Sustainable Building Materials as Drivers of Environmentally Friendly Architecture: Evidence from Perception of Bamboo and Unfired Clay Bricks

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Article

Sustainable Building Materials as Drivers of Environmentally Friendly Architecture: Evidence from Perception of Bamboo and Unfired Clay Bricks

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Abstract

The construction industry is among the most resource-intensive and environmentally damaging sectors, largely due to reliance on energy-intensive materials such as cement and steel. Growing concerns over climate change and resource depletion have increased interest in sustainable building materials as drivers of environmentally friendly architecture. This study examines the role of bamboo and unfired clay bricks in promoting sustainable architectural practices. A mixed-methods approach was adopted, combining literature review, comparative case studies, questionnaire surveys, and semi-structured interviews with architects, engineers, and construction professionals. Data from 150 respondents and interviews with 20 professionals were analysed to evaluate environmental performance, feasibility, user perception, and barriers to adoption. Findings indicate that bamboo and unfired clay bricks are widely regarded as environmentally preferable due to their low carbon footprint, renewability, biodegradability, and reduced production energy. Key factors influencing their eco-friendliness include carbon emission reduction, biodegradability, and availability of renewable resources. However, limited awareness, regulatory challenges, resistance to change, technical concerns, and skill requirements remain major obstacles to widespread adoption. The study concludes that bamboo and unfired clay bricks hold strong potential to advance environmentally friendly architecture, particularly in developing countries, if supported by appropriate policies, technical standards, capacity building, and increased stakeholder awareness.

Keywords: sustainable building materials; environmentally friendly architecture; bamboo construction; unfired clay bricks; low-carbon construction

1. Introduction

The construction industry, despite its significant contribution to global economic development, is widely recognized as one of the most environmentally intensive sectors due to its high demand for energy, raw materials, and water resources, resulting in substantial greenhouse gas emissions and ecological degradation. Building materials used in construction play a major role in environmental pollution and resource depletion, contributing to soil erosion, deforestation, and the overexploitation of natural resources. Construction activities also generate enormous quantities of waste, including hazardous substances such as asbestos, lead, and volatile organic compounds, which negatively affect air and water quality and pose serious risks to human health and ecosystems. The release of harmful emissions during material production, transportation, and on-site construction further exacerbates climate change and environmental pollution. To mitigate these impacts, sustainable construction practices—such as the adoption of environmentally friendly materials, waste minimization strategies, and energy-efficient processes—must be embraced alongside strict compliance with environmental regulations [1].

Globally, the construction sector accounts for approximately 70% of electricity consumption and 12% of potable water use, while generating between 45% and 65% of landfill waste. Additionally, building-

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related activities are responsible for nearly 30% of total greenhouse gas emissions, with about 18% attributed specifically to material production, processing, and transportation [1]. These alarming figures underscore the urgent need to reconsider material choices and construction methods. Conventional building materials such as concrete and steel are particularly energy-intensive and carbon-heavy, with cement production alone contributing approximately 5% of global carbon dioxide emissions due to the calcination process and fossil fuel consumption [2,3]. Beyond their environmental burden, these materials often involve chemical additives that pose long-term health and environmental risks.

In response to these challenges, increasing global attention has been directed toward sustainable building materials as viable alternatives capable of reducing the environmental footprint of the built environment. Green building materials—defined by their low embodied energy, reduced emissions, renewability, recyclability, and minimal environmental impact throughout their life cycle—have been identified as a critical pathway toward achieving sustainable development goals [2,3]. Life Cycle Assessment (LCA) studies consistently demonstrate that material selection significantly influences a building's overall environmental performance, often more than operational energy alone, particularly in low-energy and passive buildings [3,4].

Among emerging sustainable materials, bamboo and unfired clay bricks have gained renewed interest due to their environmental, structural, and socio-economic advantages. Bamboo is a rapidly renewable material with a high strength-to-weight ratio, low embodied energy, and excellent carbon sequestration capacity, making it a promising substitute for conventional structural materials in both low-rise and medium-rise construction [5,6]. Similarly, unfired clay bricks offer a low-carbon alternative to fired masonry units, requiring significantly less energy during production while providing favorable thermal, hygroscopic, and indoor air quality benefits [7,8]. Their ability to be sourced locally further reduces transportation emissions and supports region-specific sustainable construction practices.

