

Cost-Effective Sustainable Materials for Low-Rise Building Construction

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ABSTRACT

In recent years, the need for cost effective and eco friendly materials for low rise building construction has emerged with the growing demand for affordable housing. Considerable carbon emissions, energy use, and production costs for conventional construction materials underscore the need for exploring sustainable alternatives. The aim of this study is to explore the feasibility of using locally sourced materials, recycled resources or alternative construction methods to lower the cost of a building while maintaining structural form, structural integrity, durability and energy efficiency. The study uses a comparative assessment method to assess building materials using initial construction cost, embodied energy, carbon emissions, thermal performance, maintenance needs and lifecycle cost. It also addresses the importance of climate responsive architectural design, utilization of materials efficiently and avoiding the generation of waste to enhance the sustainability of low-rise residential buildings. The opportunities and challenges of using traditional building materials and locally available resources in developing countries particularly in Nigeria are highlighted. Expected outcomes involve recognizing practical material-selection strategies, considering the trade-offs between cost and environmental quality, and suggesting ways to incorporate environmental materials into residential building. Effective selection of materials is highlighted as an approach that should take into account both the upfront construction costs and environmental and economic impacts over the life cycle of the building. The results will help architects, engineers, builders, policy makers, and housing developers to encourage low-rise buildings that are affordable, durable, resource efficient, and environmentally responsible.

Keywords: Sustainable building materials, low-rise construction, cost optimization, affordable housing, embodied energy, carbon emissions, lifecycle cost, environmental sustainability.

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INTRODUCTION

The construction industry plays a significant role in economic development and housing provision; however, rising building costs, resource depletion, and environmental degradation have increased the need for sustainable construction practices. Low-rise buildings, particularly residential housing, offer opportunities to integrate affordable materials, energy-efficient designs, and locally available resources to improve economic and environmental performance. Raj et al. (2021) examined low-cost materials and construction techniques for sustainable housing, highlighting the importance of affordable building solutions. Similarly, Kirubakaran and Murali (n.d.) reviewed sustainable building materials for low-cost housing, emphasizing the relevance of material selection in achieving affordability and sustainability.

Cost-effective sustainable construction involves selecting materials that balance initial expenditure, durability, structural performance, maintenance requirements, and environmental impact. Traditional materials, including earth-

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based products, timber, and other locally sourced resources, can support affordable housing when appropriately selected and applied. In Nigeria, traditional building materials offer potential economic and environmental advantages, although challenges relating to durability, standardization, and wider acceptance must be addressed (Onyegiri & Ugochukwu, 2016). Alternative construction techniques can also reduce

material waste and improve cost efficiency in low-height buildings (Chaudhary & Wall, 2017).

Beyond initial construction expenditure, sustainable material selection requires consideration of energy consumption, carbon emissions, and long-term building performance. Omer (2002) discussed low-energy building materials, while Bansal et al. (2021) examined embodied energy, carbon dioxide equivalent emissions, and construction costs in Indian housing. In addition, energy-efficient residential design can improve building performance while controlling costs (Evola et al., 2014). Sustainable architectural approaches and building-envelope assessments further support the development of environmentally responsible low-rise buildings (Zhogoleva & Teryagova, 2017; Žigart et al., 2018). Comparative evaluation of structural systems is also important for identifying suitable solutions for energy-efficient residential construction (Sareh, 2012).

Despite these opportunities, selecting sustainable materials remains challenging because of variations in local availability, material prices, technical expertise, building standards, and environmental performance. This study therefore examines cost-effective sustainable materials for low-rise building construction, focusing on their affordability, durability, energy efficiency, and environmental implications. It aims to identify practical material-selection strategies and construction approaches that reduce overall building costs while promoting resource efficiency and long-term sustainability.

LITERATURE REVIEW

Sustainable Building Materials for Low-Cost Housing

Sustainable building materials play an important role in reducing construction expenditure, conserving natural resources, and minimizing environmental impacts. Materials such as stabilized earth blocks, bamboo, timber, recycled aggregates, and locally available resources offer potential alternatives to conventional materials when their structural suitability, durability, and availability are properly assessed. Raj et al. (2021) reviewed low-cost materials and construction techniques for sustainable housing in India, highlighting the importance of affordable material selection and appropriate construction practices. Similarly, Kirubakaran and Murali (n.d.) examined sustainable building materials for low-cost housing, emphasizing the relevance of material efficiency and sustainability in affordable residential development.

