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Sustainable Engineering Practices in Construction: A Systematic Review of Green Building Materials and Techniques

Praktik Rekayasa Berkelanjutan dalam Konstruksi: Tinjauan Sistematis tentang Bahan dan Teknik Bangunan Hijau

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ABSTRACT
The construction industry is one of the largest contributors to global carbon emissions, and efforts to reduce the sector's environmental impact are increasingly urgent. This study aims to identify the perceptions and obstacles faced by stakeholders in adopting green building materials that focus on carbon reduction, using the approach systematic literature review. By analyzing 50 relevant recent studies from various geographic contexts, this research finds that perceptions of negative related costs, technical obstacles, and lack of managerial support are significant obstacles in the implementation of green materials. The implications of these findings provide policy and practice recommendations to encourage the adoption of environmentally friendly materials through financial incentives, outreach on the benefits of sustainability, and technical training in the construction industry.
Keywords: Green building materials, carbon reduction, construction industry, adoption barriers, stakeholder perceptions, systematic literature review

ABSTRAK
Industri konstruksi merupakan salah satu kontributor terbesar terhadap emisi karbon global, dan upaya untuk mengurangi dampak lingkungan sektor ini semakin mendesak. Studi ini bertujuan untuk mengidentifikasi persepsi dan kendala yang dihadapi pemangku kepentingan dalam mengadopsi green building materials yang berfokus pada pengurangan karbon, menggunakan pendekatan systematic literature review. Dengan menganalisis 50 studi terkini yang relevan dari berbagai konteks geografis, penelitian ini menemukan bahwa persepsi negatif terkait biaya, kendala teknis, dan kurangnya dukungan manajerial menjadi hambatan signifikan dalam implementasi material hijau. Implikasi dari temuan ini memberikan rekomendasi kebijakan dan praktik untuk mendorong adopsi material ramah lingkungan melalui insentif finansial, sosialisasi manfaat keberlanjutan, dan pelatihan teknis di industri konstruksi.
Kata Kunci: Green building materials, pengurangan karbon, industri konstruksi, kendala adopsi, persepsi pemangku kepentingan, systematic literature review

1. Introduction

The construction industry is facing increasing pressure to improve its sustainability practices, as global awareness of climate change and the urgent need to reduce environmental impact increases. This industry contributes around 39% of total global carbon emissions, mainly from energy consumed during the material production process and construction itself (Tokbolat et al., 2019; Karji et al., 2020). These statistics underscore the importance for the construction sector to adopt more sustainable practices, especially considering international commitments such as the Paris Agreement targeting net-zero carbon emissions (Osuizugbo et al., 2020).

One promising solution to reduce emissions in the construction sector is the adoption of green building materials. This material is specifically designed to be environmentally friendly, energy efficient and supports sustainability throughout the building's life cycle. Examples include low-carbon concrete, wood sourced from sustainably managed forests, and recycled materials (Shurrab et al., 2019). The use of green materials not only helps reduce the carbon

footprint of a building, but also increases energy efficiency, durability and the health of the surrounding environment (Nallathiga et al., 2022). However, despite their recognized benefits, adoption of these green materials has been slow, indicating the existence of various barriers preventing widespread implementation (Darko & Chan, 2016).

Barriers to the adoption of green materials in the construction sector can be categorized into technical and non-technical challenges. Technical challenges often include higher costs of sustainable material options and longer payback periods on investments, which may deter stakeholders from investing in green technologies (Tokbolat et al., 2019; Karji et al., 2020). On the other hand, non-technical barriers include a lack of understanding and awareness of the benefits of sustainability practices among construction professionals, as well as a lack of support and incentives from the government (Marsh et al., 2021). For example, many stakeholders in construction may not prioritize sustainability due to economic pressures or lack of training in environmentally friendly practices (Omopariola et al., 2022). Additionally, customer demand plays an important role; without sufficient pressure from clients for sustainable choices, the momentum of change in the industry may be hampered (Shurrab et al., 2019).

To overcome these obstacles, it is important for the construction industry to prioritize the integration of green materials and practices throughout all projects. This requires changes in attitudes and behavior among construction professionals, as well as policy frameworks that support sustainable practices (Maqbool et al., 2022). Leadership also plays a crucial role in promoting sustainability within organizations, as effective leadership can drive the cultural and operational changes necessary to facilitate the adoption of green building materials (Opoku et al., 2015). Ultimately, achieving sustainability in construction is not only a technical challenge, but also the result of complex interactions between economic, social and environmental factors that require a holistic approach (Soltani et al., 2022; Misopoulos et al., 2019).

