# A Review Study on Materials, Techniques, Energy-efficiency on Sustainable Construction Management

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**Abstract -** *Sustainable construction management and building materials are very important for making the built environment better for the economy and society while also having less of an effect on the environment. The review emphasizes the integration of innovative materials, vernacular knowledge, and modern technological solutions to minimize energy consumption, reduce greenhouse gas emissions, and enhance occupant comfort. Sustainable building approaches and contribute significantly to environmental protection, resource conservation, and long-term economic resilience. The use of sustainable materials, building construction, energy design, and cost planning based on the life cycle can be seen as a viable solution for environmentally friendly construction. The review concentrates on four principal aspects of sustainable construction: materials, construction methodologies, energy efficiency, and cost-effectiveness. The study that was looked at shows how using sustainable and waste-based materials like waste plastic, crushed marble, recycled aggregates, bamboo, and other low-carbon options can help the environment while still being strong and long-lasting.*

**KEY WORDS: Sustainable Construction, Construction techniques, Energy efficiency**

## 1. INTRODUCTION

Sustainable construction management is a systematic approach that integrates sustainability into every stage of a project—from planning and design to construction, operation, and demolition. It aims to reduce environmental impact while improving resource efficiency, economic value, and long-term performance. Unlike traditional construction management, it not only focuses on cost, time, and quality but also emphasizes environmental protection, energy efficiency, waste reduction, and social responsibility. As urbanization increases, the construction industry's heavy use of natural resources and energy has led to pollution and environmental degradation. Sustainable construction management addresses these issues by promoting eco-friendly practices that support economic growth while ensuring a better quality of life for present and future generations. Sustainable construction management uses architectural design principles to create energy-efficient and environmentally compatible buildings. It focuses on passive strategies like natural ventilation, daylighting, insulation, and climate-based orientation, along with renewable energy sources such as solar and wind. Features like green roofs, rainwater harvesting, and efficient building envelopes help reduce environmental impact and maintain ecological balance.

Another vital component to consider in Sustainable Construction Management is the use of sustainable building materials that are environmentally friendly. When We produce traditional building materials (e.g., concrete, steel, and brick), they use a lot of energy to produce them and create a lot of carbon dioxide in doing so. Due to this, modern construction projects have begun implementing more sustainable options like bamboo, recycled steel, engineered wood products, recycled aggregate materials, concrete made from fly ash, and other green materials in their projects because they are not only better for the environment but will also help to become more efficient with resources when promoting reuse and recycling, which leads to less waste from construction projects.

Along with material management, Waste Management & Resource Efficiency are critical components to sustainable construction management because construction & demolition activities produce huge amounts of waste of Concrete Debris, Metal Scrap, Wood, and Packing Materials. Effective Waste Management strategies, such as Recycling, Re-using, & Properly Disposing of, can greatly reduce both the amount of environmental pollution & Landfill consumption. Some techniques that help to reduce the amount of waste generated during construction are Modular Construction, Prefabrication, and Lean Construction Practices.

Despite the growing awareness of sustainable construction practices, several challenges still hide their widespread implementation, particularly in developing countries. Some of the problems are high upfront costs, not enough technical knowledge, not enough support from policymakers, and resistance to change from traditional building methods. But more and more people are becoming concerned about the environment, and governments are making rules that encourage the use of sustainable building methods around theworld.

### 1.1 Fundamental Elements of Sustainable Construction

A fundamental concept in sustainable construction management is the triple bottom line, which consists of three key pillars: environmental sustainability, economic sustainability, and social sustainability. Sustainable construction management recognizes three distinct elements: environmental, economic, and social sustainability. Environmental sustainability focuses on how to minimize the ecological impact of construction by reducing energy use, conserving water, reducing greenhouse gas emissions, and using renewable resources. The emphasis of economic sustainability is on creating long-term value through cost-effective construction techniques; this involves maximizing energy efficiency, minimizing building maintenance costs, and maximizing building performance. Social sustainability, on the other hand, is concerned with the health, safety, and welfare of the occupants of a building as well as the surrounding community.