Despite their potential, the adoption of bamboo and unfired clay bricks remains limited due to technical, regulatory, cultural, and perception-related barriers. Consequently, there is a growing need for empirical research that evaluates their performance, feasibility, and acceptance within contemporary architectural practice, particularly in developing countries where resource constraints and rapid urbanization intensify environmental challenges [5,9].

Against this backdrop, this study investigates sustainable building materials as drivers of environmentally friendly architecture, with specific focus on bamboo and unfired clay bricks. By examining their environmental performance, practical feasibility, and adoption challenges through empirical data and case studies, the research contributes to the growing body of knowledge aimed at promoting sustainable material choices and advancing environmentally responsible architectural practices.

1.1. Current Trends and Challenges of Sustainable Practices in Environmentally Conscious Built Environment

Sustainable building materials are crucial for creating a sustainable and environmentally conscious built environment. The selection of eco-friendly materials is a rapid step towards sustainable architecture [10]. They reduce the construction industry's carbon footprint and address resource scarcity by promoting the use of renewable, recycled, and locally sourced materials [11]. Sustainable building materials also offer economic advantages such as energy efficiency, reduced maintenance costs, and enhanced building performance over the long term [2]. Innovative techniques such as modular construction, prefabrication, and adherence to green building certifications (e.g., LEED, BREEAM) are being increasingly utilized to advance environmental sustainability in construction. Noteworthy examples of sustainable building materials include recycled steel, engineered wood products, and eco-friendly insulation materials [2]. Current sustainable practices in the construction industry are largely shaped by the adoption of circular economy principles, renewable energy, and green technology.

Circular economy has emerged as a key trend, emphasizing efficient resource use, waste reduction, and material reuse throughout the building life cycle; from design and construction to operation and deconstruction. By maintaining materials and components at their highest value and

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distinguishing between technical and biological cycles, circular economy practices promote sustainability and innovation in construction. Strategies such as design for deconstruction, BIM, and adaptive reuse are increasingly applied to reduce environmental impacts, resource consumption, and waste generation, while also delivering economic and environmental benefits.

Renewable energy integration is another major trend driving sustainability in construction. The use of solar, wind, and geothermal energy reduces greenhouse gas emissions, improves energy efficiency, and supports global efforts to combat climate change. Supportive government policies, incentives, and subsidies have accelerated the adoption of renewable technologies, making them more viable for construction projects. These energy systems are increasingly incorporated into building envelopes and services, contributing significantly to the transition toward environmentally responsible construction practices.

Green technology also plays a central role in sustainable construction, reflecting a global commitment to environmentally responsible development across both developed and developing countries. Technologies such as cool roofs, energy-efficient systems, recycled and eco-friendly materials, and improved health and safety measures enhance building performance while minimizing environmental impacts. Overall, the growing adoption of green technology underscores a collective effort to reduce the ecological footprint of buildings and promote long-term sustainability in the construction industry.

1.2. Assessment of Traditional Construction Materials

For centuries, natural and locally sourced materials such as timber, stone, clay, and lime have formed the backbone of traditional construction practices across different regions of the world. These materials were historically favored due to their availability, cultural acceptance, and relatively low technological requirements. However, rapid urbanization, population growth, and industrialization have significantly altered construction practices, leading to the large-scale exploitation of natural resources and increased reliance on energy-intensive materials such as cement, steel, and fired bricks. As a result, many traditional construction systems are now considered environmentally unsustainable due to resource depletion, excessive energy consumption, waste generation, and reduced adaptability to contemporary performance requirements.