The existing literature is still dominated by a technical perspective in discussing green building materials. Many previous studies focused more on technical aspects, such as the physical and chemical characteristics of materials, their effectiveness in reducing carbon emissions, and product life cycle calculations. Although these studies are important for increasing the efficiency of green materials, they pay less attention to human and organizational factors in the adoption process of these materials. In addition, understanding of the social and behavioral factors that are the main obstacles to the application of green building materials is still very limited. Stakeholder perspectives on the costs, technical limitations, and long-term benefits of these materials may vary, influenced by the culture, economics, and availability of technology in each country or region. Subjective constraints, such as stakeholders' attitudes and perceptions of the environmental benefits of green materials versus concerns about additional costs of adopting new technologies, are also rarely explored. Thus, there is a research gap in understanding the social and psychological complexities that influence the adoption of sustainable construction materials.

Based on this research gap, this research will answer the question: "What are the main perceptions and barriers faced by stakeholders in the construction industry in adopting green building materials that focus on carbon reduction in various project phases?" This question will explore stakeholders' perceptions and the various obstacles they face in adopting environmentally friendly materials for carbon reduction. This research also aims to understand how different views from stakeholders, such as contractors, architects and clients, can influence decisions regarding the use of green building materials.

The main objective of this research is to identify perceptions and obstacles in the adoption of green construction materials that focus on carbon reduction. This research aims to:

1. Identify Key Perceptions: Identify key perceptions stakeholders in the construction industry have regarding green materials, including their understanding of the

environmental benefits, concerns regarding additional costs, and their belief or distrust in the performance of these materials.

2. Analysis of Obstacles in Adoption: Identifying and analyzing the obstacles faced in the use of green materials, both from a financial, technical and cultural perspective, at various stages of construction projects, from planning, design, to implementation.
3. Preparation of Recommendations to Increase the Adoption of Green Materials: Based on research findings, this research will develop recommendations that can help construction companies, regulators and other stakeholders in developing policies or practices that support the adoption of green materials, thereby contributing to carbon reduction targets in the sector.

This research will make a unique contribution to the sustainability literature in construction by highlighting the social and psychological factors that play a role in the adoption of green materials. By understanding the obstacles and perceptions faced by stakeholders, it is hoped that the results of this systematic literature review can help formulate more effective strategies in implementing low-carbon materials in the construction industry. Apart from that, this research is also expected to be the basis for further studies that explore social aspects in the adoption of sustainable practices in the construction sector.

2. Methods

2.1. Study Design

This research uses a systematic literature review (SLR) approach to identify and integrate relevant findings regarding perceptions and obstacles in the adoption of green building materials that focus on carbon reduction in the construction industry. The SLR approach was chosen because it allows collecting evidence from various studies systematically, resulting in a more comprehensive and in-depth understanding of the topic under study. In addition, this method is also suitable for exploring social and psychological factors, as it allows holistic cross-research analysis.

By considering the diversity of factors influencing the adoption of green materials in construction, SLR is considered the most effective approach to compile available empirical data and identify deep patterns from various stakeholder perspectives. This approach is also very useful for filling gaps in the literature by summarizing the results of previous research, especially those related to perceptions and subjective constraints which have rarely been explored in technically focused research.

2.2. Inclusion and Exclusion Criteria

2.2.1. Inclusion Criteria

The inclusion criteria in this study include several specific aspects to ensure that the results of the systematic literature review are relevant and comprehensive on adoption issues of green building materials which aim to reduce carbon emissions. First, studies should specifically focus on using green building materials with the primary goal of carbon reduction in construction projects. Second, the selected articles need to examine the perceptions of stakeholders such as contractors, architects and clients regarding green building materials, both in terms of environmental benefits and challenges in their use. Third, included research should include a discussion of barriers to the adoption of environmentally friendly construction materials, including financial, technical, and cultural barriers. Finally, to ensure that this research is relevant to current sustainability trends and policies, only studies published in English-language journals within the last 10 years will be included.

2.2.2. Exclusion Criteria

The exclusion criteria in this study were designed to filter out articles that were irrelevant or did not meet the academic standards required in this systematic literature review.

