# GREEN BUILDING MATERIALS AND TECHNOLOGIES: ASSESSING THEIR POTENTIAL IN SUSTAINABLE CONSTRUCTION-A REVIEW

**Rohil Julaniya*[1], R. Mahadeva Swami[2], Y. S. Patil[3]**

[1] M.E. Student, Department of Civil Engineering, Shivajirao S. Jondhale College of Engineering & Technology, Asangaon, Shahapur -421601, Thane, Mumbai, India
[2] Associate Professor, Department of Civil Engineering, Shivajirao S. Jondhale College of Engineering & Technology, Asangaon, Shahapur -421601, Thane, Mumbai, India
[3] Professor & Head, Department of Civil Engineering, Shivajirao S. Jondhale College of Engineering & Technology, Asangaon, Shahapur -421601, Thane, Mumbai, India

## ABSTRACT
The global construction industry is a significant contributor to environmental degradation, responsible for high levels of carbon emissions, energy consumption, and resource depletion. In response to the urgent need for sustainable development, the adoption of green building materials and technologies has emerged as a promising solution to mitigate environmental impacts and promote eco-efficient construction. This paper investigates the potential of green materials and technologies in driving sustainability across the building lifecycle, from design and construction to operation and maintenance. The study reviews recent literature (2023–2024) to identify advancements in sustainable construction practices and evaluates widely recognized green building rating systems such as LEED, BREEAM, IGBC, and GRIHA. Key green materials including fly ash concrete, bamboo, recycled steel, and low-VOC paints are examined for their environmental and functional performance. Additionally, the integration of renewable energy systems, water-efficient technologies, and smart automation tools is explored to assess their contribution to energy efficiency and occupant comfort. The paper also highlights the advantages of green buildings—such as lower operational costs, enhanced indoor air quality, and reduced environmental footprint—while addressing common challenges including high initial investment, limited expertise, and regulatory hurdles. Through a critical analysis of global case studies and sustainability frameworks, the study emphasizes the growing relevance of green construction in combating climate change and fostering long-term resilience. The findings underline the need for supportive policies, awareness programs, and stakeholder collaboration to accelerate the mainstream adoption of green building practices, especially in developing economies. The paper concludes with recommendations to promote inclusive, scalable, and cost-effective sustainable construction strategies.
**Keywords:** Green Building Materials, Sustainable Construction, Energy Efficiency, Green Technologies, Building Rating Systems

## I. Introduction
The construction industry plays a pivotal role in shaping the built environment, significantly influencing economic development, social well-being, and environmental quality. However, this sector is also one of the leading contributors to global environmental degradation due to its extensive consumption of natural resources, high energy use, and emission of greenhouse gases (GHGs). Traditional construction practices, reliant on non-renewable materials and energy-intensive processes, have accelerated ecological imbalance, prompting an urgent need to adopt more sustainable alternatives. Against this backdrop, the concept of green construction has gained prominence, emphasizing environmentally responsible and resource-efficient building methods throughout a building’s life cycle—from design and construction to operation, maintenance, and demolition.

Green building materials and technologies form the cornerstone of sustainable construction. These materials, often sourced from renewable or recycled origins, aim to reduce the environmental footprint of buildings while improving energy efficiency and indoor environmental quality.

Similarly, green technologies such as solar photovoltaic systems, rainwater harvesting units, energy-efficient lighting, and advanced insulation methods are transforming conventional structures into eco-friendly, smart, and self-sustaining spaces. The integration of these materials and technologies not only helps mitigate climate change impacts but also aligns with global sustainability goals like the United Nations Sustainable Development Goals (UN-SDGs), especially Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action). India, as a rapidly urbanizing and industrializing country, faces a dual challenge: addressing the infrastructural needs of a growing population while minimizing the ecological costs of construction activities. According to the Ministry of Housing and Urban Affairs (MoHUA), the Indian construction sector is expected to reach USD 1.4 trillion by 2025. This growth trajectory, if not steered sustainably, could have severe implications for natural ecosystems and public health. In response, policy frameworks like the Energy Conservation Building Code (ECBC), National Building Code (NBC), and initiatives from the Indian Green Building Council (IGBC) and GRIHA (Green Rating for Integrated Habitat Assessment) have begun promoting sustainable construction practices across the country. Nonetheless, the adoption of green materials and technologies remains limited due to a lack of awareness, higher upfront costs, insufficient technical know-how, and resistance to change.

