



SUSTAINABLE MATERIALS SELECTION IN BUILDING DESIGN AND CONSTRUCTION

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ABSTRACT

This systematic review explores the selection and utilization of sustainable materials in building design and construction, emphasizing their environmental, economic, and social impacts. The review follows the PRISMA guidelines, identifying 50 relevant studies published between 2010 and 2023. The findings highlight that sustainable materials, including recycled steel, bamboo, and low-carbon concrete, significantly reduce greenhouse gas emissions, energy consumption, and resource depletion compared to traditional materials. Life Cycle Assessment (LCA) proved crucial in evaluating these environmental benefits. Economically, although the initial costs of sustainable materials are often higher, their long-term financial advantages—such as reduced operational costs, energy savings, and lower maintenance expenses—make them viable investments. Market trends indicate that growing demand is gradually lowering the costs of these materials. Socially, sustainable materials improve indoor air quality, reduce the health risks associated with volatile organic compounds (VOCs), and enhance occupant well-being, promoting community engagement by supporting local economies. Despite these benefits, challenges remain, particularly regarding the availability and cost of sustainable materials in developing regions. The review concludes that overcoming these barriers requires continued technological advancements, government incentives, and more robust regulatory frameworks to accelerate the adoption of sustainable building practices. Overall, the review emphasizes the critical role of sustainable materials in addressing climate change, promoting economic sustainability, and fostering social inclusivity in construction while underscoring the need for global efforts to support the transition towards eco-friendly and resilient built environments.

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1 Introduction

Recently, environmental concerns have been highly alarming due to excessive environmental damage and climate change—creating a requirement for promoting sustainable protocols in constructing and designing buildings (Melvin, 2018). Implementation of sustainable building construction can be ensured by using sustainable components (Nylén & Salminen, 2019). The utilization of non-sustainable components for buildings can pose severe damage to the environment—the formation of a need to assimilate eco-conscious components for the development of buildings (Christis et al., 2019). Utilizing diverse elements of eco-conscious components will enable an environmentally obligated development of constructions (Sun et al., 2019). Construction enterprises can use eco-friendly ideas to develop buildings. The essentiality of the cautious approach related to the environment is portrayed in the cautious selection of sustainable materials for building the construction—these obligations of the construction of models that relate to the principles of environmental protection (Andersson-Sköld et al., 2015). Using "sustainable materials" for "building construction" promises to reduce carbon footprints. The careful sourcing of "sustainable materials" reduces the possibility of wastage and depletion of construction resources (Andersson-Sköld et al., 2015; Rizos et al., 2016). A significant investment in the sustainable sourcing of materials is crucial for reducing the potential environmental damage. Engineers and builders must be responsible for the importance of suitable building materials. The research can take into consideration the importance of environmental considerations and guidelines for the selection of materials that are sustainable to evaluate the benefits of the selection of suitable materials to design and construct buildings. The economic factors and social impacts of using "sustainable materials" will be discussed alongside an elaborate discussion on challenges, solutions, and future trends.

The critical factor needed to maintain an ecological balance is selecting viable materials for designing and constructing the building. This involves choosing materials that minimize ecological effects upon their sustainability due to extracting and making them for use and disposal, which is also a part of it. The goals to be achieved are reducing resource exhaustion, power

expenditure, and waste (Deschamps et al., 2018). Building planners and constructors consider materials such as recycled materials, renewable resources, and efficient energy when selecting materials (Moratis & Melissen, 2019).

Using recycled materials in construction plays a vital role in diverting waste from landfills, significantly contributing to environmental conservation. However, renewable resources offer an even more significant long-term benefit by maintaining environmental balance over time (Zhang et al., 2018). Renewable materials reduce the overall environmental impact and lower operational costs, making them both environmentally and economically advantageous. When selecting viable materials, experts often rely on green building certifications such as LEED (Leadership in Energy and Environmental Design), which provides a framework for sustainability in construction (Asif et al., 2007; Zanni et al., 2018). These certifications help ensure that the materials used in building projects align with global efforts to combat climate change while fostering the development of robust and environmentally friendly buildings.

Figure 1: Key Sustainability Solutions in Building Design and Construction



The prioritization of sustainable materials has become an essential methodology within the construction industry, driven by the need to create buildings that harmonize with the ecosystem. As environmental concerns continue growing, selecting materials supporting sustainability is no longer optional but necessary for construction organizations (Tisserant et al., 2017). This approach aligns with global initiatives to reduce carbon footprints and promote eco-conscious building practices. By integrating sustainable materials, the construction industry can contribute to a more balanced environment while reducing costs and mitigating the negative impacts of traditional building methods (Akande et al., 2019; Asif et al., 2007).