Traditional and Locally Available Materials

Traditional building materials can support sustainable construction by reducing transportation requirements, encouraging local production, and utilizing regionally available resources. In Nigeria, Onyegiri and Ugochukwu (2016) discussed the advantages and challenges of traditional building materials for low-cost housing, demonstrating their

relevance to affordable residential development. However, their application requires consideration of durability, moisture resistance, structural performance, construction skills, and compliance with building standards. Therefore, locally sourced materials should be evaluated according to their environmental benefits, technical suitability, and long-term economic value.

Cost Optimization and Alternative Construction Techniques

Cost optimization involves selecting materials and construction methods that minimize total expenditure without compromising safety, quality, or functionality. Chaudhary and Wall (2017) investigated cost optimization through alternative construction techniques for low-height buildings, supporting the consideration of innovative building methods as potential strategies for reducing construction costs. In addition, Sareh (2012) compared three structural systems for low-rise energy-efficient residential buildings, providing a relevant basis for examining how structural-system selection influences building efficiency and performance. These studies indicate that construction costs should be assessed alongside material requirements, labor expenses, construction time, and maintenance needs.

Energy Efficiency and Environmental Performance

The environmental sustainability of building materials depends partly on their embodied energy, carbon emissions, and contribution to operational energy consumption. Omer (2002) provided an overview of low-energy building materials, establishing the importance of considering energy requirements in material selection. Bansal et al. (2021) examined embodied energy, CO₂-equivalent emissions, and construction costs in Indian housing, comparing low-rise and high-rise development models. Their work provides a useful basis for assessing the relationship between building configuration, material consumption, environmental impacts, and economic feasibility.

Building-envelope design is also important because walls, roofs, windows, and insulation influence heat transfer and energy demand. Žigart et al. (2018) assessed the environmental impacts of building-envelope components for low-rise buildings, supporting the integration of environmental assessment into material-selection decisions. Consequently, sustainable construction should consider both the environmental burden of producing building materials and their contribution to energy performance throughout the building's service life.

Sustainable Architectural Design for Low-Rise Buildings

Sustainable architectural design combines material selection, building orientation, natural ventilation, daylighting, and energy-efficient building systems to improve overall building



performance. Evola et al. (2014) explored cost-effective design solutions for low-rise residential nearly zero-energy buildings in Mediterranean climates, illustrating the relevance of integrating energy performance with economic considerations. However, design strategies must be adapted to local climatic conditions, construction practices, and available resources rather than transferred directly between regions.

Zhogoleva and Teryagova (2017) examined sustainable architectural design methods for bio-positive buildings within low-rise residential developments. This perspective broadens sustainability beyond cost reduction to include resource conservation and positive environmental contributions. For affordable housing, combining climate-responsive design with durable, locally available materials may help reduce operating expenses while improving indoor comfort.

Research Gap

The reviewed literature establishes the importance of affordable materials, traditional construction resources, alternative building techniques, energy efficiency, and environmental assessment. Nevertheless, selecting sustainable materials requires balancing initial construction costs against durability, maintenance, embodied energy, carbon emissions, and operational energy demand. A context-specific comparative assessment is therefore needed to identify which combinations of materials and construction techniques provide the strongest balance between affordability and environmental performance in low-rise buildings, particularly in Nigeria and comparable developing economies.

This study addresses that need by examining sustainable material alternatives and construction strategies using economic, technical, and environmental criteria. The aim is to support practical material-selection decisions that promote affordable, durable, and environmentally responsible low-rise housing.

RESEARCH METHODOLOGY

This study adopts a comparative literature-based research methodology to evaluate cost-effective sustainable materials and construction techniques for low-rise buildings. The approach examines published research on traditional building materials, alternative construction systems, energy-efficient materials, and sustainable housing practices. Relevant studies by Raj et al. (2021) and Kirubakaran and Murali (n.d.) provide a basis for identifying low-cost materials and their suitability for affordable housing. Research by Onyegiri and Ugochukwu (2016) supports the assessment of traditional materials in the Nigerian context.