Another significant aspect of sustainable construction management is the use of sustainable and environmentally friendly building materials. Conventional building materials such as cement, steel, and bricks often require high energy consumption during production and generate significant carbon emissions.

### 1.2 Implementation of Green Building

Sustainable construction management also includes putting in place green building standards, rules, and certification systems, in addition to thinking about the environment and materials. There are many international frameworks that help people design and build green buildings. Some of these are LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and other national green building rating systems. By looking at how well buildings perform in areas like energy efficiency, water conservation, indoor air quality, and material sustainability, these standards encourage developers and contractors to be more environmentally responsible.

## 2. LITERATURE REVIEW

The construction industry is widely recognized as a major contributor to environmental degradation due to excessive resource consumption, high energy demand, and large-scale waste generation. In response, researchers and practitioners have increasingly focused on sustainable construction approaches that integrate eco-friendly materials, efficient construction techniques, energy-conscious design, and long-term cost efficiency. The reviewed literature collectively emphasizes that sustainability in construction must address material selection, construction processes, operational energy performance, and lifecycle economics in a holistic manner.

## 1. Sustainable Materials:

Previous studies highlight the importance of using sustainable and alternative building materials to reduce environmental impact. Materials such as bamboo, waste plastic, crushed marble, recycled aggregates, and natural fibers have been widely explored due to their low embodied energy and reduced carbon footprint. Bamboo, in particular, is recognized as a rapidly renewable resource with high tensile strength, flexibility, and seismic resistance, making it suitable for sustainable housing and structural applications. Research also emphasizes the reuse of bamboo scrap and construction waste to support circular economy principles and minimize landfill disposal. Waste plastic and industrial by-products have demonstrated improved durability, crack resistance, and acceptable compressive strength when used in construction elements such as paver blocks and road pavements. Overall, sustainable materials contribute significantly to resource conservation and environmental protection while maintaining structural performance.

**Y. A. Abera et al [24]**

"Sustainable building materials: A comprehensive study on eco-friendly alternatives for construction"

The present study investigates the potential use of pyrolysis low density Plastic (LDPE) as a modifier for asphalt paving materials. Five different blends including conventional mix were subjected to binder testing such as rheological tests, as well as to some other tests related to the homogeneity of the system. Further, its effect on the moisture sensitivity and low temperature performance of stone matrix asphalt (SMA) mixtures was studied.

Research results indicate that modified binders showed higher softening point, keeping the values of ductility at minimum range of specification of (100+ cm), and caused a reduction in percentage loss of weight due to heat and air (i.e. increase durability of original asphalt). The results indicated that the inclusion of LDPE in SMA mixtures can satisfy the performance requirement of high-temperature, low temperature and much rain zone.

This research begins with a comprehensive review of literature on sustainable construction materials, examining recent studies and industry publications to identify environmentally friendly options. It focuses on recycled materials (recycled aggregates, recovered wood), bio-based materials (bamboo, hempcrete), and low-carbon alternatives (geopolymers, fly ash-based products). Each material is analyzed based on its production, properties, applications, and environmental benefits.

Sustainable building materials have become essential in addressing environmental issues in the construction industry, particularly in reducing carbon emissions, resource consumption, and waste generation. As a result, both researchers and practitioners are increasingly exploring eco-friendly alternatives to traditional materials.

Recycled materials, especially aggregates from construction and demolition waste, help reduce mining and landfill use. Recovered wood also supports sustainability by minimizing reliance on virgin timber. Bio-based materials such as bamboo offer high strength and rapid renewability, while hempcrete provides effective thermal and acoustic insulation.

Low-carbon materials like geopolymers and fly ash-based products present viable alternatives to conventional cement, significantly lowering greenhouse gas emissions while utilizing industrial byproducts.

Despite their advantages, challenges remain in terms of performance, cost, regulations, and public acceptance. Ongoing research emphasizes material performance evaluation and environmental impact analysis to support their adoption.

The ability of the construction industry to adopt global practices of sustainability is hindered by a lack of adequate provision for specialized training for management and construction staff.