To systematically evaluate the environmental impacts associated with traditional construction materials, Life Cycle Assessment (LCA) has emerged as one of the most widely adopted analytical tools. LCA provides a holistic framework for assessing the environmental performance of building materials throughout their entire life cycle—from raw material extraction and processing, through manufacturing, transportation, construction, use, maintenance, and end-of-life disposal or recycling. The LCA methodology consists of four main phases: (1) goal and scope definition, (2) life cycle inventory analysis, (3) life cycle impact assessment, and (4) interpretation of results. This approach enables a comprehensive comparison of materials and construction systems based on indicators such as global warming potential, energy demand, resource depletion, and waste generation.

Several LCA-based studies have compared the environmental performance of traditional and conventional construction materials, consistently highlighting the significant environmental burden associated with commonly used materials such as cement and steel. Material selection plays a critical role in minimizing the environmental footprint of buildings, noting that conventional construction materials often exhibit high embodied energy and carbon emissions. Cement production alone accounts for approximately 5–8% of global anthropogenic CO_2 emissions due to the calcination process and fossil fuel combustion required during manufacturing [3,12]. Similarly, steel production is highly energy-intensive and contributes substantially to greenhouse gas emissions, particularly in regions where electricity generation is dependent on fossil fuels [13].

Traditional materials such as timber, while often perceived as environmentally benign, also present sustainability challenges when sourced unsustainably. Large-scale timber extraction contributes to deforestation, biodiversity loss, and habitat degradation, particularly in tropical regions [14]. Although timber has the potential to act as a carbon sink, unsustainable forestry

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practices and long transportation distances can significantly offset these benefits [15]. In addition, chemically treated timber used in modern construction may introduce health and environmental risks during use and disposal.

Construction and demolition activities associated with traditional building practices generate substantial amounts of waste, including surplus materials, packaging waste, and demolition debris. According to the European Commission, construction and demolition waste accounts for approximately 35–40% of total solid waste generated globally, much of which ends up in landfills [16]. These waste streams contribute to land degradation, soil and water contamination, and increased pressure on landfill capacity. Transportation of raw materials and finished products over long distances further exacerbates environmental impacts through increased fuel consumption and emissions, particularly in regions reliant on imported construction materials.

Recognizing the environmental limitations of traditional construction materials has become a critical step in advancing sustainable construction practices. In countries such as the United Kingdom, there is a growing emphasis on reducing embodied carbon in buildings through stricter regulations, material performance assessment, and the promotion of low-impact alternatives. Policies such as whole-life carbon assessment requirements and the increased adoption of environmental product declarations (EPDs) reflect a shift toward evidence-based material selection [5,17]. These developments underscore the importance of reassessing both traditional and contemporary construction materials to reduce environmental impacts and support the transition toward environmentally friendly architecture.

1.3. Bamboo and Unfired Clay Bricks as Alternatives

Bamboo and unfired clay bricks are promising alternatives within the realm of sustainable building materials. Bamboo is a rapidly renewable resource that has garnered attention for its remarkable strength, rapid growth rate, and significant potential for carbon sequestration. Its versatility spans various applications within construction, from structural components to finishing materials [6]. Unfired clay bricks, rooted in tradition, have undergone revitalization through innovative stabilization techniques.

Unfired clay bricks are an eco-friendly and sustainable alternative to traditional clay bricks, requiring less energy and emitting fewer greenhouse gases during production. Using Ground Granulated Blast Furnace Slag (GGBS) as a partial substitute for conventional stabilizers in their production can improve durability and reduce emissions [18]. These bricks are made from a mixture of clay, laterite, stone dust, cement, and water, and are compressed using a simple machine. They are cost-effective, environment-friendly, and require less skill to construct, making them suitable for affordable housing and owner-builder projects in Nigeria [19]. The manufacturing process of unfired clay bricks does not require large mines, and any blemishes resulting from clay extraction can be repaired easily without causing excessive environmental harm. In conclusion, unfired clay bricks offer a practical and sustainable alternative for affordable housing construction in Nigeria [19].