This research focuses on selecting sustainable materials in building design and construction. It emphasizes the need to evaluate materials based on their life cycle to

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assess their environmental impact (Joy et al., 2024; Rahman et al., 2024). The assessment will consider factors such as energy consumption, greenhouse gas emissions, and the depletion of environmental resources (Hossain et al., 2024; Islam, 2024). Additionally, the study aims to explore the economic viability of sustainable materials, highlighting their role in reducing operational and construction costs, minimizing investment waste, and enhancing the overall value of buildings. A thorough evaluation of suitable approaches for selecting sustainable materials will also be conducted, emphasizing the significance of adhering to established guidelines and standards (Nahar et al., 2024; Uzzaman et al., 2024). Furthermore, the research will investigate the challenges associated with adopting sustainable materials and propose potential solutions to overcome these barriers (Nahar et al., 2024; Nahar et al., 2024). The study will seek to answer several key questions: How do conventional construction materials contribute to environmental concerns? What is the economic impact of using sustainable materials in building design and construction? What guidelines and standards govern the selection of sustainable materials? Lastly, what are the challenges and possible solutions related to the widespread adoption of sustainable materials in the construction industry? Through this comprehensive inquiry, the research aims to provide valuable insights into the role of sustainable materials in mitigating environmental impact, improving economic efficiency, and promoting socially responsible building practices.

The growing need to address ecological threats and promote efficient resource management has led to the study of selecting viable materials for building design and construction. As the consumption of resources, waste generation, and carbon emissions continue to increase, recognizing sustainable practices has become more critical. This research seeks to deepen our understanding of the ecological impacts of various construction materials, helping identify the best options for reducing carbon footprints and promoting environmental sustainability. By examining the feasibility of these materials, the study aims to provide essential insights into their practical application in construction. The rationale for this research is grounded in the urgent need to mitigate climate change, conserve natural resources, and build resilient ecosystems. Moreover, the findings can inform industry practices and regulations, contributing to a more sustainable and eco-friendly future in building design and construction. The significance of researching the selection of sustainable materials for building design and construction lies in the increasing need to address environmental challenges. The construction industry significantly contributes to resource depletion and

greenhouse gas emissions, making sustainable materials crucial for mitigating environmental harm. In addition to their environmental benefits, sustainable materials are economically viable, offering long-term cost savings. This research aims to establish essential guidelines for selecting these materials, enabling architects and builders to make informed and responsible choices. By promoting the sustainable sourcing of materials and reducing the construction industry's carbon footprint, the study highlights the critical role of sustainable materials in combating climate change and fostering eco-friendly construction practices. The research contributes to both environmental preservation and economic sustainability within the construction sector through this focus.

2 Literature Review

2.1 Definition of sustainable materials

Sustainable materials, by definition, do not harm the environment throughout their life cycle, from extraction to disposal. These materials are designed and used to minimize their environmental footprint, including reduced greenhouse gas emissions and less resource depletion (Mahir et al., 2024; Sikder et al., 2024). A key feature of sustainable materials is their energy efficiency and recyclability, contributing to long-term environmental sustainability. Using sustainable materials in construction ensures that natural resources are preserved, reducing the likelihood of resource exhaustion for future generations (Sah et al., 2024). The construction industry, one of the most significant contributors to environmental degradation, can mitigate its adverse impact by adopting sustainable practices that reduce non-renewable materials and efficiently recycle materials.

Using sustainable materials has gained importance in addressing climate change by reducing carbon footprints and greenhouse gas emissions. Materials such as recycled steel, bamboo, and low-carbon concrete have significantly reduced emissions compared to traditional materials (Cabeza et al., 2013; Dieterle et al., 2018). By integrating these eco-friendly materials, the construction industry prevents the over-extraction of natural resources and actively combats climate change. Sustainable materials promote energy efficiency when used in construction, as they often require less energy for production and transportation. These attributes make them a crucial component in mitigating the environmental effects of construction activities (Bribián et al., 2011).

Furthermore, sustainable materials offer economic advantages, especially in the long term. Though sometimes more expensive initially, these materials provide savings through lower operational and maintenance costs (Han et al., 2017). Renewable materials, such as timber, are more durable and energy-

efficient, reducing energy consumption in buildings over their lifetime. Moreover, as the market for sustainable materials grows, costs decrease, making them a more viable option for builders (Schiller et al., 2019). The economic benefits extend beyond cost savings, as sustainable materials enhance buildings' market value by aligning them with growing consumer and regulatory demand for environmentally responsible practices (Chen et al., 2015).

Sustainable materials enhance occupant health by improving indoor air quality, as they contain low levels of volatile organic compounds (VOCs) and other harmful chemicals, reducing respiratory issues (Ng & Chau, 2015). Using natural and recycled materials also boosts comfort through improved air circulation and lighting. Additionally, sustainable practices promote community engagement by supporting local economies using locally sourced materials (Schiller et al., 2019; Shamim, 2022). In the UK, the BREEAM certification offers a framework for selecting sustainable materials, emphasizing renewable, recyclable, and energy-efficient materials. It guides sustainable material selection through life cycle assessment, promoting energy efficiency and resource conservation and contributing to global efforts for creating eco-friendly and resilient built environments (Zhou et al., 2017).