**Kmetz .M et al [23]**
The study examines building decarbonization through a lifecycle-based analytical approach, identifying operational and embodied carbon as key contributors to emissions. The study highlights strategies such as energy efficiency, renewable energy integration, electrification, and the use of low-carbon materials. It emphasizes that sustainable construction management is critical in implementing these strategies through effective planning, material selection, and stakeholder coordination. The research concludes that reducing the carbon footprint of buildings is essential for achieving long-term environmental sustainability and global net-zero targets.

**Arvind Singh Gaur et al [22]**
The study investigates the use of construction and demolition waste in the production of concrete paver blocks through experimental analysis of mechanical and durability properties. The study demonstrates that partial replacement of natural aggregates with recycled materials provides adequate strength and durability while significantly reducing environmental impact and material costs. The findings highlight that effective material selection and waste utilization are key components of sustainable construction management, promoting resource efficiency and reducing landfill waste.

**Lakshmi et at [24]**
The journal investigates the use of plastic waste and bottom ash in paver block production through experimental analysis of mechanical and durability properties. The study demonstrates that these waste materials can partially replace conventional aggregates while maintaining acceptable strength and durability. The findings highlight that incorporating recycled materials reduces environmental impact, lowers construction costs, and promotes resource efficiency. The research emphasizes that sustainable construction management relies on effective material selection and waste utilization strategies to achieve environmental and economic sustainability.

**Bhukya Govardhan Naik et al [24]**
The study on the journal investigates the use of waste glass as a substitute for fine aggregate in paver block production using an experimental and analytical approach. The study employs response surface methodology to optimize material proportions and evaluates mechanical and durability properties. The findings indicate that waste glass can effectively replace natural sand at optimal levels, improving resource efficiency and reducing environmental impact. The research highlights that sustainable construction management relies on innovative material selection, waste utilization, and data-driven optimization to achieve environmentally responsible construction practices.

**Samer Qaidi et al [23]**
The study presents a comprehensive review of the use of waste glass as an environmentally friendly aggregate in concrete, analyzing its effects on fresh and mechanical properties. The study finds that partial replacement of natural aggregates with waste glass can maintain or improve concrete performance at optimal levels while significantly reducing environmental impact. The research highlights that sustainable construction management relies on effective material selection, waste recycling, and optimized mix design to achieve resource efficiency and reduce the carbon footprint of construction materials.

**M. Amran et al [21]**
The journal presents a comprehensive review of fly ash-based eco-efficient concrete, analyzing its effects on fresh and short-term mechanical properties. The study highlights that partial replacement of cement with fly ash improves workability and reduces carbon emissions, although early-age strength may be slightly reduced. The findings emphasize that sustainable construction management depends on efficient material selection, utilization of industrial by-products, and optimized mix design to achieve environmentally responsible and resource-efficient construction practices.

**David Pearlmutter et al [20]**
The journal review examines the role of nature-based solutions in promoting a circular economy within the built urban environment through a comprehensive literature review and conceptual framework. The study highlights the integration of green materials, ecological systems, and sustainable site design to enhance resource efficiency and environmental performance. The findings emphasize that sustainable construction management must incorporate circular economy principles and ecosystem-based

approaches to achieve long-term sustainability, urban resilience, and reduced environmental impact.
The pursuit of sustainable building materials has ornamental analyses. Many studies have been undertaken to estimate the total environmental effect of these materials, allowing for direct comparisons with traditional counterparts.
Finally, the literature illustrates the importance of re-emerged as a critical component of the construction moving sustainable building materials in the construction industry's attempts to solve environmental concerns and business. This extensive research seeks to add to the current adopt more environmentally friendly methods.

**N. Bheel et al [22]**
The study investigates the use of sugarcane bagasse ash, metakaolin, and millet husk ash as ternary cementitious materials in concrete through experimental analysis of fresh, mechanical, and environmental properties. The study demonstrates that partial replacement of cement with these materials can maintain structural performance while significantly reducing embodied carbon. The findings highlight that sustainable construction management relies on the adoption of low-carbon materials, efficient mix design, and waste utilization strategies to achieve environmentally responsible construction practices.
An experimental study on fresh, mechanical properties and embodied carbon of concrete blended with sugarcane bagasse ash, metakaolin, and millet husk ash as ternary cementitious material.
Enhancing the circular economy with nature-based solutions in the built urban environment: green building materials, systems and sites. Blue-Green Systems
A thorough body of knowledge by conducting a detailed evaluation of investigation of eco-friendly alternatives for construction eco-friendly alternatives and their potential to revolutionize materials has become critical in the industry's desire to the way we design our built environment. This study lowers its ecological imprint and migrates.

