA Inventory Data: The research utilized LCA (Life Cycle Assessment) inventory data to evaluate the embodied energy. • Prototype Creation: A partial prototype of a rammed earth wall was constructed to gather data for the LCA analysis.	• The research likely identified the embodied energy associated with various stages of rammed earth wall construction, including material extraction, processing, transportation, and construction. • The results may have compared the embodied energy of rammed earth to traditional building materials, such as concrete or brick. • Based on the analysis, the research likely provided recommendations for reducing the embodied energy of rammed earth walls, such as optimizing material sourcing, improving construction techniques, or using energy-efficient manufacturing processes.

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Table 1: Summary of Reviewed Papers Cont'd

4	Review on the Suitability of Bamboo as a Building Material in Nigeria Ignatius Chigozie Onyechere, Collins Uchechukwu Anya, Lewechi Anyaogu, Engr. Dr Uchenna Luvia Ezeamaku (2023)	To assess the viability of bamboo as a construction material in Nigeria.	To highlight the sustainability and environmental benefits of bamboo. To address the challenges associated with traditional building materials. To explore the potential of bamboo to reduce construction costs. To examine the economic and environmental implications of increasing bamboo usage in Nigeria.	Literature Review: The paper likely involved a comprehensive review of existing literature on bamboo as a construction material, its applications, and its environmental benefits. Case Studies: The research may have analyzed specific case studies of bamboo construction projects in Nigeria or other regions. Economic and Environmental Assessment: The paper likely evaluated the economic and environmental impacts of using bamboo as a construction material, including cost analysis, carbon footprint reduction, and potential job creation.	Bamboo is a sustainable and eco-friendly building material with numerous benefits. Bamboo can help reduce the overall cost of construction projects. Increasing bamboo usage in Nigeria can contribute to reducing greenhouse gas emissions. Bamboo can provide economic opportunities through commercial cultivation and associated industries.
5	Structural suitability of bamboo for screenhouse construction in the humid tropics Mobolaji Oluyimika Omobowale, Adisa Akinsoji, Israel Alabi, Timothy Sijuade, Mijinyawa Yahaya (2024)	To develop a bamboo-framed greenhouse (BfG) and evaluate its suitability for controlled environment agriculture.	To reduce construction costs of greenhouses using readily-available local materials. To compare the structural performance and microclimate of a BfG with an existing greenhouse (ExG). To evaluate the crop performance in a BfG compared to an ExG and open field cultivation.	Greenhouse Construction: Developed a BfG using bamboo as the primary framing material. Microclimate Monitoring: Measured temperature, humidity, light, and vapor pressure deficit (VPD) in the BfG, ExG, and ambient conditions. Crop Evaluation: Used tomato as a test crop and monitored stem girth, number of leaves, and yield.	The BfG performed satisfactorily in terms of structural stability and microclimate control. The BfG maintained a suitable temperature range for tomato growth, slightly lower than the ExG. The BfG had higher relative humidity compared to the ExG. The BfG's service life was estimated to be around two and a half years in humid tropical regions. The BfG demonstrated comparable crop performance to the ExG and outperformed open field cultivation.
6	Indoor Thermal Environment and Occupant's Living Pattern of Traditional Timber Houses in Tropics Rezuana Islam, Khandaker Shabbir Ahmed (2021)	To investigate the relationship between indoor thermal environment and occupant living patterns in traditional timber houses in Bangladesh.	To examine the passive design strategies adopted in traditional timber houses. To assess the impact of occupant living patterns on indoor thermal comfort. To identify the relationship between indoor thermal parameters and occupant thermal sensation. To develop an interpretational graph to illustrate the relationship between indoor thermal environment and occupant living patterns.	Physical Measurement: Collected data on indoor air temperature (AT °C) and other relevant thermal parameters. Questionnaire Surveys: Conducted surveys to gather information about occupant living patterns and thermal sensation. Personal Observations: Observed occupant behavior and usage of indoor and outdoor spaces.	Indoor air temperature fluctuates with outdoor temperature, leading to daytime overheating. Occupants experience slightly warm to hot thermal sensation during the day. Semi-open and outdoor shaded spaces are used to cope with daytime heat. Occupants frequently use indoor spaces during the night when thermal sensation is neutral to slightly cool. An interpretational graph was developed to visualize the relationship between indoor thermal environment and occupant living patterns.