Bamboo has become a popular sustainable building material due to its unique properties and environmental benefits [6,7]. It is a renewable resource that grows quickly and can be used for various construction applications due to its high strength, low weight, and ease of workability. Bamboo is highly elastic, making it ideal for construction in earthquake-prone areas. Moreover, its low embodied energy compared to other construction materials like concrete, steel, and plastic, contributes to its environmental friendliness [6]. Bamboo can grow in various climatic conditions, making it adaptable and sustainable. Its biodegradability adds to its appeal as a sustainable construction material. Bamboo is an excellent sustainable building material, owing to its renewable nature, quick growth, and low environmental impact. Its use in construction supports sustainable architecture and design, and it offers opportunities for eco-friendly building practices [7].

Unfired clay bricks have been rediscovered as a sustainable and healthy building material that utilizes the abundant natural resource of clay. Clay has been used for construction for a long time, thanks to its excellent thermal and acoustic properties and its ability to be reused or returned to the

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ground without any harm to the environment. To overcome the challenges associated with using clay as a building material, researchers have experimented with stabilizing clay mixtures with sawdust, cement, lime, and sand binders. The addition of sawdust and the use of clay in this "rediscovered" building material had a positive impact on the environment, and the compressive strength of the unfired clay bricks met acceptable standards for clay masonry units [9].

The use of unfired clay bricks is a viable option for sustainable construction, particularly when using illitic clays, which are commonly used as a raw material in brick production. Using unfired illitic bricks can reduce the environmental impact of construction, and their geotechnical parameters are suitable for earth construction. The compressive and flexural strengths of the unfired illitic bricks are within recommended limits in earth standards, and when bound with a standard hydraulic-lime mortar, they can achieve a 28-day strength of 2.45 N/mm², meeting structural requirements in some European masonry standards [8].

Although stabilization techniques can improve durability, they may lower strength and vapor permeability, without significantly altering thermal properties. The use of unfired clay bricks can contribute to the sustainability of construction by reducing energy consumption and the demand for natural resources. Furthermore, ceramic bricks are a versatile building material with a growing global demand, making the adoption of unfired clay bricks a promising approach in the construction industry [8].

2. Materials and Methods

Data collection methods include interviews with key stakeholders in the architectural and construction sectors, surveys, case studies, and literature reviews, providing a comprehensive basis for evaluating the feasibility of integrating sustainable materials into architectural practice.

The study area combines global and local perspectives. International case studies are analyzed to identify best practices and lessons from the use of bamboo and unfired clay bricks in different contexts, while Nigeria serves as the primary local study area for empirical data collection through questionnaires and interviews. Nigeria's socio-economic and environmental conditions make it a suitable context for assessing sustainable construction amid rapid urbanization, resource constraints, and environmental challenges. Stakeholders targeted include architects, engineers, builders, developers, and environmental experts across both urban and rural settings.

Data collection relies on both primary and secondary sources. Primary data are obtained through surveys and interviews, while secondary data are sourced from existing literature and documented case studies. A comparative case study approach is used, involving selected international and local projects that extensively utilize bamboo and unfired clay bricks. Environmental impact assessment surveys are also conducted, with 150 questionnaires distributed to professionals involved in such projects to evaluate parameters such as energy consumption, carbon footprint, waste generation, and resource depletion. Together, these methods support a robust assessment of sustainable building materials within local and global architectural contexts.

3. Discussion of Results

3.1. Key Factors in Assessing the Eco-Friendliness of Bamboo and Unfired Clay Bricks in Building Projects

The survey conducted on eco-friendly building materials revealed that 70.4% of the respondents considered a reduction in carbon footprint as one of the most important factors in assessing the eco-friendliness of bamboo and unfired clay bricks in building projects. This result indicates that people are becoming more aware of the impact of greenhouse gases on the environment, and they are actively looking for ways to mitigate it.

Another 57.4% of the respondents agreed that the ability of the building materials to biodegrade at the end of their lifespan is also a critical factor in determining their eco-friendliness. This factor is essential in ensuring that the building materials do not end up in landfills, where they will take years to decompose, leading to environmental pollution.

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Furthermore, 51.9% of the respondents believed that the availability of renewable resources is another key factor in determining the eco-friendliness of bamboo and unfired clay bricks. The use of renewable resources in the production of building materials ensures that the environment is not depleted of resources that may take centuries to regenerate.