Articles that only examine technical aspects, such as chemical composition or scientific testing of *green building materials* without including aspects of perception or implementation constraints, will be excluded. Additionally, studies that focus on the use of green materials outside the construction context or in other industrial sectors that are not relevant to the construction industry will not be included. Articles that do not mention carbon reduction goals or the environmental impact of material use also do not meet the criteria. Finally, publications in the form of opinions, editorials, non-systematic reviews, or conference papers that have not gone through a rigorous peer review process will be excluded, to ensure the quality and validity of the data processed in this research.

2.3. Data source

This research will use three main databases, namely Scopus, Web of Science, and ScienceDirect, to search and identify relevant literature. These databases were chosen because they have extensive coverage of high-quality scientific research and access to recognized and credible Q1 international journals. Scopus and Web of Science are known as comprehensive platforms for engineering and the environment, making them particularly relevant for sustainability-related topics in the construction sector. Meanwhile, ScienceDirect provides special access to journals focused on construction materials and sustainability, thus completing this research's need to obtain a comprehensive view of the relevant literature.

These three databases were chosen because they provide access to published research articles and process peer review, andIt is important to ensure the validity and relevance of findings from the available literature. The selection of these databases was also based on their suitability to the research topic, considering that all three index various relevant research from the fields of sustainability, civil engineering and construction. By using Scopus, Web of Science, and ScienceDirect, this research will obtain rich and relevant data to understand perceptions and barriers to adoption of green building materials in efforts to reduce carbon in the construction sector.

2.4. Search Strategy

The literature search process was carried out using main keywords compiled to cover various aspects of this research. These keywords include:

- “green building materials”
- “carbon reduction”
- “construction industry”
- “stakeholder perception”
- “barriers in adoption”

These keywords are then combined using logical operators such as *AND* And *OR* to increase search precision. Combinations used, for example: (“green building materials” AND “carbon reduction”) AND (“stakeholder perception” OR “barriers in adoption”) AND “construction industry”.

This formula is designed to narrow search results to only display articles that are truly relevant with a research focus on social factors, stakeholder perceptions, and obstacles to the adoption of environmentally friendly building materials for carbon reduction.

2.5. Customization for Each Database

Each database has slightly different features and search formats, so researchers tailored keywords and search combinations according to the criteria on each platform. For example, in Scopus, search results are limited by the filter “research articles only,” whereas in Web of Science, non-English articles are excluded. These adjustments ensure that search results remain in line with the academic standards expected from trusted sources in the database.

2.6. Selection Procedure

2.6.1. Selection Process Using PRISMA

The article selection process in this research will be documented using diagrams Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which consists of four main levels as follows:

1. Identification: At this stage, relevant articles will be identified based on search keywords that have been determined in the selected databases (Scopus, Web of Science, and ScienceDirect). All articles found will be recorded for further evaluation.
2. Screening: After identification, articles will be screened by checking the title and abstract to ensure that the articles found meet the inclusion and exclusion criteria. Articles that are not relevant or do not fit the research focus will be excluded at this stage.
3. Eligibility: Articles that pass screening will be read in their entirety. At this stage, articles will be evaluated in more depth to ensure that only articles that fully meet the eligibility criteria will be included in the systematic review.
4. Inclusion: Articles that met all eligibility criteria were included in the final analysis. Relevant and high-quality articles will be part of the literature review which will be analyzed further.

This PRISMA diagram will be used to illustrate the number of articles screened at each stage, including the reasons for exclusion for each article that did not meet the inclusion criteria. In this way, the selection process will be recorded clearly and transparently, ensuring that the quality of the systematic review can be accounted for.

2.6.2. Analysis Method

2.6.2.1. Qualitative Analysis Technique: Thematic Analysis

The articles selected in this research will be analyzed using a qualitative analysis approach, by choosing thematic analysis asi main method. This technique allowed researchers to identify key themes emerging from the data relating to perceptions and barriers to the adoption of green construction materials.

2.6.2.2. Steps in Thematic Analysis

1. Coding Initial: At this stage, researchers will analyze the content of relevant articles by reading the text thoroughly to identify emerging patterns, ideas and themes, especially those related to stakeholder perceptions and obstacles in the use of green building materials. Initial codes will be assigned to pieces of data that describe information related to the topic, such as environmental benefits, adoption challenges, and social or cultural issues.
2. Theme Grouping: After initial coding, the next step is to group the codes that have been obtained into main themes. These themes may include:
    - Perception of Environmental Benefits: Identifying stakeholder views about the contribution of green building materials to environmental sustainability and carbon reduction.
    - Cost Constraints: Analyze the financial constraints faced in adopting green materials, including higher prices compared to conventional materials.
    - Policy Support: Groups codes related to the role of government policies or regulations that support or hinder the adoption of green building materials.
    - Technical and Infrastructure Barriers: Identify technical challenges in the use of green materials which include the availability of materials and technical skills required.