Research Design and Data Collection

The study uses secondary data collected from academic journal articles, conference proceedings, and published technical literature. Sources are selected based on their

relevance to sustainable construction, material affordability, environmental performance, and low-rise residential buildings. Studies on energy-efficient residential design, such as Evola et al. (2014), and sustainable architectural approaches, such as Zhogoleva and Teryagova (2017), inform the assessment of design-related cost savings and environmental benefits.

Evaluation Criteria

The selected materials and construction techniques are assessed using economic, environmental, and technical criteria. Economic indicators include initial construction costs, transportation expenses, and maintenance requirements. Environmental indicators include embodied energy, carbon emissions, and resource consumption, informed by Omer (2002) and Bansal et al. (2021). Technical indicators include durability, structural suitability, thermal performance, and resistance to local climatic conditions. Alternative construction techniques are also considered for their potential to reduce labor costs and material waste (Chaudhary & Wall, 2017; Sareh, 2012).

Data Analysis

The collected information is analyzed through qualitative comparison and descriptive synthesis. Conventional materials and construction systems are compared with sustainable alternatives to identify potential cost savings, environmental advantages, and technical limitations. Where comparable numerical data are available, construction costs, embodied energy, and carbon emissions are assessed using consistent units and clearly defined assumptions. The environmental performance of building-envelope components is considered using the approach discussed by Žigart et al. (2018).

Reliability and Limitations

To improve reliability, findings are compared across multiple publications, with attention to differences in geographical location, material availability, construction standards, and building design. The analysis recognizes that material costs and environmental performance vary by region and project specifications. Since the methodology relies on secondary sources, the conclusions depend on the quality and comparability of published evidence. The study therefore emphasizes transparent assumptions and recommends local cost data and material testing before practical implementation.

Cost-Effective Sustainable Materials and Construction Strategies

Cost-effective sustainable materials and construction strategies are essential for reducing the financial and environmental burdens of low-rise building construction. Selecting locally available materials, recycled resources, and low-energy alternatives can reduce transportation expenses, material waste, and embodied carbon while

Table 1: Research Framework for Evaluating Sustainable Materials in Low-Rise Buildings

Assessment category	Key indicators	Evaluation method	Supporting references
Economic performance	Initial cost, transport, installation, maintenance	Comparative cost assessment	Raj et al. (2021); Chaudhary and Wall (2017)
Environmental performance	Embodied energy, CO ₂ e emissions, resource use	Environmental-impact comparison	Omer (2002); Bansal et al. (2021)
Technical performance	Durability, structural suitability, thermal efficiency	Review of reported material properties	Sareh (2012); Žigart et al. (2018)
Local availability	Material supply, sourcing distance, local production	Which	Onyegiri and Ugochukwu (2016); Kirubakaran and Murali (n.d.)
Energy efficiency	Insulation, passive design, operational energy demand	Comparative review of building-design strategies	Fly away and
Sustainable design	Resource efficiency, waste reduction, environmental integration	Assessment of sustainable design principles	Zhogoleva and Teryagova (2017)

supporting affordable housing development. Raj et al. (2021) highlight the importance of low-cost materials and sustainable construction techniques, while Kirubakaran and Murali (n.d.) discuss sustainable building materials for affordable housing. In Nigeria, traditional materials can provide locally appropriate alternatives, although their suitability depends on durability, availability, construction standards, and maintenance requirements (Onyegiri & Ugochukwu, 2016).

Alternative construction techniques, including prefabrication, modular components, and optimized structural systems, can also reduce material consumption and labor costs. Chaudhary and Wall (2017) examine cost optimization through alternative techniques for low-height buildings, while Sareh (2012) compares structural systems for energy-efficient low-rise residential buildings. Material selection should therefore consider both initial expenditure and long-term performance.

Energy-efficient building envelopes, passive cooling, natural ventilation, and climate-responsive design can further reduce operational energy consumption. Evola et al. (2014) investigate cost-effective design solutions for low-rise residential nearly zero-energy buildings, while Omer (2002) reviews low-energy building materials. Sustainable architectural approaches can also support environmentally beneficial residential development (Zhogoleva & Teryagova, 2017). Furthermore, embodied energy, carbon emissions, and the environmental impacts of envelope components should be considered alongside construction costs (Bansal et al., 2021; Žigart et al., 2018).