Also, 48.1% of the respondents agreed that energy efficiency during production is another critical factor in assessing the eco-friendliness of building materials. This factor is vital in ensuring that the production process of the building materials does not consume too much energy and contribute to environmental pollution.

However, only 1.9% of the respondents believed that the ability to be reused and embodied energy (efficiency in energy use during production) are key factors in assessing the eco-friendliness of bamboo and unfired clay bricks in building projects.

In conclusion, the survey results indicate that reducing carbon footprint is the most crucial factor in determining the eco-friendliness of bamboo and unfired clay bricks in building projects. The ability of the building materials to biodegrade, the availability of renewable resources, and energy efficiency during production followed this factor, respectively. The ability to be reused and embodied energy were not considered as significant factors in determining their eco-friendliness.

3.2. Barriers to the Adoption of Bamboo and Unfired Clay Bricks in Construction Projects

Results show a clear trend towards higher ratings, with the majority rating this barrier as a high concern, indicating a significant gap in understanding the advantages of sustainable materials. Strategies such as education campaigns, workshops, seminars, and informational materials aimed at highlighting the benefits of sustainable materials could play a crucial role in raising awareness and bridging the knowledge gap. Moreover, collaboration between stakeholders, including industry players, environmental organizations, educational institutions, and policymakers, is essential to develop comprehensive awareness strategies and promote the adoption of sustainable materials. By increasing awareness and understanding of the benefits associated with these materials, it is possible to overcome this barrier and accelerate the transition towards more sustainable practices and materials in various industries.

Research also showed higher initial cost as a barrier compared to traditional materials. This indicates that while there is recognition of the initial cost being higher for alternative materials compared to traditional ones, it is not overwhelmingly considered a significant obstacle. The distribution of ratings, with only a few individuals rating it as a high barrier, suggests that there is potential for strategies such as cost-benefit analyses, long-term savings considerations, and increased awareness of the benefits of alternative materials to mitigate this perceived barrier effectively.

The third barrier stated was resistance to change from conventional practices. it is evident that this barrier is perceived as a significant challenge by a considerable number of respondents. While there are still respondents who rated this barrier lower, indicating a lesser degree of resistance, the fact that nearly half of the respondents rated it as a high barrier suggests that overcoming resistance to change is a critical aspect of promoting the use of alternative materials. Strategies such as education and awareness campaigns highlighting the benefits of alternative materials, showcasing successful case studies, and providing incentives for adopting these materials may be essential in addressing this barrier effectively. Additionally, engaging stakeholders and fostering a supportive environment for innovation and experimentation could play a crucial role in overcoming resistance to change.

The fifth barrier stated was the regulatory constraints specific to sustainable materials. While some individuals may not perceive regulatory constraints as a major obstacle, there are still challenges that need to be addressed to facilitate the widespread use of sustainable materials. Strategies such as advocating for clearer and more supportive regulations, engaging with regulatory bodies to streamline approval processes, and providing guidance and resources for compliance could help alleviate this barrier. Additionally, continued dialogue and collaboration between stakeholders, including policymakers, industry experts, and environmental advocates, are essential to navigate regulatory challenges effectively and promote the adoption of sustainable materials.

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3.3. Future Outlook and Recommendations for Bamboo and Unfired Clay Bricks Usage

As the construction industry grapples with the urgent need for sustainable practices, the spotlight has turned to innovative materials like bamboo and unfired clay bricks. With a growing emphasis on reducing environmental impact and promoting eco-friendly alternatives, prioritizing these materials in future projects represents a pivotal step towards a more sustainable construction sector. This introduction delves into the rationale behind advocating for bamboo and unfired clay bricks, highlighting their potential to revolutionize construction practices and contribute significantly to environmental conservation efforts.

In the survey conducted, it was found that a significant majority of respondents support the use of bamboo and unfired clay bricks in the construction industry. Out of the total respondents, 71% agreed that the construction industry should prioritize the use of these sustainable materials for future projects. This is a positive development as bamboo and unfired clay bricks are renewable resources and have a lower carbon footprint compared to traditional building materials.