**W. E. Farrant et al [22]**
The use of alternative and waste-based materials in concrete through experimental evaluation of fresh and mechanical properties. The study demonstrates that partial replacement of conventional materials can maintain performance while reducing environmental impact. The findings emphasize that sustainable construction management relies on efficient material selection, reduction of carbon-intensive materials, and optimized mix design to achieve resource-efficient and environmentally responsible construction practices.
There is a rising interest in sustainable building materials in the literature, with considerable research concentrating on material characterization, performance evaluation, and environmental analysis.
Influence of sugarcane bagasse ash and silica fume on the mechanical and durability properties of concrete.

## 2. Sustainable Construction Techniques:
Construction techniques play a critical role in translating sustainable material choices into effective building performance. The literature emphasizes techniques such as waste minimization during construction, recycling of construction debris, prefabrication, and efficient project management practices. Sustainable construction methods integrate traditional knowledge with modern technology, promoting climate-responsive design and locally adapted building practices. Studies also highlight the importance of project management tools, lifecycle assessment, and green certification frameworks to ensure efficient planning, stakeholder coordination, and sustainability compliance. Innovative approaches, including parametric and digital design tools, further optimize material usage and enhance construction efficiency.

**P. U. Okoye, I. A. Odesola, and K. C. Okolie et al [22]**
"Evaluating the Importance of Construction Activities for Sustainable Construction Practices in Building Projects in Nigeria," Journal of Sustainable Construction Materials and Technologies
Unsound construction in developing nations such as Nigeria has been identified in research.
Feeble regulations and weak enforcement render it difficult to implement sustainable practices, as well as enforcing those who don't meet the regulations. Increased awareness and sensitization of project leaders and workers can exacerbate such issues, creating a challenge in the use of sustainable practices in the long run. There is a need for long-term studies in order to monitor how effective the practices of sustainability are in the long term, as well as how the involvement of the community influences the use of sustainable construction practices.
We must merge traditional knowledge and practices with contemporary notions of sustainability to synthesize solutions appropriate to particular circumstances.

**Sai Trivedi. S et al [23]**
The journal presents a comprehensive review of sustainable approaches for processing and treating construction and demolition waste. The study analyzes various mechanical, chemical, and recycling techniques to improve material recovery and reduce environmental impact. The findings highlight that effective waste management, recycling strategies, and resource optimization are key components of sustainable construction management. The research concludes that integrating waste processing techniques into construction practices enhances resource efficiency and supports the transition toward a circular construction economy.

**W. Ma et al [23]**
The journal explores the transition towards a circular economy in construction and demolition waste management through a comprehensive literature review and framework

development. The study highlights strategies such as waste reduction, reuse, recycling, and design for deconstruction to improve resource efficiency and minimize environmental impact. The findings emphasize that sustainable construction management requires the integration of circular economy principles and advanced construction techniques across the project lifecycle to achieve long-term sustainability.
Towards a circular economy for construction and demolition waste management in China: critical success factors. Sustainable Chemistry and Pharmacy. Moreover, hempcrete, a hemp fiber and lime combination, has shown remarkable thermal and acoustic qualities, making it an appealing choice for sustainable building insulation.

**R. Maderuelo-Sanz et al [22]**
The study investigates the use of lightweight construction systems incorporating recycled materials to enhance building performance. Through experimental evaluation of acoustic properties, the study demonstrates that such systems can achieve effective sound insulation while reducing material consumption and environmental impact. The findings emphasize that sustainable construction management depends on the adoption of innovative construction techniques, including lightweight and prefabricated systems, to improve efficiency, resource utilization, and overall sustainability.
The incorporation of environmentally friendly building materials into the construction sector necessitates a thorough grasp of their qualities and prospective uses. Yet, there are still issues to address in terms of material performance, cost-effectiveness, regulatory compliance, and public acceptance. Addressing these impediments and providing evidence-based data to promote the informed selection and integration of eco-friendly options in construction methods is critical.
Thermal and acoustical evaluation of bio-composites made of agricultural waste for ceiling tiles.