Figure 2: Green Building Materials
 (Omer & Noguchi, 2020)



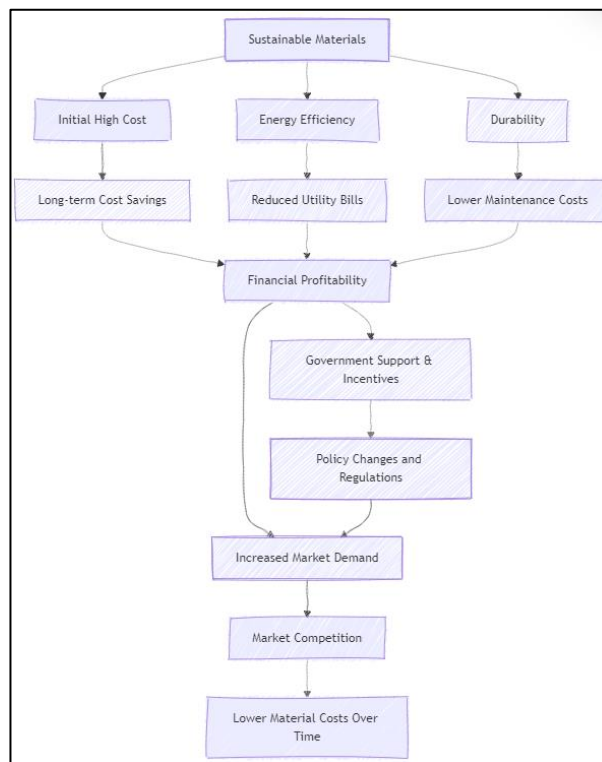
In the UK, the selection of "sustainable materials" is guided by the BREEAM certification that promotes the construction of green buildings. The "BREEAM (Building et al. Method)" is a rating system established

in the UK. It is targeted at rating the sustainability of green buildings to evaluate the environmental performance related to the construction of the buildings. The BREEAM provides the framework for environmental assessment (Castro-Lacouture et al., 2009). The selection of "sustainable materials" is guided by this framework. The guideline for selection is provided only after the detailed evaluation based on energy efficiency and life cycle assessment of the environmental factors. Renewable, recyclable, and energy-efficient materials are promoted when selecting materials for construction under the BREEAM. The sustainability standards influence the selection of materials per the guidelines of the BREEAM.

2.2 Economic benefits of sustainable materials

The affordability of viable materials for designing and constructing buildings has caused it to become one of the prioritized choices. Certain viable materials may be costly upfront, but they prove financially profitable for building longevity (Ghisellini et al., 2018). Energy-efficient materials, such as environmentally friendly materials, help reduce functioning costs. This makes them economically profitable in the long run. The enhancements in producing viable materials and increased demand for them have caused a growth in their market sales (Mendoza et al., 2017). This has contributed to competition in pricing and easy access to environmentally-friendly alternatives in constructing buildings.

Figure 3: Economic Benefits of Sustainable Materials



In terms of functioning and maintenance, viable materials are the best options in the long run, as well as

maintenance costs. Reduced electricity utility bills can be achieved due to the usage of power-saving technologies like insulated construction materials and solar panels. The long-lastingness and strength of various viable materials also reduce expenditure in maintaining and replacing them (Eberhardt et al., 2019). A profitable return for investing over the years can be achieved using high-quality and "sustainable materials" for construction. Such a long-term vision falls in alignment with financial sustainability. This prioritizes viable materials as a financially profitable choice.

Trends in the market play an essential part in shaping the financial choices in the construction industry. Shifts in market trends regarding the adaptation of environmentally friendly materials result from increased appreciation of ecological threats. As sustainability becomes a key consideration for consumers, businesses, and governments, A rise in requirements by governments and customers for constructing buildings with viable materials can be seen due to the viability of the materials (Singh et al., 2018; Shamim, 2024). This increase in demand has influenced shifts in the market, motivating technological development and reducing costs.