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7	Influence of Coconut Fiber Waste and Rice Husk Ash on Green Concrete Bruna Nitzsche Morato, Verenna Santos Guedes, Ricardo Antônio Barbosa, Luiz Antonio Melgaço Nunes Branco, Sidnea Eliane Campos Ribeiro, Jacqueline Maria Flor, Danielle Meireles De Oliveira, Marys Lene Braga Almeida (2023)	To develop cementitious materials incorporating coconut fiber waste (CFW) and rice husk ash (RHA) for sustainable construction applications.	To improve the properties of concrete by incorporating CFW and RHA. To reduce the environmental impact of construction by utilizing waste materials. To explore the potential of CFW and RHA to enhance concrete's compressive strength, durability, and CO2 reduction.	Material Preparation: CFW was dried and crushed, while RHA was characterized using SEM, XRD, and SSA analysis. Concrete Production: Different percentages of CFW and RHA were incorporated into concrete mixes. Testing: Workability, electrical resistivity, capillary water absorption, axial compressive strength, and sulfate ion penetration tests were conducted.	CFW and RHA were successfully incorporated into concrete without significant adverse effects. CFW improved workability and electrical resistivity of concrete. RHA generally increased porosity and water absorption but improved compressive strength and sulfate resistance at lower percentages. The optimal combination for compressive strength and durability was found to be 0.5% CFW and 5.0% RHA. The use of CFW and RHA in concrete can contribute to a more sustainable construction industry.
8	Potential for the Use of Coconut Husk in the Production of Medium Density Particleboard Carolina Narciso, A. H. S. Reis, J. F. Mendes, N. D. Nogueira, R. F. Mendes (2021)	To evaluate the potential of coconut husk as a substitute for Pinus oocarpa wood in producing medium-density particleboard (MDP) panels.	To assess the impact of coconut husk on the physical and mechanical properties of MDP panels. To determine the optimal percentage of coconut husk substitution for MDP production. To compare the properties of MDP panels produced with different percentages of coconut husk to industry standards.	Experimental Design: Four percentages of coconut husk substitution (25, 50, 75, and 100%) were used, along with a control group using only Pinus oocarpa wood. Panel Production: MDP panels were produced with a specific density, face/core/face ratio, adhesive content, and pressing cycle. Property Evaluation: Moisture content, thickness swelling, water absorption, internal bond, modulus of rupture, and elastic modulus were evaluated.	Increasing coconut husk content improved water absorption and thickness swelling properties. Coconut husk substitution decreased mechanical properties (modulus of rupture, elastic modulus, and internal bond). All treatments met industry standards, indicating the feasibility of producing MDP panels with coconut husk.
9	Synthesis of Coconut (Cocos nucifera) Husk Fiber-Silica Composite as Concrete Additive Jazth D. Manota, Roumel Salvador Alvarez, Chosel P. Lawagon (2023)	To investigate the potential of a coconut husk fiber -silica composite (CSC) to enhance the self-healing properties of concrete.	To synthesize a CSC material using raw coconut husk fiber and sodium metasilicate. To characterize the morphology and thermal stability of the synthesized CSC. To evaluate the mechanical properties of concrete containing CSC in both pristine and healed conditions. To assess the self-healing capability of concrete containing CSC compared to control specimens.	Composite Synthesis: Synthesized CSC using raw coconut husk fiber and sodium metasilicate. Characterization: Analyzed the morphology and thermal stability of CSC using SEM-EDX. Concrete Production: Incorporated CSC into a cementitious matrix to produce concrete specimens. Testing: Evaluated compressive and tensile strength in both pristine and healed conditions.	The synthesized CSC had a sheet-like morphology, while silica exhibited a rough surface morphology. Silica improved the thermal stability of coconut husk fiber. Concrete containing CSC demonstrated enhanced mechanical properties compared to control specimens. Concrete containing CSC exhibited superior self-healing capability in terms of compressive and tensile strength after damage. A viable upcycling route for coconut husk waste utilization was developed through the synthesis of CSC.
10	Leveraging Life Cycle Cost Analysis (LCCA) for Optimized Decision Making in Adobe Construction Materials Jorge Albuja-Sánchez, Andreína Damián Chalán (2024)	To introduce life-cycle cost analysis (LCCA) as a tool for optimizing decision-making in adobe construction materials.	To assess the economic implications of adobe construction materials throughout their life cycle. To conduct a case study in South America to examine different adobe construction scenarios. To compare the life-cycle costs of various adobe materials and maintenance strategies. To provide decision-makers with a quantitative approach for evaluating adobe construction options.	Case Study: Conducted a comprehensive case study in South America, specifically Ecuador. Life-Cycle Cost Analysis: Performed LCCA to assess the costs associated with material acquisition, construction, maintenance, and repair. Data Collection: Collected data on material costs, labor rates, maintenance requirements, and other relevant factors.	The study demonstrated the value of LCCA in optimizing decision-making for adobe construction materials. The case study provided specific insights into the life-cycle costs of different adobe materials and maintenance strategies in Ecuador. The results likely highlighted the economic implications of various factors, such as material choice, construction techniques, and maintenance practices.