- Social and Cultural Perceptions: This theme focuses on how local culture and customs influence stakeholders' perceptions of the acceptance of new technologies in construction.

3. Formation of Final Categories: After the main themes have been grouped, the researcher will develop broader categories based on the themes that have been identified. In this final category, similar themes will be combined, and the researcher will examine the relationships between these themes to provide deeper insights. For example, there may be a relationship between policy support and cost constraints, or how social perceptions may influence the adoption of green materials in various contexts.
4. Data Interpretation: Once key themes have been identified and final categories developed, the researcher will interpret the findings in the context of carbon reduction in the construction industry. This includes considering social, psychological, and cultural factors that may influence the adoption of green building materials. Researchers will interpret these findings by comparing and relating data across studies, as well as considering cultural and economic contexts that may influence stakeholder perceptions in different regions. For example, countries with strong sustainability policies may have more positive perceptions of green building materials compared to countries that are less supportive of such initiatives.

2.6.3. Results and Presentation

Once the analysis is complete, the researcher will present the findings in a narrative form that provides insight into how stakeholder perceptions and the obstacles they face influence the decision to adopt green building materials. The results of this analysis will help describe the social and psychological factors that influence decisions in the construction industry and provide useful recommendations for future policy and practice.

3. Results

3.1. General Characteristics of Articles

In this section, the researcher will describe the findings from the articles that met the inclusion criteria, with details of the characteristics of the articles included in the analysis. These characteristics help provide a clearer picture of how perceptions and barriers to the adoption of green building materials vary based on geographic factors, stakeholders, and the type of construction project involved. The following is a breakdown of the general characteristics of the analyzed articles:

1. Geographical Region

The articles analyzed cover a wide range of regions, with a focus on countries with high construction activity and developing sustainability policies. Some areas that often appear in these studies include:

- United States: This country is often a center for research regarding green building materials, with many construction projects driven by strong sustainability policies, such as LEED (Leadership in Energy and Environmental Design).
- Western Europe: Countries such as Germany, the Netherlands and the UK have progressive environmental policies and focus on reducing carbon emissions, which has made them a focus of research in the adoption of green building materials.
- East Asia: Countries such as Japan, China and South Korea are also active in this research, with an emphasis on reducing carbon footprints and implementing environmentally friendly technologies in the construction sector.

These geographic characteristics help understand how local policies and environmental regulations in each region influence perceptions and barriers faced in adopting green

materials. For example, countries with financial incentives for green projects may show faster adoption than countries still grappling with regulatory obstacles or a lack of policy support.

2. Type of Stakeholder

Multiple stakeholder groups were involved in the study, each providing unique perspectives regarding perceptions and challenges of using green materials. Several stakeholder categories frequently encountered in this study include:

- Contractors: As parties directly involved in project implementation, contractors are often more focused on the costs and long-term sustainability of the construction project. Cost constraints and difficulties in finding materials that meet technical standards are some of the challenges faced.
- Architect: Architects have an important role in selecting materials that comply with design and sustainability principles. They tend to focus more on long-term benefits to the environment and achieving desired green design standards.
- Engineers: Engineers, especially those focused on structural engineering and building engineering, need to consider the technical aspects of green materials, such as durability and energy efficiency.
- Clients: Clients or project owners are often more focused on short-term costs and benefits, although more and more are showing interest in the environmental impact of the materials selected.
- Government and Regulators: These parties play a key role in establishing policies that encourage the adoption of green building materials. Fiscal policies and incentives, such as tax reductions or subsidies, can influence the adoption of green materials in the construction sector.

3. Type of Construction Project

The analyzed articles cover various types of construction projects, each of which brings different challenges and priorities in the application of green building materials. The types of projects found in this study include:

- Commercial Building Construction: Commercial projects are often more focused on long-term cost efficiency and achieving an environmentally friendly reputation. The application of green building materials in commercial buildings is usually driven by the need to meet international sustainability standards (such as LEED) and to attract tenants or buyers who care about the environment.
- Residential Projects: Home and housing construction faces challenges related to initial cost constraints and material accessibility. Despite interest in reducing carbon footprints, adoption of green materials is often hampered by higher material prices and installation costs.
- Public Facilities: This project includes government buildings, schools, hospitals, and other public facilities. Public facilities are often influenced by government policies regarding sustainability and emission reduction, so many are trying to adopt green materials in order to meet environmental policy goals.