## 3. Energy Efficiency:

Energy efficiency in sustainable construction management refers to the practice of designing, constructing, and operating buildings in a way that minimizes energy consumption while maintaining comfort and performance. It involves the use of passive design strategies such as proper building orientation, natural ventilation, and daylighting to reduce dependence on artificial systems. Efficient building envelopes, including insulation and high-performance windows, help in reducing heat loss or gain. The integration of energy-efficient systems like LED lighting and advanced HVAC, along with renewable energy sources such as solar panels, further enhances efficiency. Additionally, proper planning and management during construction reduce energy use and waste. Overall, energy efficiency helps lower operational costs, reduce environmental impact, and improve the sustainability of buildings.

**Al Azari et al [24]**
The journal identifies 44 driving factors influencing sustainable construction adoption. However, while significant research has been conducted on aspects of sustainable construction, most of the previous studies were based on the literature review. Also, very little work has attempted to qualify the CSF's and more studies were achieved towards environmental factors. There are various metrics that are used to measure project performance and delivery. While some measuring units focus on the completed projects, others measure the procedures, practices, strategies and actions that occurred across the project supply chain. The procedures, practices, strategies and actions are the CFs (16,17,32].

**Abdul-Aziz et al 1331**, migrant construction workers are frequently subjected to harsh treatment by their employers, marked by exploitative wages, insecure employment, forced labor, low safety standards, and inadequate living conditions. He developed a project management competency framework for Industrialized Building System (IBS) construction using a mixed-method approach involving literature review and expert validation. The study positions IBS as a key strategy for sustainable construction management by promoting efficient resource utilization, waste minimization, and improved construction quality. It identifies technical, managerial, and behavioral competencies as essential for integrating sustainability principles into project delivery. The findings highlight that effective management of IBS processes enhances environmental performance, optimizes resource efficiency, and supports long-term economic and social sustainability. The research underscores the critical role of skilled professionals and structured management systems in successfully implementing sustainable construction practices.

**O.Z.ONI et al [24][25]**
Oni et al. (2025) employed a quantitative research approach using a structured questionnaire survey of 158 construction professionals, analysed through fuzzy synthetic evaluation. The study identified environmental, economic, and social dimensions as key pillars of sustainable construction management. Findings revealed that factors such as eco-friendly materials, waste management, financial investment in safety, and stakeholder engagement significantly influence sustainable health and safety practices. The research concludes that integrating safety within sustainability frameworks enhances project performance, reduces risks, and supports long-term industry resilience.

**Selamawit Mamo Fufa et al**, **Cecilie Flyen et al**, and **Anne-Cathrine Flyen et al [21]**
The journal examines the role of existing and historic buildings in achieving emission reduction targets using a lifecycle-based approach combining literature review and case study analysis. The study finds that refurbishment and adaptive reuse significantly reduce greenhouse gas emissions by extending building lifespan and minimizing material consumption. It highlights the importance of energy-efficient

retrofitting and lifecycle assessment in sustainable construction management, while also emphasizing the socio-cultural value of heritage buildings. The research concludes that integrating refurbishment strategies into construction management practices is essential for achieving long-term sustainability and carbon reduction goals.

## 3. DISCUSSION

The review of literature on sustainable construction management reveals that integrating sustainability principles across materials, construction techniques, energy efficiency, and lifecycle cost significantly improves environmental, economic, and social outcomes in the construction industry.

### 3.1 Sustainable Materials Performance

The analysis shows that alternative and waste-based materials such as bamboo, recycled aggregates, fly ash, waste plastic, and glass demonstrate strong potential in reducing environmental impact while maintaining structural integrity.

- Studies confirm that partial replacement of conventional materials (cement, sand, aggregates) with industrial by-products reduces carbon emissions and resource depletion.
- Materials like bamboo and bio-based composites exhibit high strength, renewability, and adaptability, making them suitable for sustainable structural applications.
- Waste-derived materials (plastic, glass, bottom ash) improve durability, crack resistance, and cost efficiency when used optimally.