The most effective strategy is to combine locally appropriate materials, efficient construction techniques, and climate-responsive design. Material selection should be based on verified local prices, structural performance, durability, embodied energy, and lifecycle costs to achieve affordable and environmentally responsible low-rise housing.

Results, Discussion, and Environmental Evaluation

The evaluation of cost-effective sustainable materials for low-rise building construction focuses on construction affordability, material durability, energy efficiency, and environmental performance. Raj et al. (2021) and Kirubakaran and Murali (n.d.) highlight the relevance of low-cost materials and sustainable construction approaches for affordable housing. Locally available materials, including stabilized earth blocks, bamboo, and timber, may reduce transportation expenses and dependence on conventional materials when they are appropriately sourced, processed, and tested. However, their suitability depends on local availability, structural requirements, moisture resistance, and maintenance needs (Onyegiri & Ugochukwu, 2016).

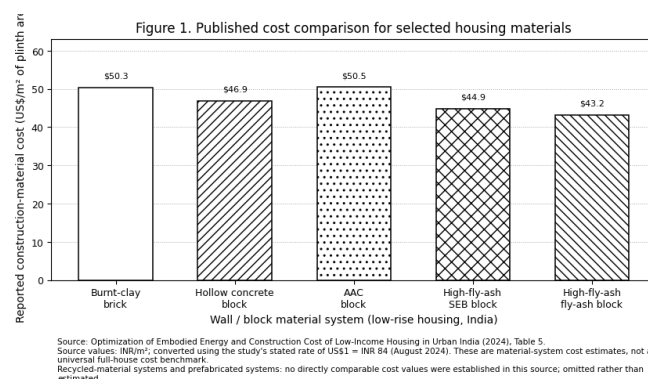


Figure 1: Construction costs are based on published Indian housing data and converted to USD using the exchange rate reported in the source. Costs are study-specific and may vary by location, material availability, labor, and building design. Missing comparable data for recycled-material and prefabricated systems are not estimated.



Table 2: Cost-Effective Sustainable Materials and Construction Strategies for Low-Rise Buildings

<i>Material or strategy</i>	<i>Cost-effectiveness</i>	<i>Sustainability benefits</i>	<i>Key considerations</i>
Stabilized earth blocks	Potentially lower costs where suitable soil and local production are available	Reduced transport requirements and potentially low embodied energy	Soil quality, moisture resistance, and stabilization requirements
Traditional materials, including bamboo and timber	May reduce procurement costs when locally available	Renewable-resource potential and support for local industries	Treatment, durability, fire safety, and building-code compliance
Recycled aggregates and reused materials	Potential savings through reduced demand for virgin materials	Resource conservation and construction-waste reduction	Material quality, contamination, and structural suitability
Prefabrication and modular construction	Potential reduction in labor time, waste, and construction delays	Improved material efficiency and process control	Transport, equipment, and initial setup costs
Energy-efficient building envelopes	Potential lifecycle savings through lower energy demand	Reduced operational emissions and improved thermal comfort	Climate suitability, insulation costs, and installation quality
Passive design and natural ventilation	May reduce dependence on mechanical cooling and artificial lighting	Lower operational energy consumption	Building orientation, shading, ventilation, and local climate

Source: Synthesized from Raj et al. (2021), Kirubakaran and Murali (n.d.), Evola et al. (2014), Onyegiri and Ugochukwu (2016), Chaudhary and Wall (2017), Omer (2002), Bansal et al. (

Table 3: Comparative Evaluation of Sustainable Materials for Low-Rise Buildings

<i>Material</i>	<i>Cost considerations</i>	<i>Sustainability benefits</i>	<i>Limitations</i>
Stabilized earth blocks	Potentially low production and transport costs when locally available	Reduced dependence on energy-intensive materials	Requires moisture protection and quality control
Bamboo and timber	Cost depends on supply, treatment, and labor	Renewable resource potential and carbon storage in suitable applications	Vulnerability to fire, pests, and moisture
Recycled aggregates	Potential savings where processing facilities exist	Reduces demand for virgin aggregates and construction waste	Quality and availability may vary
Conventional concrete	Established production and construction systems	Durability and widespread technical familiarity	Cement production contributes substantially to embodied emissions
Energy-efficient envelope materials	May involve higher initial investment	Potential reductions in heating and cooling demand	Performance depends on climate and installation quality

Source: Developed from the sustainable-material and construction-cost considerations discussed by Raj et al. (2021), Kirubakaran and Murali (n.d.), Omer (2002), and Žigart et al. (2018). The comparisons are qualitative and require validation using local cost and performance data.