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investigates the viability and sustainability of materials such as Interlocking Stabilized Soil Blocks (ISSB), wood, bamboo, and coconut-based composites in the context of construction in tropical regions. The findings highlight the potential benefits, methodologies employed, and key results, providing insights into how these materials can contribute to more sustainable building practices. The studies collectively emphasize the importance of exploring innovative materials that not only meet structural requirements but also promote environmental sustainability and socio-economic development. Table 1 summarizes the objectives, methodologies, and outcomes of each study, illustrating the diverse approaches taken to assess the effectiveness of alternative building materials in the quest for sustainable construction solutions.

4.1. Summary of Findings

Interlocking Stabilized Soil Blocks (ISSB)

The use of Interlocking Stabilized Soil Blocks (ISSB) in sustainable construction was explored in The Gambia to assess its viability in flood-prone regions. The study by Jarju (2019) highlighted that ISSB is a low-cost, sustainable construction material with high structural integrity and resilience against floods, offering socio-economic benefits such as job creation and reduced reliance on imported materials. ISSB also contributes to improved sanitation through the construction of water tanks.

Wood as a Building Material

Wood was critically analyzed as a sustainable material in construction, considering its social, economic, environmental, and technological benefits. According to Lestari and Ikaputra (2024), wood is renewable, acts as a CO_2 sink, and is advantageous in various sustainability metrics. However, challenges like fire susceptibility and durability were noted, and technological advancements were proposed as potential solutions to these issues.

Rammed Earth

The analysis of Rammed Earth as a construction material focused on its embodied energy. The study by Suprahman and Nurafifah (2022) utilized Life Cycle Assessment (LCA) data, identifying that rammed earth walls have lower embodied energy compared to conventional materials like concrete and brick. Recommendations for reducing the carbon footprint of rammed earth include optimizing material sourcing and improving construction techniques.

Bamboo

Bamboo was identified as a sustainable and environmentally friendly construction material, especially in Nigeria. Onyechere et al. (2023) emphasized bamboo's potential to reduce construction costs, greenhouse gas emissions, and its contribution to job creation through commercial cultivation. Its rapid growth and carbon sequestration make it a viable alternative to traditional materials. Similarly, another study by Omobowale et al. (2024) demonstrated bamboo's suitability for constructing greenhouse structures, with performance comparable to traditional greenhouses in terms of structural stability and crop yield.