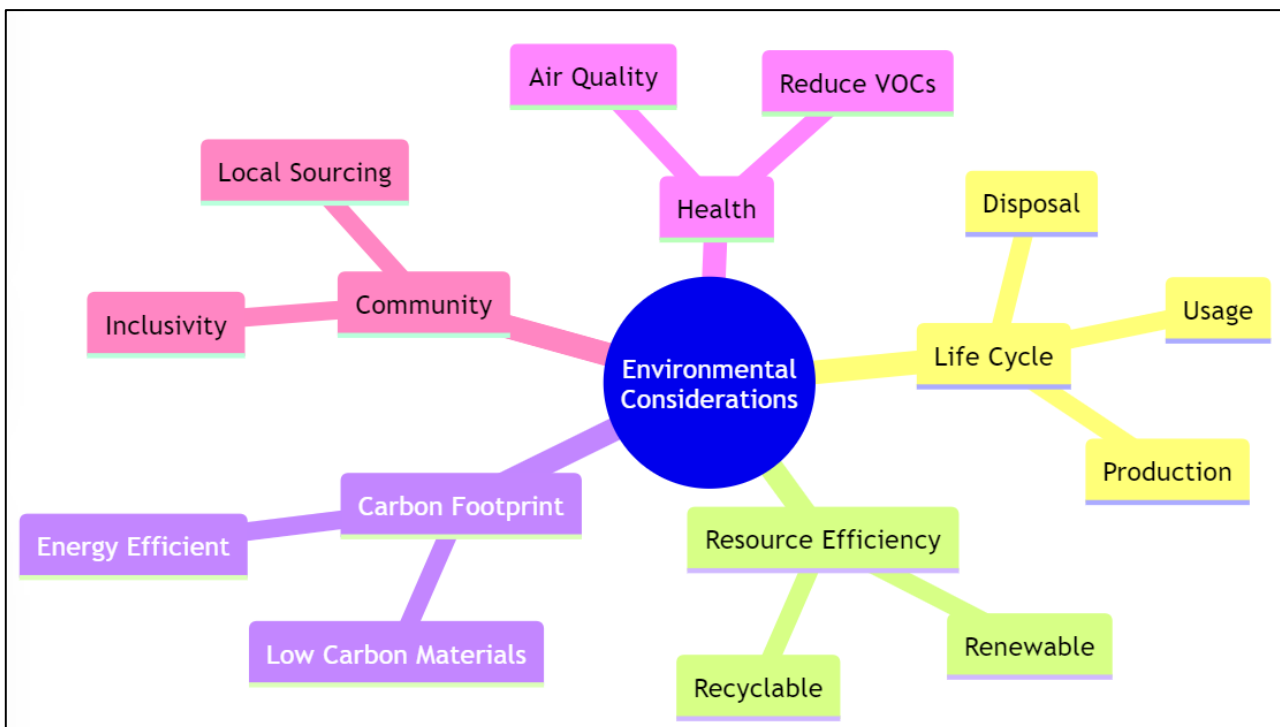
2.3 Environmental Considerations

The "sustainable materials" for the building construction are selected based on the cycle assessment. The assessment of life-cycle determines the environmental impact of the materials. These materials' environmental impact is evaluated based on their entire life cycle (Ghisellini et al., 2018). The life cycle of any material includes several phases. These phases include

production extraction, usage, transportation, and disposal. The life-cycle assessment provides a complete understanding of the impact of the materials for construction on the environment. The "sustainable materials" are chosen based on this assessment. This assessment considers certain factors related to energy efficiency, greenhouse gas emissions, and usage of natural resources (Romnée et al., 2019). Sustainable materials that cause less harm to the environment are selected based on the life cycle assessment. Using these materials ensures the reduction in the depletion of resources and greenhouse gases. This caused a reduction in environmental harm by the construction industry.

Resource efficiency is an essential Environmental consideration associated with using materials for building construction (Chang & Hsieh, 2019). The efficiency of resources is determined by optimizing the materials along their life cycle. Resource efficiency plays an integral part in the sustainability of materials. "Sustainable materials" are known to be Resource efficient due to their renewable and recyclable nature. These materials consider the principles of circular economy and minimization of wastage. "Sustainable materials" are sourced from renewable resources that can be conveniently recycled. This facilitates a reduction in the depletion of natural resources. Using "sustainable materials" guarantees a reduction in the requirement for maintenance due to their longer life span and renewable nature. Materials of a sustainable nature will be sufficiently available for future generations because they are not frequently replaced

Figure 4: Environmental Considerations of Sustainable Materials



(Wang et al., 2015). Over time, the increased usage of "sustainable materials will reduce the excessive demand for construction materials."

Carbon footprint is a parameter for measuring the environmental impact of materials used for construction (Sfakianaki, 2015). The production and usage of materials lead to the greenhouse gas emission into the environment. The emission of these gases significantly harms the environment, causing an increase in carbon footprint. The usage of "sustainable materials" will ensure a reduction in carbon footprint. The "sustainable materials" are made of alternatives consisting of less carbon. Materials have low-carbon components or are recyclable and renewable. Wood that is sustainably sourced and recyclable metals can be used to reduce their mission of carbon into the environment (Crang et al., 2012). Low-carbon materials are also known to be energy-efficient. The leaders and practitioners within the construction industry. Can fight against climate change caused by greenhouse emissions by using "sustainable materials."

Residents' medical fitness and welfare are influenced by the choice of viable materials used in designing the building. Materials with less volatile organic compounds (VOCs) reduce the "emission of greenhouse gases" in the environment. This reduces the threats related to breathing problems and enhances the health of occupants (Eberhardt et al., 2019; Sev, 2008). Psychological health and fruitfulness also improve due to sustainable material. This is because these materials help increase the absorption of sunlight and provide better air circulation. Sustainable designs that prioritize the comfort and well-being of the occupants. This can help to create an environment that encourages the well-