Comparative Cost and Performance Evaluation

Alternative construction techniques can reduce material waste, labor requirements, and overall building expenditure when supported by appropriate design and construction management (Chaudhary & Wall, 2017). Nevertheless, the lowest initial cost does not necessarily represent the best economic outcome over a building's service life. Maintenance, repairs, replacement, and operational energy consumption should also inform material selection. Comparative assessments of low-rise residential structural systems can help identify solutions that balance affordability, energy efficiency, and structural performance (Sareh, 2012).

Environmental Impact and Energy Efficiency

Environmental evaluation should consider both embodied impacts associated with material extraction, manufacturing, and transportation, and operational impacts arising from building energy consumption. Bansal et al. (2021) examine embodied energy, carbon dioxide equivalent emissions, and construction costs in Indian housing, providing a basis for considering the relationship between building configuration and environmental performance. Omer (2002) further supports the consideration of low-energy building materials as part of energy-conscious construction.

Building-envelope selection is also important because

Table 4: Environmental and Lifecycle Evaluation Indicators

Indicator	Evaluation method	Desired performance
Initial construction cost	Cost per square meter	Lower affordable construction expenditure
Embodied energy	Energy consumed during material production and processing	Reduced energy intensity
Embodied carbon	Carbon dioxide equivalent emissions across defined lifecycle stages	Lower material-related emissions
Operational energy	Estimated annual energy use for cooling, heating, and lighting	Reduced energy demand
Durability and maintenance	Service life, repair frequency, and replacement needs	Longer service life and lower maintenance burden
Resource efficiency	Material utilization, recycled content, and construction waste	Reduced virgin-resource consumption
Climate suitability	Thermal performance under local climatic conditions	Improved comfort and energy efficiency

Source: Adapted conceptually from Bansal et al. (2021), Omer (2002), Evola et al. (2014), and Žigart et al. (2018).

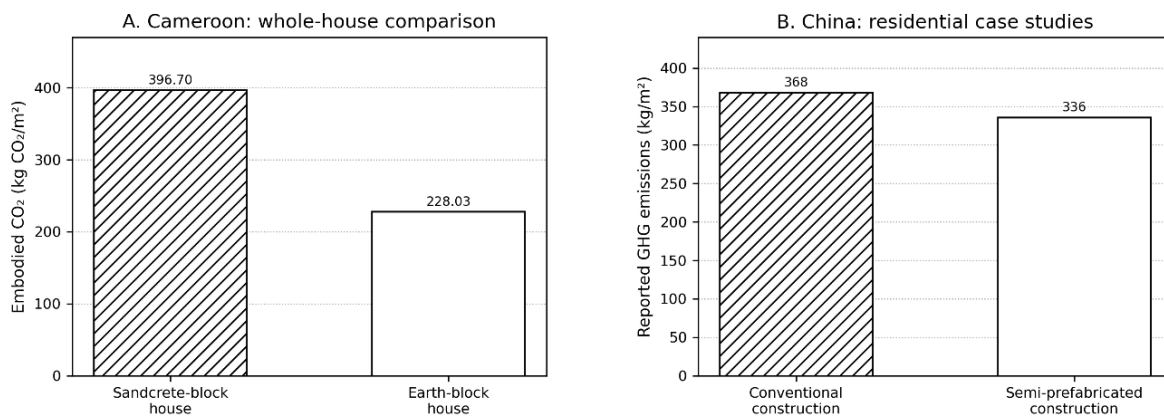


Figure 2: Embodied carbon and greenhouse gas emissions are reported from published residential construction case studies in Cameroon and China. Differences in building specifications, geographic context, and assessment boundaries limit direct comparison across studies. Values for recycled-material systems are omitted where comparable verified data are unavailable.

wall, roof, and insulation characteristics influence heat transfer and indoor comfort. Žigart et al. (2018) examine the environmental impacts of envelope components for low-rise buildings, while Evola et al. (2014) investigate cost-effective design solutions for low-rise residential nearly zero-energy buildings in Mediterranean climates. These studies support the need to evaluate materials alongside climate-responsive design rather than treating material cost as an isolated factor.