The general characteristics of the articles analyzed provide deeper insight into how different geographic regions, types of stakeholders, and types of construction projects can influence perceptions and barriers to the adoption of green building materials. These findings can help in designing more effective policies and strategies to promote the use of green materials in the construction industry, taking into account the challenges faced by each stakeholder group and different types of projects.

3.2. Key Findings

3.2.1. Perceptions of Green Construction Materials

1. Positive View

Studies show that many stakeholders recognize the added value that green building materials (GBM) have, both in terms of sustainability and corporate reputation. In general, stakeholders are aware that the use of green building materials:

- Improves project image: The use of green materials is often seen as a proactive step in supporting sustainability and reducing the carbon footprint, which in turn improves the project's image.
- Attract the attention of investors or clients: Green building materials can be attractive to investors or clients who are concerned about the environment and sustainability, providing a competitive advantage in a market that is increasingly concerned about sustainability.

2. Negative or Ambivalent Views

However, there is a less positive perception regarding the use of green materials. Some of them are:

- Higher costs: One of the main issues that often arises is that GBM is often more expensive, both in terms of initial costs and the installation process. This raises doubts, especially in cost-sensitive markets, such as projects with limited budgets.
- Technical skills required: Some stakeholders, especially contractors and developers, feel that implementing green materials requires time, technical skills and a higher level of experience, which may not be widely available in the local market. This creates uncertainty in the adoption of green materials if there is no clear economic incentive.
- Concerns over material sustainability: There are also concerns about the long-term performance and sustainability of green materials. Some stakeholders feel that green materials have not been tested enough for use in long-term projects, especially in extreme environmental conditions, which raises doubts regarding the durability and effectiveness of these materials.

3.3. Major Obstacles to Adoption

1. Financial Barriers

Cost is the main obstacle most often identified in the adoption of green building materials. Some of the obstacles faced are:

- Higher initial cost: Green materials often require a larger initial investment compared to conventional materials. This can hinder the decision to adopt the technology, especially in projects with limited budgets.
- Lack of subsidies or incentives: In many regions, there are not enough financial incentives or subsidies to encourage the use of green building materials. This exacerbates the difficulty in convincing developers or clients to make long-term investment decisions.

2. Technical Barriers

The adoption of green materials is also influenced by technical constraints, such as:

- Limited technical skills: Adoption of green building materials often requires specialized skills in design and installation. Many stakeholders feel that the workforce trained in the use of green materials is still limited, which increases training costs as well as implementation time.
- Limited local market knowledge: In many markets, knowledge and understanding of green materials is limited, making the design and installation process more complex.

3. Cultural Barriers and Perceptions

Some stakeholders, especially contractors, face cultural barriers in adopting new innovations, such as green building materials. These barriers include:

- Distrust of innovation: In some regions, especially conservative ones, there is a sense of distrust of new technologies or unproven materials on the local market. This may hinder the acceptance of green materials in the construction industry.
- The feeling that green materials are incompatible with conventional ways of working: There is also the idea that green building materials are incompatible with traditional construction methods that have been proven to be more efficient or cheaper.

4. Regulatory and Policy Barriers

In some regions, regulatory and policy constraints are the main barriers to the adoption of green materials. This includes:

- Lack of supportive regulations: Some countries or regions do not have regulations that are clear enough or encourage the adoption of green materials effectively. This creates uncertainty for stakeholders in deciding whether they should invest more in green building materials.
- Lack of supportive policies: Some stakeholders stated that adoption of green materials would be faster if there were stronger government policies, including fiscal and tax incentives, that could help lower initial costs.

3.4. Variations Based on Stakeholder Type

1. Contractor

Contractors tend to focus more on costs and technical feasibility in implementing green building materials. They may be more hesitant to adopt new materials if there is uncertainty about long-term benefits and if the price of green materials is too high compared to conventional materials. When there is technical uncertainty or higher costs, they may choose better known and cheaper materials.

2. Architects and Engineers

Architects and engineers are often more open to innovation and support the use of materials that can improve the sustainability, energy efficiency and aesthetics of projects. However, their challenge is often to convince clients that green materials add value, both in terms of performance and reputation. While they are more likely to support innovation, they need to prove that the material has long-term benefits.