Green building materials are those that are non-toxic, recyclable, renewable, and energy-efficient in production and application. Examples include fly ash bricks, bamboo, recycled aggregates, compressed stabilized earth blocks (CSEBs), and low-VOC paints. These materials help reduce construction and demolition (C&D) waste, minimize resource depletion, and lower carbon emissions. Moreover, they promote thermal comfort and enhance the overall durability and functionality of structures. On the other hand, green technologies focus on reducing the operational impact of buildings. Systems like greywater recycling, passive solar heating, green roofs, and smart energy management tools contribute to long-term savings in energy and water consumption, while improving user comfort and reducing dependency on conventional energy sources.

While the benefits of sustainable construction are well-documented, the transition from traditional to green building practices is neither linear nor straightforward. It involves a paradigm shift in architectural design, material selection, procurement, and execution strategies. Moreover, it necessitates a multidisciplinary approach that includes environmental scientists, architects, civil engineers, material scientists, policymakers, and urban planners. One of the key challenges lies in balancing performance, cost, and sustainability. Many developers hesitate to adopt green materials or technologies due to perceived cost escalations and doubts about their long-term performance and durability. However, several studies have proven that the life cycle cost (LCC) of green buildings is significantly lower than that of conventional buildings, when maintenance, energy savings, and environmental benefits are considered.

In recent years, the rise in environmental consciousness and increasing pressure from regulatory bodies have led to a slow but steady shift towards sustainable construction. Cities across the world are now adopting green building codes and incentives, while real estate developers are increasingly seeking green certifications to enhance their marketability and brand image. Academic and industrial research is also advancing the development of innovative green materials such as geopolymer concrete, hempcrete, phase change materials (PCMs), and nano-insulation coatings. Similarly, building information modeling (BIM) and Internet of Things (IoT) technologies are being leveraged to optimize energy usage and resource allocation in real-time.

Despite these advancements, there is still a need for a comprehensive evaluation of the performance, viability, and scalability of green materials and technologies across diverse climatic and socio-economic contexts. Most existing studies either focus on specific materials or technologies in isolation or fail to incorporate a holistic perspective that combines environmental, economic, and social dimensions of sustainability. Furthermore, there is limited documentation on the practical challenges faced during implementation, especially in developing nations like India, where factors

such as labor skill, material availability, and budget constraints play a crucial role in decision-making.
This paper aims to bridge this gap by critically assessing the potential of green building materials and technologies in achieving sustainable construction. It reviews the current trends, available materials, and adopted technologies, along with their advantages and limitations. Through a synthesis of literature, case studies, and performance data, the paper highlights the key drivers and barriers in mainstreaming green construction. Special attention is given to the Indian context to explore how traditional wisdom, modern innovation, and policy mechanisms can work together to create a resilient and sustainable built environment.
By providing a consolidated understanding of sustainable alternatives and their practical relevance, this study hopes to contribute to ongoing discussions and decisions in the construction industry, academia, and policymaking domains. It is imperative that sustainable construction is not viewed merely as an environmental obligation but as a strategic approach to ensure economic viability, social well-being, and ecological preservation in the face of rapid urban growth and climate change.