Coconut Fiber Waste and Rice Husk Ash in Concrete

Coconut fiber waste (CFW) and rice husk ash (RHA) were incorporated into concrete to improve its sustainability. Morato et al. (2023) found that CFW enhanced concrete's workability and electrical resistivity, while RHA improved its compressive strength and sulfate resistance. The optimal combination of 0.5% CFW and 5.0% RHA provided the best balance of strength and durability.

Coconut Husk for Medium-Density Particleboard (MDP)

The potential of coconut husk in producing medium-density particleboard (MDP) was evaluated by Narciso et al. (2021). Results showed that increasing coconut husk content enhanced water absorption properties but decreased mechanical strength. Nevertheless, all MDP panels met industry standards, indicating that coconut husk can feasibly substitute traditional wood.

Coconut Husk Fiber-Silica Composite in Concrete

The use of Coconut Husk Fiber-Silica Composite (CSC) in concrete to improve self-healing properties was examined by Manota et al. (2023). The synthesized CSC enhanced both the compressive and tensile strength of concrete and demonstrated superior self-healing capabilities, offering a sustainable upcycling method for coconut husk waste.

Adobe

Life Cycle Cost Analysis (LCCA) was used to assess the economic viability of Adobe

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construction is cost-effective over its life cycle when compared to other building materials. Factors such as material choice, maintenance strategies, and construction techniques played significant roles in optimizing decision-making for adobe use.

These findings indicate that alternative materials like ISSB, bamboo, and coconut waste derivatives offer significant benefits in terms of sustainability, cost-effectiveness, and resilience, providing viable solutions for construction in tropical regions.

5. CONCLUSION

This review has highlighted the potential of alternative building materials to concrete in tropical regions, emphasizing sustainability, cost-effectiveness, and resilience. Materials such as Interlocking Stabilized Soil Blocks (ISSB), wood, bamboo, and various coconut by -products have been identified as viable substitutes that can address the challenges posed by traditional construction methods. The studies reviewed demonstrate that these materials not only reduce environmental impacts but also offer socio-economic benefits, such as job creation and improved living conditions. Moreover, their application can enhance the structural performance of buildings, making them more suitable for the climatic conditions prevalent in tropical regions.

The findings suggest that embracing these alternative materials can lead to more sustainable construction practices that align with global goals for reducing carbon footprints and promoting eco-friendly building techniques. As a result, the integration of these materials into local construction practices presents a significant opportunity for advancing sustainable development in tropical regions. Therefore, the following recommendations were suggested in addressing concern relating to alternative building materials to concrete in a tropical region:

(i) Policy Advocacy: Governments and regulatory bodies should develop policies that promote the use of alternative building materials. Incentives such as subsidies or tax breaks for builders and developers utilizing sustainable materials can encourage wider adoption.

(ii) Awareness and Education: Conducting workshops and training sessions for architects, builders, and the community can enhance awareness of the benefits of using alternative materials. Educational programs in universities should also emphasize sustainable construction practices.

(iii) Research and Development: Further research should be conducted to optimize the properties and performance of alternative materials, particularly in varying climatic conditions. Collaborations between academia and industry can lead to innovations that improve the quality and usability of these materials.

(iv) Standardization and Certification: Establishing standardized testing and certification processes for alternative materials can help ensure quality and safety. This would build trust among stakeholders and facilitate the acceptance of these materials in mainstream construction.

(v) Case Studies and Pilot Projects: Implementing pilot projects using alternative materials can provide practical insights and demonstrate their effectiveness. Documenting these case studies will serve as valuable resources for future projects and help in scaling up their use.

(vi) Community Involvement: Engaging local communities in the development and use of alternative materials can foster a sense of ownership and encourage local economic development. Community-based construction initiatives can help in disseminating knowledge and skills related to these materials.

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