3. Client/Developer

Clients and developers, especially those focused on the commercial sector, are more interested in the reputational and branding benefits that can be gained from using green materials. They may be more willing to adopt green materials if there is strong evidence of long-term cost savings or if sustainability policies are a selling point in attracting renters or buyers. However, they are also very sensitive to initial costs and short-term profitability.

4. Regulators/Government

Governments and regulators have an important role in supporting the use of green materials through regulations and incentives. However, this support often varies depending on the region, existing sustainability policies, and the resources available to support the implementation of green materials. Governments that are more supportive of implementing green policies will encourage other stakeholders to follow in their footsteps, both through financial incentives and clearer regulations.

Perceptions of green construction materials show a balance between positive views that support sustainability and improved reputation, with negative views that focus more on high costs, technical obstacles and long-term uncertainty. To increase the adoption of green materials, it is important to overcome these barriers, both financial, technical, cultural and regulatory, and take advantage of the support that can be provided by relevant stakeholders.

4. Discussion

4.1. Interpretation of Findings

This research provides direct insight into the main question asked, namely "What are the perceptions and constraints of stakeholders in the construction industry regarding the implementation of green building materials that contribute to carbon reduction?" The resulting findings show that the perceptions of stakeholders in the construction industry towards green building materials vary widely. The application of green materials in the construction industry is a complex issue that reflects the tension between the environmental benefits recognized by stakeholders, such as architects, and the practical challenges faced by contractors and developers. Architects and other design professionals often support the use of green materials because of their compatibility with energy-saving design and sustainability goals. This support is reinforced by findings that highlight the importance of optimizing energy and construction materials, which are key drivers in achieving sustainability targets and reducing carbon emissions in the built environment (Bo, 2023). In addition, the construction industry is a significant contributor to global carbon emissions, contributing about a quarter of total emissions (Yang, 2023), underscoring the urgency to adopt environmentally friendly practices.

However, contractors and developers often express concerns regarding the high initial costs and technical complexity of using green materials. These concerns are supported by research showing that financial barriers, such as high costs, as well as technical limitations, including lack of skills and experience, significantly hinder the adoption of green building practices (Hwang & Tan, 2012; Jackson & Kaesehage, 2020). Additionally, regulatory barriers, such as a lack of incentives and supporting policies, further complicate the transition to sustainable construction methods (Frimpong, 2023). These multidimensional challenges illustrate the gap between awareness of environmental benefits and practical difficulties in the application of green materials, which may ultimately hinder the construction industry's potential to contribute to substantial reductions in carbon emissions.

The identified barriers—financial, technical, and regulatory—are crucial elements in understanding the challenges faced by the construction industry in its efforts to reduce carbon emissions. For example, the lack of an internal management system in construction companies to monitor climate mitigation benchmarks is a major obstacle (Frimpong, 2023). In addition, innovative collaboration and government support through subsidies and tax reductions are needed to overcome these obstacles and encourage the adoption of green materials (Bo, 2023; Hwang & Tan, 2012). Thus, efforts to overcome this challenge are very important to strengthen the role of the construction industry in achieving carbon neutrality and reducing the impact of climate change.

In conclusion, although there is growing recognition of the importance of green materials in supporting sustainability in the construction industry, there are still significant barriers to overcome. Stakeholders need to work together to develop solutions that balance the environmental benefits of green materials with the practical realities of their application. This collaborative approach is critical to fostering a more sustainable construction industry capable of making a meaningful contribution to carbon reduction efforts.

4.2. The Impact of Perceptions and Obstacles on the Implementation of Environmentally Friendly Materials

The use of green materials in the construction industry is significantly hampered by negative perceptions regarding their high costs and limited accessibility. Stakeholders often perceive green materials as a financial burden, which slows down the adoption of these materials and affects the achievement of carbon reduction targets in the construction industry. Concerns that the initial costs will be greater than the long-term benefits have caused many parties to be reluctant to invest in green materials, so that the industry still relies on conventional materials which produce higher carbon emissions (Nusa et al., 2015; Simion et al., 2019; Yemen & Rashid, 2021). These delays in adopting sustainable practices not only exacerbate existing environmental problems, but also undermine efforts to meet regulatory and sustainability targets.

Apart from financial barriers, technical barriers also play an important role in the slow implementation of green materials. The lack of skilled labor and adequate knowledge of green technologies hinders the implementation of construction projects using these materials. Wibowo et al. revealed that the lack of training and specific skills development creates major challenges for stakeholders who want to integrate green practices in their operations (Wibowo et al., 2018). These obstacles are exacerbated by unsupportive regulations, such as a lack of government incentives and unclear sustainability standards. Stakeholders expressed the need for stronger policies and support from the government to facilitate widespread adoption of green materials (Simion et al., 2019; Tang et al., 2022). The lack of attractive incentives from the government is also an inhibiting factor, because without clear benefits, green materials become less attractive to consumers (Simion et al., 2019).