Discussion and Practical Implications

Sustainable material selection requires balancing affordability, technical suitability, and environmental responsibility. Traditional materials can support low-cost housing in Nigeria, but challenges involving standardization, technical expertise, durability, and public acceptance must be addressed (Onyegiri & Ugochukwu, 2016). Similarly, bio-positive architectural approaches can inform building designs that consider resource use and environmental

integration throughout the development process (Zhogoleva & Teryagova, 2017).

The overall evaluation should therefore prioritize materials that meet building regulations, provide adequate structural performance, and demonstrate favorable lifecycle costs. Actual cost and environmental comparisons should use consistent functional units, comparable building designs, and clearly defined lifecycle boundaries. This approach supports evidence-based decisions without assuming that every sustainable material is automatically cheaper or environmentally superior.

CONCLUSION

Cost-effective sustainable materials offer significant opportunities to improve the affordability, durability, and environmental performance of low-rise buildings. Locally sourced materials, traditional construction resources,



recycled components, and alternative building techniques can reduce material expenditure and transportation costs while supporting more sustainable housing development (Raj et al., 2021; Onyegiri & Ugochukwu, 2016). The selection of appropriate materials should also consider embodied energy, carbon emissions, thermal efficiency, and long-term maintenance requirements rather than focusing exclusively on initial construction costs (Omer, 2002; Bansal et al., 2021). Furthermore, integrating energy-efficient structural systems, sustainable building-envelope components, and climate-responsive architectural design can improve building performance and reduce operational energy consumption (Evola et al., 2014; Žigart et al., 2018). Alternative construction methods and bio-positive architectural principles also provide opportunities to optimize resources and promote environmentally responsible residential development (Chaudhary & Wall, 2017; Zhogoleva & Teryagova, 2017). Overall, sustainable material selection requires balancing economic feasibility, structural performance, resource availability, and environmental impact (Kirubakaran & Murali, n.d.; Sareh, 2012).

RECOMMENDATIONS

1. Prioritize locally available materials: Builders should assess traditional and locally sourced materials for affordability, durability, and suitability to local environmental conditions, particularly in developing countries (Onyegiri & Ugochukwu, 2016; Raj et al., 2021).
 2. Adopt lifecycle cost assessment: Material selection should account for initial construction expenditure, maintenance, replacement, and operational energy costs to identify economically viable solutions over the building's service life (Evola et al., 2014; Bansal et al., 2021).
 3. Promote alternative construction techniques: Construction professionals should evaluate resource-efficient methods that reduce material waste, labor requirements, and overall project costs without compromising structural safety (Chaudhary & Wall, 2017; Sareh, 2012).
 4. Improve energy and environmental performance: Architects and engineers should integrate energy-efficient materials, suitable building-envelope systems, and climate-responsive designs to reduce energy consumption and environmental impacts (Omer, 2002; Žigart et al., 2018).
 5. Strengthen quality assurance and technical training: Appropriate material testing, construction standards, and professional training should be encouraged to ensure that sustainable alternatives meet required safety, durability, and performance criteria (Kirubakaran & Murali, n.d.).
 6. Encourage sustainable housing policies: Policymakers and housing developers should support research, awareness, and incentives for affordable sustainable materials and environmentally responsible low-rise construction, incorporating bio-positive design principles where practical (Zhogoleva & Teryagova, 2017).
- In conclusion, integrating cost-effective sustainable materials

with appropriate construction techniques and lifecycle-based decision-making can contribute to affordable, energy-efficient, and environmentally responsible low-rise housing. Further comparative studies should assess local material prices, structural performance, and environmental impacts under different climatic and economic conditions to guide practical implementation.

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