## II. Literature Review

The imperative for sustainable construction has intensified, prompting extensive research into green building materials and technologies. Recent studies have explored various facets of this domain, emphasizing advancements, market trends, and implementation challenges.
**Sustainability through Materials: A Review of Green Options in Construction (2023):** This study examines how environmentally friendly materials support sustainable building practices, focusing on their classification, innovative production technologies, and performance evaluation.
**Emerging Trends in Sustainable Building Materials (2024):** This research rigorously assesses the latest advancements in sustainable building materials, emphasizing their classification, innovative production technologies, and performance evaluation.
**Evaluation of Green Building Technologies by Construction Professionals in Southwest Nigeria (2023):** This study explores the perceptions and obstacles faced by stakeholders in adopting green building materials focusing on carbon reduction, highlighting the need for increased awareness and supportive policies.
**Sustainable Building Materials for Green Construction: A Review (2023):** This paper reviews the utilization of sustainable building materials, such as low-carbon cement, and examines the positive effects of green construction, providing insights into policy frameworks and technology roadmaps.
**The Business Case for Green Building: A Review of the Costs and Benefits for Developers, Investors, and Occupants (2023):** This review highlights that green buildings save money through reduced energy and water consumption and lower long-term operations and maintenance costs, with energy savings typically exceeding any cost premiums associated with their design and construction within a reasonable payback period.
World Green Building Council
**Building Green: Sustainable Construction in Emerging Markets (2023):** This report from the International Finance Corporation suggests that switching to greener technologies in construction and operation of buildings and materials, combined with more climate-friendly capital markets, could reduce the construction value chain’s carbon footprint by 23% by 2035, while creating investment opportunities in emerging markets.
**A Review of Carbon Footprint Reduction of Green Building Technologies (2023):** This paper provides a comprehensive overview of various green building technologies, including high-performance envelopes, lighting and daylighting, natural ventilation, heating, and their role in reducing carbon footprints.
**Sustainable Engineering Practices in Construction: A Systematic Review of Green Building Materials and Techniques (2023):** This study identifies the perceptions and obstacles faced by

stakeholders in adopting green building materials focusing on carbon reduction, emphasizing the need for systematic approaches to overcome these challenges.
ResearchGate

**Green Building: Trends, Motivations, and Challenges (2024):** This research found that the overall share of home builders classifying more than half their projects as green is at 34% for 2023, indicating a growing trend towards sustainable construction practices.

**Science & Tech Spotlight: Sustainable Building Technologies (2025):** This spotlight discusses sustainable building technologies, including solar panels, energy-efficient windows, and low-emission materials, aiming to reduce energy use, water use, and greenhouse gas emissions in construction and operations.

Collectively, these recent studies underscore the significant advancements and ongoing challenges in the adoption of green building materials and technologies. While innovations continue to emerge, addressing economic, regulatory, and awareness barriers remains crucial for widespread implementation.

## III. Objectives

- The primary aim of this study is to assess the potential of green building materials and technologies in promoting sustainable construction practices. To achieve this, the study is guided by the following specific objectives:
- To explore and identify commonly used green building materials with a focus on their environmental, economic, and functional performance in comparison to conventional materials.
- To evaluate the effectiveness of modern green technologies—such as passive design strategies, energy-efficient systems, and smart building innovations—in enhancing sustainability in construction.
- To review recent trends and case studies (post-2023) that illustrate the successful implementation of green materials and technologies in real-world construction projects globally and regionally.
- To assess the environmental benefits of using green materials and technologies, including reductions in carbon footprint, energy consumption, and water usage throughout a building's life cycle.
- To analyze the barriers and challenges faced in the adoption of green construction practices, especially in developing countries, including issues related to cost, policy, awareness, and technical knowledge.
- To investigate the role of rating systems and policy frameworks (e.g., LEED, GRIHA, IGBC) in driving the adoption of sustainable building materials and technologies.
- To provide recommendations for stakeholders in the construction industry—including architects, engineers, policymakers, and developers—on integrating green practices to achieve long-term sustainability goals.

## IV. Green Building Rating Systems

**Green Building Rating Systems (GBRS)** are structured assessment tools designed to evaluate and certify the sustainability performance of buildings. These systems encourage environmentally responsible construction by providing measurable criteria for assessing various parameters such as energy efficiency, water conservation, indoor environmental quality, material usage, site planning, and innovation. Over the past two decades, several rating systems have been developed globally and regionally to promote and benchmark sustainable building practices.