Overall, the results indicate that material innovation is a key driver of sustainability, though performance optimization and standardization remain necessary.

### 3.2 Effectiveness of Sustainable Construction Techniques

The findings highlight that adopting modern construction techniques significantly enhances sustainability outcomes:

- Prefabrication and modular construction reduce on-site waste, construction time, and energy consumption.
- Recycling and reuse strategies minimize landfill burden and promote circular economy practices.
- Integration of traditional knowledge with modern technology improves climate responsiveness and local adaptability.

However, implementation challenges such as lack of regulations, weak enforcement, and limited technical awareness—especially in developing regions—limit widespread adoption.

### 3.3 Energy Efficiency and Building Performance

Energy efficiency emerges as a critical component in sustainable construction management:

- Passive design strategies such as natural ventilation, daylighting, and building orientation significantly reduce operational energy demand.
- Advanced systems like energy-efficient HVAC, LED lighting, and renewable energy integration (solar, wind) enhance building performance.
- Lifecycle studies confirm that operational energy and embodied carbon are the major contributors to environmental impact.

The results emphasize that combining design strategies with technology can substantially lower long-term energy consumption and emissions.

### 3.4 Lifecycle Cost and Economic Feasibility

The review indicates that while sustainable construction may involve higher initial costs, it offers significant long-term economic benefits:

- Reduced maintenance, operational, and energy costs improve lifecycle cost efficiency.
- Use of recycled and locally available materials lowers material and transportation costs.
- Sustainable practices enhance building lifespan and asset value.

Despite these advantages, financial constraints and lack of incentives remain major barriers to adoption.

### 3.5 Integration of Circular Economy Principles

A key outcome across multiple studies is the importance of transitioning toward a circular construction model:

- Emphasis on reuse, recycling, and design for deconstruction improves resource efficiency.
- Waste materials are effectively reintegrated into construction cycles, reducing environmental burden.
- Nature-based and ecosystem-integrated solutions enhance urban resilience and sustainability.

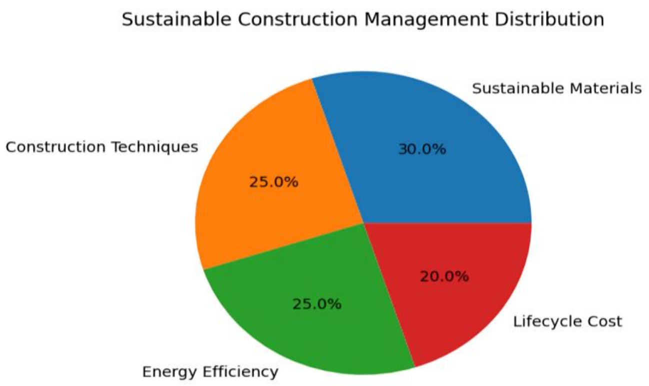
### 3.6 Challenges and Research Gaps

The discussion also identifies several limitations:

- Lack of skilled professionals and training in sustainable practices
- Regulatory and policy gaps in enforcing green construction
- Public resistance and low awareness
- Insufficient long-term performance data for alternative materials

These gaps indicate the need for stronger policy support, education, and technological advancement.

### A PIE CHART BASED ON SUSTAINABLE CONSTRUCTION MANAGEMENT




Sustainable Materials – 30%
Construction Techniques – 25%
Energy Efficiency – 25%
Lifecycle Cost – 20%

## CONCLUSION

Sustainable construction management is essential for addressing environmental, economic, and social challenges in the construction industry by reducing impacts across a project's lifecycle. The findings highlight that using sustainable materials lowers carbon emissions, conserves resources, and improves waste utilization, while efficient methods like prefabrication and recycling enhance productivity and minimize waste. Energy efficiency through passive design and renewable systems further reduces environmental impact. Although initial costs are high, long-term savings in operation and maintenance make it economically viable. Adopting a circular economy approach supports material reuse and sustainability. However, challenges such as high costs, lack of expertise, weak policies, and limited awareness hinder its implementation, requiring stronger regulations, better training, and technological advancement.

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