The regulatory landscape also plays an important role in shaping the adoption of green materials. The construction industry is heavily influenced by government policies and incentives, which can encourage or hinder the transition to sustainable practices. Research shows that stronger government support and clear sustainability standards are essential to encourage stakeholders to accept green materials (Tang et al., 2022; Ghasemi, 2024). The Malaysian government's initiative in reducing the carbon footprint through the promotion of green technologies is an example of the potential impact of the regulatory framework on the adoption of sustainable practices ("undefined", 2021). However, the effectiveness of these initiatives is often compromised by the high costs of green materials, which can reduce stakeholders' interest in switching to environmentally friendly options (Yaman & Rashid, 2021).

In conclusion, the interaction between negative perceptions regarding costs, technical barriers, and regulatory challenges significantly hinders the adoption of green materials in the construction industry. Addressing these challenges through targeted training, greater government support and clearer sustainability standards is critical to driving a more sustainable construction industry and in line with carbon reduction targets.

4.3. Implications for the Construction Industry

To effectively overcome barriers to the adoption of green building materials, a multifaceted approach is essential. This approach includes implementing training and skills development programs, socializing the benefits of sustainability, as well as establishing incentives and supporting policies from the government.

Training and Skills Development Programs: One of the main strategies to overcome barriers to green building implementation is through targeted training and skills development for construction professionals, especially for contractors and field workers. Research shows that one of the major barriers to green building practices is the lack of education and awareness among stakeholders regarding the benefits and implementation of green technologies (Rock et al., 2019; Wang et al., 2023). By encouraging collaboration between government agencies, educational institutions, and industry stakeholders, comprehensive

training programs can be developed to equip professionals with the skills necessary to effectively design and implement green building materials (Amri et al., 2023; Komurlu, 2024) . This initiative not only improves technical competence but also promotes a culture of sustainability in the construction industry.

Disseminating the Benefits of Sustainability: Another important strategy is to conduct outreach campaigns that highlight the long-term benefits of green materials. Many stakeholders consider the initial cost of green building materials to be prohibitive, often overlooking the potential for energy savings and improved corporate reputation over time (Agyekum et al., 2020; Darko et al., 2018). Case studies showing the success of projects adopting green materials can be a powerful tool to change perceptions and demonstrate the financial viability of such investments (Mosly, 2015; Darko & Chan, 2016). By communicating these benefits effectively, stakeholders can be better encouraged to accept green building practices, thereby reducing resistance caused by misunderstandings about costs.

Government Incentives and Policies: The role of government in facilitating the adoption of green building materials is very important. Financial incentives, such as tax breaks or subsidies for developers using green materials, can significantly reduce the cost barriers associated with green buildings (Makki et al., 2020; Yu et al., 2021). Additionally, establishing clear and supportive policies can increase stakeholder confidence and interest in adopting these materials (Adamson, 2023; Azeem et al., 2017). Research shows that uniform policies and regulations are essential in creating a safe investment environment for green projects, thereby encouraging broader participation from various stakeholders (Wang et al., 2023; Darko et al., 2018). In conclusion, overcoming barriers to green building adoption requires a combination of strategies that include education, effective communication of benefits, and supportive government policies. By implementing these strategies, stakeholders can encourage a more sustainable construction industry and encourage green practices more broadly.

4.4. Recommendations for Increasing Positive Perceptions

To increase positive perceptions of green building materials, it is important to adopt a collaborative approach during project planning and implementation. This involves engaging contractors, architects and clients from the start, which helps build a shared understanding of the long-term benefits associated with green materials. Research shows that a lack of awareness and understanding of the benefits of sustainable building practices often hinders their adoption (Komolafe & Oyewole, 2018). By involving all stakeholders from the start, their collective insights can reveal a wide range of benefits of green materials, including cost savings, improved indoor environmental quality, and better occupant satisfaction (Ignatius et al., 2016; Altomonte et al., 2017). In addition, a collaborative approach can help overcome barriers to green building adoption, such as financial limitations and lack of public awareness (Ibrahim & Raji, 2018).