3.4. Feasibility of Using Sustainable Building Materials in Various Architectural Designs and Structures

During the interview conducted among 20 professionals, consisting of 12 architects and 8 civil engineers, the participants were asked about their experience with sustainable building materials. The primary goal of the interview was to assess the feasibility of using sustainable building materials in different architectural designs and structures.

The popularity of bamboo architecture is increasing globally due to its sustainability and aesthetic appeal, according to a study. Studies support this argument, noting that bamboo architecture is an excellent alternative to traditional building materials because of its low carbon footprint and renewable nature. Similarly, studies highlight that bamboo architecture is an innovative solution to sustainable construction due to its strength, durability, and adaptability.

Furthermore, the study found that unfired clay bricks have a low environmental impact due to their minimal energy consumption during production. The literature review supports this finding, stating that unfired clay bricks are an environmentally friendly alternative to traditional bricks due to their low carbon footprint. Similarly, studies argue that unfired clay bricks are an excellent choice for ecological architecture as they are reusable and recyclable.

During the interview conducted, it was revealed that bamboo and unfired clay bricks are both naturally occurring, renewable, and recyclable materials that boast lower environmental impacts compared to traditional alternatives. Bamboo's rapid growth helps sequester carbon dioxide, while unfired clay bricks, made from local soil, minimize energy-intensive manufacturing processes and transportation needs. Their durability, with bamboo rivaling steel in strength and unfired clay bricks exhibiting long-lasting stability, makes them suitable for various structural applications.

Both materials offer excellent thermal properties, providing natural insulation (bamboo) and thermal mass benefits (unfired clay bricks) that contribute to energy efficiency in buildings. Moreover, they are cost-effective options, particularly in regions where they are abundant, reducing expenses associated with transportation and production. Beyond practicality, bamboo and unfired clay bricks also add aesthetic value, enhancing architectural designs while contributing to healthier indoor environments through better air quality (unfired clay bricks).

These combined advantages make bamboo and unfired clay bricks compelling choices for sustainable architectural projects, offering a blend of environmental benefits, durability, energy efficiency, and affordability.

3.5. Key Challenges or Barriers to Adopting Bamboo and Unfired Clay Bricks in Architectural Designs

The adoption of bamboo and unfired clay brick found in construction presents some challenges. For example, bamboo is vulnerable to decay and insect attack, limiting its use in construction. To address this issue, Researches recommend bamboo preservation methods like treatment with boron,

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boric acid, or copper. Similarly, studies suggest that the use of unfired clay bricks can be limited by their low compressive strength and susceptibility to weathering.

Furthermore, the use of bamboo and unfired clay bricks in construction requires skilled labor because of their unique properties. Studies note that the design and construction of bamboo structures require specialized knowledge and expertise. Similarly, arguments can be made that the use of prefabricated connectors in bamboo architecture requires skilled labor and specialized equipment.

In conclusion, the study demonstrates that sustainable building materials such as bamboo and unfired clay bricks have significant potential in promoting environmentally friendly architecture. However, their use in construction faces challenges that need to be addressed. Further research is necessary to develop preservation methods, improve their structural properties, and enhance the skills of construction workers to ensure their proper use and application in sustainable architecture.

From the interview conducted, it was discovered that the limited awareness and understanding among stakeholders regarding the benefits and properties of bamboo and unfired clay bricks pose a significant obstacle to their widespread adoption. This lack of knowledge, coupled with insufficient research and educational efforts, hinders effective promotion and utilization of these sustainable materials. Availability and sourcing challenges, especially in regions where these materials are uncommon, along with regulatory constraints that may not accommodate alternative materials, further impede their integration into architectural projects. Concerns about structural integrity and issues related to certification and standards also contribute to the reluctance in adopting bamboo and unfired clay bricks. To overcome these barriers, concerted efforts in education, research, advocacy for regulatory changes, and promoting market acceptability are crucial, enabling architects and stakeholders to embrace these sustainable alternatives effectively.