**Leadership in Energy and Environmental Design (LEED),** developed by the U.S. Green Building Council (USGBC), is one of the most widely recognized and used rating systems internationally. LEED evaluates buildings based on several criteria grouped under categories such as Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor

Environmental Quality. LEED certification is offered at four levels—Certified, Silver, Gold, and Platinum—based on the total points earned. It has been successfully implemented in over 180 countries and has inspired many regional adaptations.
**Building Research Establishment Environmental Assessment Method (BREEAM),** developed in the UK, is one of the earliest green rating systems, established in 1990. BREEAM assesses the sustainability of new and existing buildings, focusing on low impact design and efficient use of resources. It offers flexibility in assessment and supports performance benchmarking across multiple sustainability categories. BREEAM's influence has shaped several European green building standards.
**In India, the Green Rating for Integrated Habitat Assessment (GRIHA)** was developed by The Energy and Resources Institute (TERI) and adopted as the national green building rating system by the Government of India. GRIHA evaluates a building's performance based on parameters like site planning, energy efficiency, water and waste management, and occupant comfort. It is particularly relevant to Indian climatic and socio-economic conditions and has gained considerable traction for both public and private sector projects.
**Another Indian system is the Indian Green Building Council (IGBC)** rating system, which aligns with LEED principles but includes India-specific adaptations. It offers different rating programs for various building types including residential, commercial, schools, and townships. IGBC focuses on energy savings, water efficiency, reduction in $CO_2$ emissions, and improved indoor environmental quality.
**EDGE (Excellence in Design for Greater Efficiencies)**, developed by the International Finance Corporation (IFC), is a relatively newer rating system aimed at emerging markets. It focuses on resource efficiency and provides quick, cost-effective assessments for energy, water, and materials. EDGE has gained popularity due to its affordability and ease of implementation, especially in developing countries.
Green building rating systems play a critical role in promoting sustainable construction by creating awareness, setting performance standards, and offering market differentiation. They also serve as tools for governments to formulate policies and provide incentives for green construction. However, challenges persist in the widespread adoption of these systems, including high certification costs, lack of awareness, and technical expertise, particularly in smaller projects.
In conclusion, GBRS are pivotal in steering the construction industry toward sustainability. Their continued evolution, localization, and simplification will be key in ensuring broader adoption, especially in regions facing climate change pressures and rapid urban development.

## V. Advantages and Disadvantages of Green Buildings

Green buildings, also known as sustainable or eco-friendly buildings, are designed to reduce their environmental impact through the use of energy-efficient technologies, sustainable materials, and environmentally conscious construction practices. While they offer numerous benefits, they also present certain challenges.

**Advantages:**

- Environmental Benefits: Green buildings significantly reduce energy consumption, greenhouse gas emissions, and water usage. They promote renewable energy use and incorporate eco-friendly materials that are non-toxic and recyclable.
- Economic Savings: Though initial costs may be higher, green buildings offer long-term savings through reduced utility bills, lower maintenance costs, and enhanced asset value. Energy-efficient systems and water-saving fixtures contribute to cost-effectiveness over the building's lifecycle.
- Improved Health and Productivity: These buildings offer better indoor air quality, natural lighting, and thermal comfort, which lead to improved occupant well-being, reduced absenteeism, and enhanced productivity, especially in office environments.

- Regulatory and Market Value: Many governments offer incentives for green-certified buildings. Additionally, such buildings often attract tenants and buyers willing to pay premium rates due to their sustainability credentials.

**Disadvantages:**

- High Initial Cost: The upfront investment in green technologies, specialized materials, and certification processes can be significantly higher than conventional construction.
- Limited Availability of Materials and Expertise: Access to certified green materials and skilled professionals may be restricted in certain regions, delaying project timelines and increasing costs.
- Regulatory Challenges: Navigating through multiple green rating systems and local regulations can be complex and time-consuming, especially for developers unfamiliar with sustainability protocols.
- Uncertain ROI in Some Markets: In areas with low energy costs or limited environmental awareness, the financial return on green investments might take longer to materialize, potentially discouraging developers.