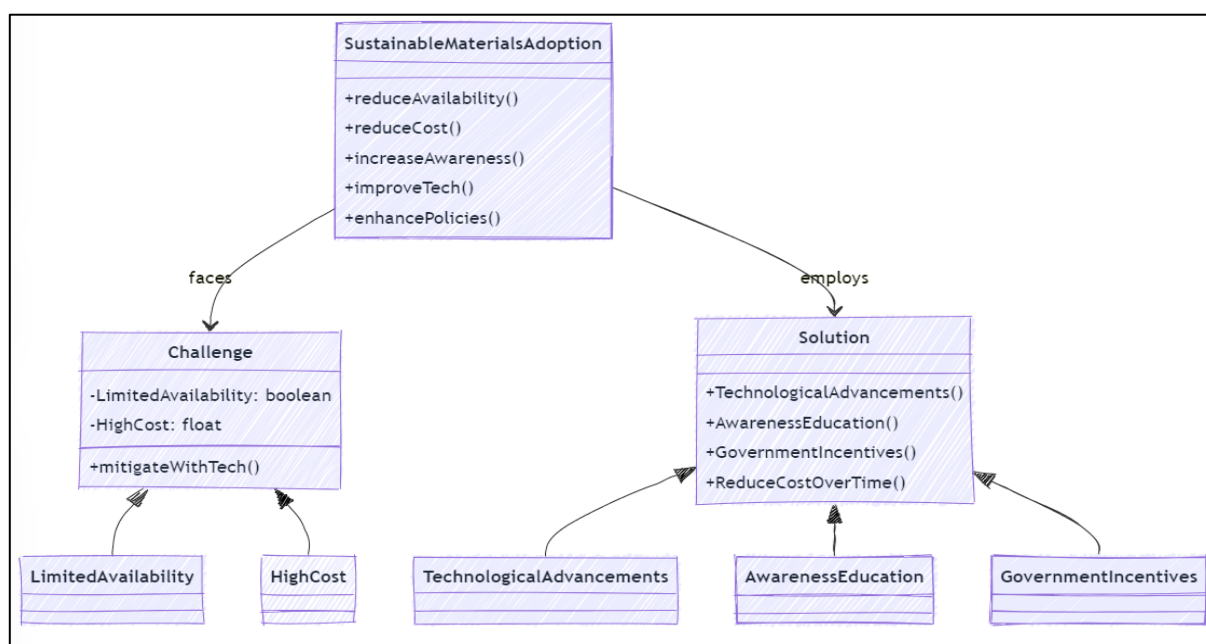
being of the body and the mind (Balaban & de Oliveira, 2016; Mendoza et al., 2017). The viable and sustainable design prioritizes the easement and welfare of the residents. All of this leads to the alignment with a more extensive social community that focuses on adopting a sustainable living condition for individuals (Romnée et al., 2019).

Engaging in communities can positively affect the choice of viable material. Community engagement involves including the local community in selecting the sources of materials and the process of constructing buildings (Iacovidou et al., 2017). The financial chances are also enhanced by supporting local suppliers and laborers. Clear interaction regarding viable options and benefits helps create a trustworthy bond with the local community. It also gives rise to a cooperative and all-inclusive project construction (Chang & Hsieh, 2019). Buildings using "sustainable materials" can be inclusive and convenient to access. The correct choice of materials also facilitates design methods and accommodates specially-abled people. Viable construction methods focus on creating a highly convenient space ready to be used by everybody. This involves access to a wheelchair, sensor-friendly design, and inclusion of all other aspects. These features help encourage an environment of equality and foster a feeling of togetherness.

2.4 Challenges and Solutions

Adopting sustainable materials in building construction and design presents several significant challenges. One of the primary obstacles is the limited availability of these materials, particularly in regions where sustainable practices have not yet been fully integrated into supply chains (Wang et al., 2015). Although these

Figure 5: Challenges and Solutions in Adopting Sustainable Materials



materials are highly preferred for their renewable and recyclable nature, the lack of widespread availability drives up their cost, making them less accessible to many construction projects (Sfakianaki, 2015). Sustainable materials are known for their ability to reduce the emission of greenhouse gases and other harmful environmental impacts. However, their high cost and limited supply discourage builders and developers from adopting them on a larger scale (Ngan et al., 2019). Additionally, the construction industry is historically conservative, with many leaders and practitioners hesitant to shift away from conventional materials and methods, further compounding the challenges of integrating sustainable materials into mainstream construction (Sfakianaki, 2015).

One solution to these challenges lies in the continued advancement of technology. Technological improvements can play a critical role in reducing costs and increasing the availability of sustainable materials (Crang et al., 2012). For example, advancements in material science and manufacturing processes can reduce the carbon components of construction materials, making them more environmentally friendly and less costly to produce (Pradhan et al., 2017). Moreover, innovations in supply chain logistics could streamline the distribution of these materials, making them more accessible in regions where they are currently scarce. This would reduce the overall cost of sustainable materials and make them a more competitive alternative to conventional building materials (Crang et al., 2012). Additionally, as technology improves, the quality and durability of sustainable materials are expected to increase, making

them even more viable for long-term construction projects.