3.6. Utilization of Bamboo and Unfired Clay Bricks in Architectural Projects

Bamboo is a sustainable building material that is widely used due to its inherent properties such as strength, durability, and flexibility. It is a renewable resource that grows faster than traditional timber, has a low carbon footprint, and is a cost-effective alternative to conventional building materials. According to earlier studies, the digital construction of bamboo architecture can be achieved through multi-technology cooperation, which can lead to the creation of new parameterized digital construction workflows of bamboo architecture from traditional bamboo construction technology. Using bamboo in building construction can reduce the demand for non-renewable resources and contribute to sustainable development.

Unfired clay bricks are another sustainable building material that can promote environmentally friendly architecture. They are made by mixing clay, water, and other organic materials, which are then pressed and dried without the use of heat. This process results in a building material that is eco-friendly, energy-efficient, and affordable. According to research, using environmentally friendly materials such as unfired clay bricks can enhance the self-image of individuals and organizations, leading to more sustainable practices. Additionally, contemporary bamboo architecture in China is a product of the integration of traditional materials and techniques, including unfired clay bricks, which have contributed to eco-friendly architecture.

Interview respondents shared their experience with the use of these materials. In a community center project, bamboo was employed for the structural framework and interior finishes, complemented by unfired clay bricks for exterior walls. This demonstrated the aesthetic appeal, energy efficiency, and sustainability of these materials, resulting in a comfortable and eco-friendly space. Respondents also expressed a personal inclination towards clay bricks in their designs, citing their versatility and aesthetic appeal. They emphasized the importance of using solid clay bricks and proper construction methods to maximize their benefits. Both bamboo and unfired clay bricks were recognized for their suitability in structural applications. Bamboo excels in columns, beams, and roofing systems for visually striking and sustainable buildings, while unfired clay bricks found use in traditional and modern architecture, enhancing the indoor environment and contributing to a

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natural aesthetic. These examples underscore the versatility, sustainability, and aesthetic appeal of bamboo and unfired clay bricks in crafting environmentally conscious and visually appealing architectural structures.

4. Conclusions

This study has demonstrated that sustainable building materials play a pivotal role in driving environmentally friendly architecture, with bamboo and unfired clay bricks emerging as viable alternatives to conventional construction materials. Through a comprehensive assessment combining literature review, empirical surveys, interviews, and case studies, the research established that these materials offer substantial environmental benefits, including reduced embodied energy, lower carbon emissions, renewability, biodegradability, and improved thermal performance. These attributes align strongly with global sustainability goals and the urgent need to reduce the environmental footprint of the built environment.

The findings reveal that professionals increasingly recognize the importance of carbon footprint reduction, biodegradability, and renewable resource availability in assessing material sustainability. Bamboo's rapid growth rate, high strength-to-weight ratio, and carbon sequestration capacity position it as a structurally efficient and environmentally responsible material, while unfired clay bricks provide a low-energy, locally sourced alternative that enhances indoor environmental quality and supports affordable housing delivery. Together, these materials demonstrate strong potential for application across a range of architectural designs and building types.

Despite these advantages, the study identified critical barriers limiting widespread adoption, including limited stakeholder awareness, resistance to departure from conventional construction practices, regulatory and certification challenges, technical limitations, and the need for skilled labor. These constraints underscore the importance of integrated strategies involving policy reform, professional training, research and development, and public awareness to enable the mainstream acceptance of sustainable materials.

In conclusion, bamboo and unfired clay bricks represent practical and environmentally sound pathways toward achieving sustainable and environmentally friendly architecture. Their successful integration into contemporary construction practice requires not only technical validation but also institutional support, regulatory alignment, and cultural acceptance. By addressing these challenges, the construction industry can significantly reduce its environmental impact while promoting resilient, low-carbon, and context-responsive architectural solutions. This study therefore provides valuable empirical evidence to inform architects, policymakers, and construction stakeholders seeking to transition toward more sustainable material choices and environmentally responsible built environments.

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Abbreviations

The following abbreviations are used in this manuscript:

LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
LCA	Life Cycle Assessment

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EPD Environmental Product Declaration
GGBS Granulated Blast Furnace Slag

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