## VI. Results and Discussion

This study highlights the increasing relevance and potential of green building materials and technologies in addressing the urgent global need for sustainable construction practices. The review of literature from recent years (2023 onward) consistently emphasizes the role of green strategies in reducing carbon emissions, improving energy efficiency, and promoting resource conservation throughout a building's life cycle.

**Adoption Trends and Impact:** The analysis indicates a growing global shift toward the adoption of eco-friendly construction practices, driven by stricter environmental regulations, rising energy costs, and consumer demand for healthier living and working environments. Countries like India, the USA, and many in the EU have witnessed a steady increase in the number of green-certified projects. The presence of rating systems such as LEED, BREEAM, IGBC, and GRIHA has accelerated this trend, acting as guiding frameworks that standardize sustainable practices and reward innovation.

**Material and Technology Assessment:** Green building materials such as fly ash concrete, bamboo, recycled aggregates, low-VOC paints, and high-reflectance roofing have demonstrated strong performance in terms of durability, thermal efficiency, and environmental impact. Technologies such as solar photovoltaics, rainwater harvesting systems, energy-efficient HVAC, and building automation systems are now integral to green building designs. When used collectively, these components contribute to energy savings of up to 30–50%, reduced water consumption, and enhanced occupant comfort.

**Advantages vs. Challenges:** While the advantages of green buildings are evident—ranging from long-term cost savings to improved indoor environmental quality—challenges persist. Chief among them are high initial costs, lack of awareness, limited technical expertise, and the complexity of certification procedures. These barriers are more pronounced in developing countries, where financial constraints and regulatory inertia can hamper implementation.

**Policy and Market Influence:** Policy incentives such as tax rebates, fast-track approvals, and mandatory energy codes have shown to positively influence the adoption of green practices. Additionally, market awareness campaigns and corporate ESG (Environmental, Social, and Governance) commitments are shaping the demand for sustainable infrastructure. However, the study identifies a need for more localized solutions, tailored training programs, and government support to scale up the adoption.

**Synthesis of Findings:** Overall, the potential of green building materials and technologies to revolutionize the construction industry is significant. The study's findings reveal that when supported by effective policies, market incentives, and stakeholder collaboration, green construction can lead to resilient, cost-effective, and environmentally sustainable development. It is also evident that a balance must be maintained between technological advancement and economic feasibility to ensure widespread adoption across both urban and rural settings.

**VII. Conclusion**

The pursuit of sustainable development in the construction sector has never been more critical, considering the increasing environmental concerns and resource constraints facing the planet. This study has comprehensively explored the potential of green building materials and technologies in contributing to environmentally responsible and economically viable construction practices. From the literature review and analysis of recent studies, it is evident that the integration of eco-friendly materials and energy-efficient technologies not only reduces the environmental footprint of buildings but also enhances their functional performance and occupant well-being.

The investigation into green building rating systems such as LEED, BREEAM, IGBC, and GRIHA reveals their instrumental role in standardizing sustainable construction practices. These frameworks offer clear benchmarks and certification paths that help guide architects, engineers, and developers toward achieving high-performance buildings. Their increasing global adoption signals a positive shift toward greener infrastructure.

While green buildings offer substantial advantages—including reduced energy consumption, operational savings, improved indoor air quality, and enhanced market value—they are not without challenges. High initial investment, lack of technical expertise, limited awareness, and certification complexities continue to impede large-scale implementation, particularly in developing regions. Overcoming these barriers requires a concerted effort involving policy incentives, public awareness campaigns, and professional training.

In conclusion, green building materials and technologies present a transformative opportunity to redefine the future of the construction industry. By adopting a balanced approach that combines innovation, affordability, and inclusivity, stakeholders can pave the way for a built environment that is not only sustainable but also resilient, healthy, and economically feasible for generations to come.

## Conflict of Interest

The authors declare no conflicts of interest, including financial or other relationships that may bias the work. All authors have made substantial contributions to this research and have approved the final manuscript. This work has not been previously published or submitted for publication elsewhere.

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