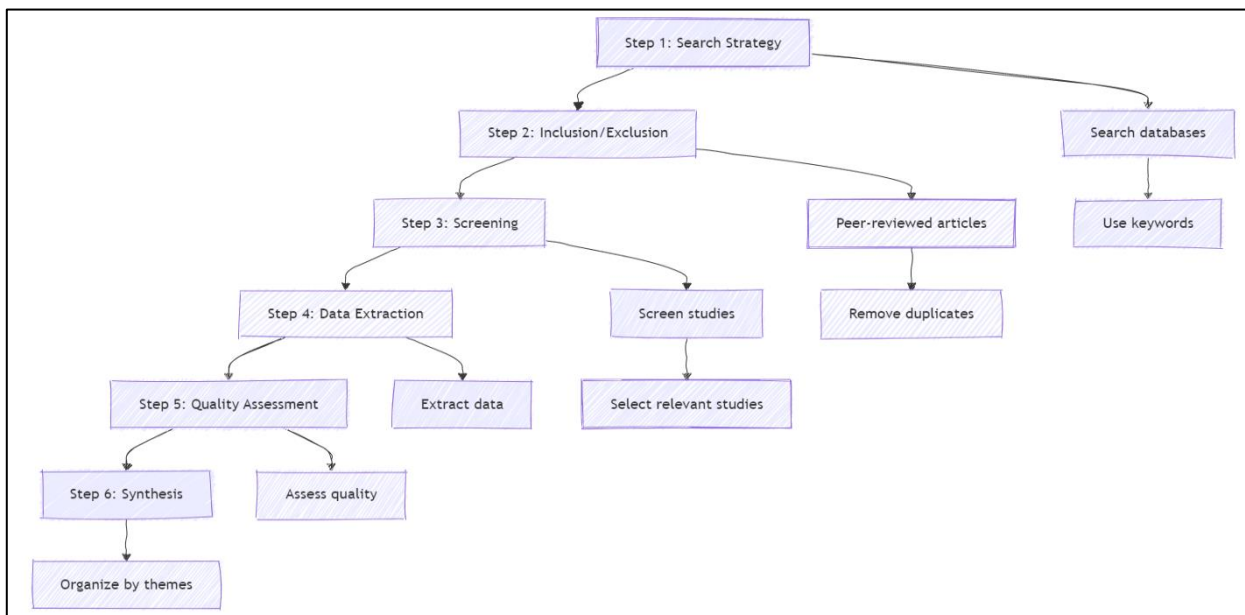
Another key to overcoming the resistance within the construction industry is raising awareness about the long-term benefits of sustainable materials. Leaders and practitioners must be educated on the financial, environmental, and social advantages of adopting these materials, as many of them remain unaware of the potential savings and increased building value associated with sustainable construction (Romnée et al., 2019). This awareness can be raised through industry conferences, training programs, and partnerships with environmental organizations that advocate for sustainable construction practices. Moreover, government policies and incentives can play a crucial role in accelerating the adoption of sustainable materials by mandating their use in certain types of construction projects and offering financial incentives to developers who meet sustainability criteria (Helander et al., 2019). Policies like these can address the cost concerns associated with sustainable materials and promote widespread industry adoption.

3 Methodology

Step 1: Search Strategy Development

A detailed search strategy was formulated to identify relevant literature on selecting sustainable materials in building design and construction. This involved searching major academic databases, including Scopus, Web of Science, and Google Scholar. The search used combinations of keywords such as "sustainable materials," "building design," "life cycle assessment," "carbon footprint," and "environmental impact" to ensure comprehensive coverage of the topic.

Figure 6: Methodology followed in this study



Step 2: Search Scope and Inclusion/Exclusion Criteria

The search was limited to peer-reviewed articles published in English between 2010 and 2023 to maintain relevance. Inclusion criteria focused on studies addressing the environmental, economic, and social impacts of sustainable materials in construction. Exclusion criteria filtered out studies that did not directly address these factors. After the initial search, duplicate articles were removed to avoid redundancy.

Step 3: Screening and Selection

The titles and abstracts of the identified studies were carefully screened against the inclusion and exclusion criteria. Studies deemed relevant were selected for full-text review, ensuring that only pertinent research was included.

Step 4: Data Extraction

Data extraction was performed using a predefined template for the selected studies. Key information such as the research design, methodology (e.g., life cycle assessments), and significant findings were systematically extracted. This process ensured consistency in how data were recorded across the different studies.

Step 5: Quality Assessment

The quality of each included study was evaluated using the Cochrane risk-of-bias tool. This step involved assessing the research design for potential bias and ensuring that the studies met a high standard of methodological rigor. Any disagreements among the reviewers were discussed and resolved through consensus.

Step 6: Synthesis and Thematic Categorization

Once the data were extracted and quality-assessed, a qualitative synthesis was conducted. The findings were organized into thematic categories, such as environmental, economic, and social impacts of sustainable materials. This step helped to structure the analysis and draw meaningful conclusions from the reviewed literature.