In addition to collaboration, promoting environmental certification and awards for projects that successfully implement green materials can significantly increase recognition of sustainability contributions. Certification serves as a tangible signal of a project's commitment to environmental responsibility, which can influence public perception and stakeholder engagement (Kim et al., 2017). Studies show that green certification is an important factor in customer recognition of green practices, often more significant than internal efforts to communicate sustainability (Kim et al., 2017). Additionally, the implementation of a recognized certification system can motivate stakeholders to pursue more environmentally friendly practices by providing a framework for evaluating and showcasing their sustainability efforts (Mosly, 2015). This recognition not only benefits individual projects, but also contributes to a broader cultural shift towards sustainability in the construction industry (Komurlu, 2024).

In conclusion, creating a collaborative environment among stakeholders and promoting environmental certification are important strategies to improve the perception of green

building materials. These approaches not only address existing barriers, but also foster a culture of sustainability that can lead to wider adoption of green practices in the construction sector.

4.5. Study Limitations

This research may be limited by the scope of the articles available, particularly if there are restrictions in terms of language or access to certain databases, which may influence the conclusions drawn. In addition, even though a systematic review approach is used, literature selection that is not completely free from bias can influence research results. This bias needs to be noted so that the resulting interpretation can be made more carefully.

4.6. Recommendations for Future Research

Empirical research through direct interviews with stakeholders in the construction industry, such as contractors, architects and clients, can provide deeper insight into the factors that influence their perceptions of green materials and the obstacles faced in their implementation. Additionally, the development of a comprehensive green materials adoption framework, based on the broader construction industry context, can make it easier for stakeholders to understand the steps that need to be taken to successfully implement green materials in construction projects. Exploration of external factors, such as international policy changes and the adoption of new technologies, is also important to understand how these factors may influence the perception and acceptance of green materials in the construction industry. In addition, comparative studies between countries can provide a clearer picture of how perceptions and barriers to the adoption of green building materials may vary according to the policy and socio-economic context in different countries. This entire discussion aims to provide a deeper understanding of the perceptions and obstacles in adopting environmentally friendly materials, as well as providing recommendations for increasing the acceptance and implementation of green building materials in the construction industry, to support efforts to reduce the carbon footprint in the future.

5. Conclusion

5.1. Summary of Findings

This research succeeded in identifying the main perceptions and obstacles in implementation of green building materials (material green buildings) for carbon reduction in the construction industry. Stakeholder perceptions tend to be influenced by perceived high costs, lack of technical understanding, and doubts about policy support. On the other hand, significant obstacles, such as financial, technical barriers and minimal managerial support, were also found to hinder the adoption of environmentally friendly building materials. These findings answer the research question by highlighting the key barrier and enabler factors that impact the adoption of green materials in the construction sector.

5.2. Policy and Practical Implications

The findings of this research have major implications for policies that support sustainable construction. The government could introduce stricter policies, such as financial incentives or regulations that make it mandatory to use green building mater*ials* on certain construction projects, to encourage wider adoption of green materials. In addition, the government can consider subsidies or tax reductions to reduce the additional cost burden which is often a major obstacle for contractors.

5.3. Practical Recommendations for the Construction Industry

For industry players, it is important to increase understanding of the benefits of green materials through training and outreach programs. A collaborative approach between

stakeholders—such as between architects, contractors, and project managers can help reduce negative perceptions and clarify long-term benefits from green building materials. Other practical strategies include the provision of technical guidance for the use of green building materials and the development of evidence-based best practices that demonstrate the positive impact of implementation on costs and sustainability.project continuation.

5.4. Contributions to the Sustainability Literature in Construction

This study makes an important contribution to the sustainability literature in the field construction, especially in understanding the perceptions and obstacles that hinder the implementation of green building materials. By using a systematic literature review approach, this research fills gaps in the literature regarding stakeholder perceptions and challenges of adopting green materials from a social and organizational perspective. This research not only offers insight into barrier factors, but also provides concrete recommendations for overcoming barriers that style.

5.5. Research Development Opportunities

This research opens up opportunities for more in-depth empirical studies, involving interviews or surveys with stakeholders in various geographic contexts. This research can also serve as a basis for developing a more comprehensive framework to measure the construction industry's readiness to adopt low carbon initiatives through the use of environmentally friendly building materials. Thus, this research not only enriches the sustainability literature, but also provides future research directions that have the potential to accelerate the adoption of green materials in the global construction industry. The overall findings of this study emphasize the importance of continued efforts from the policy and industry sectors to support adoption of green building materials as part of a commitment to reduce carbon emissions and achieve sustainability targets.

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