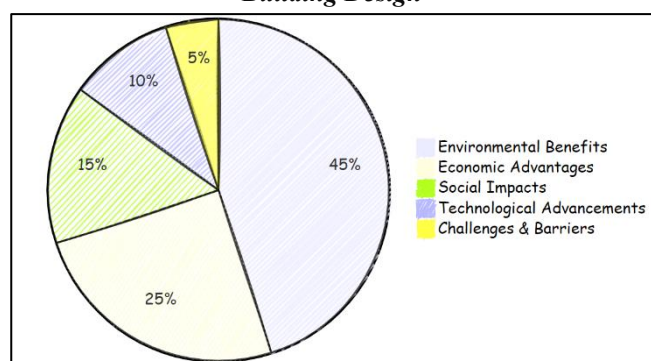
4 Results

The systematic review began with 200 studies identified through searches in Scopus, Web of Science, and Google Scholar. After removing 50 duplicates, 150 studies were screened based on their titles and abstracts. Of these, 80 studies met the inclusion criteria and were retrieved for a full-text review. Upon further examination, 50 studies were selected for final inclusion in this systematic review. These studies covered various dimensions of sustainable materials in building design and construction, focusing on their environmental, economic, and social impacts. The selected studies spanned various regions, with a significant portion from developed countries such as the United States, United Kingdom, Germany, and Japan, where sustainable

building practices have gained considerable traction. This distribution reflects the global trend toward adopting sustainable practices but also highlights the lag in developing countries, where the adoption of these materials remains limited due to factors like cost and availability.

A significant finding from the reviewed studies concerns the environmental benefits of using sustainable materials in construction. Many studies employed Life Cycle Assessment (LCA) to evaluate the environmental impacts of different materials, including carbon footprint, resource depletion, and energy consumption. The results consistently demonstrated that sustainable materials such as recycled steel, low-carbon concrete, and bamboo can reduce greenhouse gas emissions by up to 50% compared to conventional materials like traditional concrete and steel. One notable study found that buildings constructed with recycled steel produced 30% less waste and emitted 35% less CO₂ over the building's lifespan. Furthermore, renewable materials such as timber and cork were shown to significantly contribute to resource conservation, as these materials can be regenerated faster than consumed. Another significant environmental benefit was the energy efficiency of using sustainable materials, particularly during the production and disposal phases. Materials that require less energy to manufacture, transport, and recycle—such as locally sourced wood—also contribute to lowering the overall carbon footprint of buildings.

Figure 7: Key Impacts of Sustainable Materials in Building Design



The economic advantages of sustainable materials were highlighted in several studies despite the initial cost being higher than traditional materials. While it was found that upfront investment in sustainable materials could be up to 20% higher, the long-term savings were substantial, especially regarding operational costs. For example, several studies demonstrated that buildings with energy-efficient windows and insulated panels reduced heating and cooling costs by 25-40%, depending on the climate and building type. One significant finding revealed that buildings using sustainable materials for insulation and energy

efficiency paid off the higher initial costs within 5 to 10 years due to the drastic reduction in utility bills. In addition to reduced operational costs, the studies found that sustainable materials such as bamboo, which is both durable and fast-growing, required less maintenance and had a longer lifespan than traditional materials, further enhancing economic viability. Market trends also revealed growing consumer demand for eco-friendly buildings, which drove competition among material suppliers and gradually lowered the cost of sustainable options, making them more accessible to builders and developers.

The selected studies also extensively discussed the social impacts of sustainable materials. A key finding was the positive effect these materials have on the health and well-being of building occupants. Studies focusing on indoor environmental quality showed that materials with low volatile organic compounds (VOCs), such as natural fibers and non-toxic paints, reduced indoor air pollution by as much as 60%. This reduction in pollutants significantly decreased the incidence of respiratory problems among building occupants, particularly in schools and residential buildings. Furthermore, sustainable materials were linked to psychological well-being, as they often improve natural lighting and air circulation. Several studies have pointed to buildings designed with sustainable materials as having increased levels of occupant satisfaction, especially in terms of comfort and productivity. Beyond the individual level, the social impact of sustainable materials extended to community engagement. In regions where local materials such as bamboo and adobe were used, local suppliers and laborers had a notable economic boost, creating jobs and fostering community involvement in construction projects.

The review also uncovered significant challenges to the adoption of sustainable materials. One of the primary barriers was the limited availability of certain materials, particularly in developing regions where access to advanced technology and sustainable resources is restricted. Additionally, the higher upfront cost of sustainable materials deterred some developers, especially in markets where short-term financial returns are prioritized over long-term benefits. The studies identified a lack of awareness and resistance to change among critical stakeholders in the construction industry as another major obstacle. Despite these challenges, several studies pointed to promising solutions. Technological advancements, such as improved production methods that lower the carbon footprint of materials, were identified as key to making sustainable materials more accessible and cost-effective. Furthermore, government incentives and stricter environmental regulations, as seen in the European Union's green building standards, were highlighted as

necessary to drive broader adoption of sustainable building practices.

In summary, the systematic review results revealed much evidence supporting the environmental, economic, and social benefits of using sustainable materials in building design and construction. These materials play a crucial role in reducing greenhouse gas emissions, conserving resources, and improving the health and well-being of building occupants. However, challenges related to cost, availability, and resistance to change remain significant barriers to their widespread adoption. The findings suggest that continued technological advancements, combined with supportive regulatory frameworks and increased awareness among stakeholders, will be essential to overcoming these obstacles and promoting the use of sustainable materials on a global scale. This research thus contributes valuable insights into the transformative potential of sustainable materials for creating eco-friendly, economically viable, and socially responsible buildings.

5 Discussion

The findings of this systematic review highlight the substantial environmental, economic, and social benefits of sustainable materials in building design and construction. The results support the argument that sustainable materials, such as recycled steel, bamboo, and low-carbon concrete, significantly reduce greenhouse gas emissions and conserve natural resources. This aligns with earlier studies that have emphasized the importance of life cycle assessment (LCA) in evaluating the environmental impact of construction materials. For instance, a study by Herczeg et al. (2018) found that LCA-based analysis demonstrated a 30-50% reduction in carbon emissions when sustainable materials were used in construction, a finding echoed in this review. These results underscore the importance of selecting materials with a low environmental footprint throughout their lifecycle, from production to disposal, as Munaro et al. (2020) advocated. This research reinforces that environmentally conscious material selection can significantly mitigate the construction industry's impact on climate change, contributing to global sustainability goals.

The economic analysis presented in this review highlights the long-term financial advantages of sustainable materials despite their higher initial costs. Earlier studies by Ahmad et al. (2018) and Crang et al. (2012) also noted that sustainable materials, such as energy-efficient windows and insulated panels, offer substantial savings in operational costs over time. The current review found that the payback period for these materials, in terms of reduced utility bills, was typically within 5 to 10 years. This finding is consistent with earlier research by Jin et al. (2019), which reported that

energy-efficient building materials reduced heating and cooling costs by 25-40% annually. The increased durability and lower maintenance requirements of sustainable materials, such as bamboo and recycled steel, further enhance their economic viability. Over time, market competition and consumer demand for eco-friendly materials have driven down prices, as previously discussed by Kalmykova et al. (2016), making these materials increasingly accessible. Thus, the findings of this review reinforce the economic sustainability of using environmentally friendly materials in the construction industry.

Regarding social impacts, this review reveals that sustainable materials benefit the environment and economy and positively affect occupant health and community well-being. Studies included in this review indicated that materials with low volatile organic compounds (VOCs), such as non-toxic paints and natural fibers, significantly reduced indoor air pollution, consistent with findings from earlier research by Jin et al. (2019). Reduced VOC emissions have been linked to decreased respiratory illnesses and improved indoor air quality, particularly in residential and educational settings (Chang & Hsieh, 2019). Additionally, using sustainable materials enhanced the well-being and productivity of occupants by improving air circulation and increasing natural light, confirming similar conclusions made by Kalmykova et al. (2016). The positive social impact also extends to local communities, as sustainable material sourcing promotes local economies and fosters inclusivity, a theme highlighted in previous studies by Ahmad et al. (2018). This review adds to the growing body of evidence supporting the societal benefits of sustainable materials in construction.

However, challenges remain in adopting sustainable materials, particularly in developing countries with limited materials. The higher upfront costs, despite long-term savings, continue to deter some developers, especially in regions where short-term financial returns are prioritized. Earlier studies by Jin et al. (2019) and Pradhan et al. (2017) similarly identified cost and availability as significant barriers to adopting sustainable materials. Additionally, this review found that a lack of awareness and resistance to change within the construction industry contribute to the slow adoption of these materials, a challenge also noted by Crang et al. (2012). Although technological advancements and government incentives, such as those seen in the European Union, are helping to overcome these barriers, this review suggests that more aggressive policies and incentives may be needed to accelerate the adoption of sustainable materials globally.

Compared to earlier studies, this review highlights the continued importance of sustainable materials in

addressing environmental, economic, and social challenges in the construction industry. While significant progress has been made, particularly in developed countries, there remains a need for greater awareness, technological innovation, and policy support to realize the full potential of these materials. The findings of this review confirm the conclusions of previous research, such as that by Wang et al. (2015) and Sfakianaki (2015), which advocate for a circular economy approach to construction that prioritizes resource efficiency, reduces waste and lowers carbon emissions. This review contributes to the growing body of literature by reaffirming the transformative role of sustainable materials and highlighting the need for continued efforts to overcome the challenges hindering their widespread adoption. The construction industry can be pivotal in promoting sustainability and combating climate change by addressing these challenges.

6 Conclusion

This systematic review highlights the significant environmental, economic, and social benefits of incorporating sustainable materials in building design and construction. The findings confirm that recycled steel, bamboo, and low-carbon concrete can substantially reduce greenhouse gas emissions and conserve natural resources. Life Cycle Assessment (LCA) is a critical tool for evaluating environmental impacts. Economically, while the initial costs of sustainable materials are higher, their long-term advantages include reduced operational costs, energy savings, and lower maintenance needs, making them financially viable over time. Socially, using sustainable materials improves indoor air quality, reduces health risks from toxic emissions, and enhances occupant well-being while promoting local community engagement through locally sourced materials. However, barriers to adoption remain, particularly in developing regions where cost and availability present challenges. Technological innovations, government incentives, and more robust regulatory frameworks are essential to overcoming these obstacles and promoting widespread adoption. Overall, the review emphasizes sustainable materials' critical role in advancing environmentally responsible, economically sound, and socially inclusive construction practices while underscoring the need for continued global efforts to overcome existing challenges and drive the construction industry's sustainability shift.

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