Research on the application of green materials in modern buildings

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Abstract. This paper dives deep into the growing importance of green materials in today's architectural design, driven by a pressing need for environmental responsibility and sustainability. The research takes a close look at the advantages and disadvantages of green materials from perspectives of feasibility and viability, providing guiding principles for their application in architecture. Core findings indicate that these materials significantly contribute to environmental health, energy efficiency, and occupant comfort, as demonstrated by innovative real-world applications like the TECLA model of 3D-printed homes. Challenges such as high initial costs and an underdeveloped market, particularly in regions like China, pose substantial hurdles to widespread adoption. Future research avenues should focus on mitigating cost factors, developing robust evaluative metrics, and investigating the impact of governmental policies to facilitate the broader incorporation of green materials in construction. The paper serves as a critical guide for architects, policymakers, and researchers committed to advancing sustainable architectural practices.

Keywords: Green building materials; constructional engineering; sustainable architectural practices; environmental policies in construction; cost-benefit analysis; applied analysis.

1. Introduction

The field of architectural design is at the intersection of art, science, and sustainability. As environmental concerns escalate in contemporary society, a pressing imperative emerges for sustainable building practices that align with ecological imperatives. The fulcrum of this change pivots on the adoption of 'green materials,' which have far-reaching implications not only for the health of our planet but also for the health and comfort of building occupants. With further socio-economic development and reforms, people's living standards are rising, and environmental issues are becoming a common concern among the public. Under the leadership of today's green city development concept, how to reduce energy consumption in the construction process, reduce environmental pollution, and improve the living standard of the people is an important issue in front of the construction sector. The application of modern building materials and green building technology has become an important direction for the development of the construction industry. This comprehensive research paper aims to analyze the multilayered significance, applicability, and challenges of integrating green materials into modern building design. At the same time, the latest developments and research progress in this field provide readers with a comprehensive and in-depth understanding and reference.

The study has several key objectives. Initially, it seeks to define what constitutes a 'green material,' emphasizing its ecological friendliness and positive effects on human health throughout its lifecycle. Following this definitional groundwork, the paper will assess the advantages and disadvantages of green materials. This encompasses their role in enhancing comfort, promoting sustainable development, and mitigating environmental pollution. Further, principles guiding the selection and application of green materials in architectural designs will be elaborated, touching upon environmental, economic, aesthetic, and safety considerations.

The structure of the study is designed for logical flow and ease of understanding. After this introduction, Section 2 delves into defining green materials and examining their role and importance. This is followed by a critical evaluation of their advantages and disadvantages in Section 2.2. Section 3 forms the core of the paper, elaborating on the guiding principles for the application of green

materials in modern architecture, each sub-section dedicated to a specific principle such as environmental friendliness, economics, aesthetics, safety, site specificity, and comfort. Section 4 will provide real-world applications, focusing on innovative projects like TECLA to ground the discussion in practical realities. The paper will conclude with Section 5, which scrutinizes the challenges facing the application of green materials and suggests potential avenues for future research and practice.

By approaching the subject from multiple dimensions, this paper seeks to serve as a foundational text for understanding the growing significance of green materials in the architectural landscape, offering detailed, nuanced views presented in this paper will contribute significantly to future academic discourse and practical applications in the field.

2. The Importance and Significance of Green Materials in Modern Architectural Design

2.1. The Definition of Green Materials

Green materials, characterized by their ecological friendliness and positive effects on human health throughout the entire life cycle, play an essential role in promoting health and sustainability. Within architectural design, there is an emphasis on using green raw materials that have minimal impact on nature and are aligned with sustainable development goals. Industrial products such as gypsum boards are built through green structures that are lightweight and reduce costs during logistics and transportation. The sustainable use of building materials reduces waste emissions from buildings [1].

2.2. The Advantages and Disadvantages of Green Materials

In architectural design, the role of architecture is to fulfill modern societal demands for quality in the built environment. This includes responding to market and societal needs, prioritizing not only economic factors but also environmental protection. Green building materials enhance comfort and promote sustainable development, reducing pollution and boosting ecological health. Examples like green landscaping demonstrate benefits such as air purification and visual enhancement. Environmental pollution is notably aggravated by construction material waste, and construction activities generate significant noise and pollution, impacting human life. Green construction concepts can mitigate these effects. For instance, traditional methods to contain dust at excavation sites may fail in windy weather, spreading dust and disrupting nearby residents. Utilizing green safety materials for waste and sewage control can minimize this impact, showcasing the application of green materials in modern construction engineering [2, 3].

3. Principles of Green Materials Applications in Modern Architecture

3.1. The Principle of Environmentally Friendly

To be environmentally friendly, renewable materials should align with sustainable development requirements. Industry can adopt energy-saving materials, reducing energy consumption and carbon emissions. Durability and stability in materials like stone, stainless steel, and aluminum alloy minimize maintenance costs. The focus on energy-saving involves land conservation, energy consumption reduction, and renewable resource utilization, considering climatic characteristics in building design to minimize energy usage [4]. Energy-saving measures, such as heat storage and utilization of renewable resources like solar, wind, and bioenergy, are vital in this context. Building designs must adapt to various climatic characteristics, and leverage sunlight, ventilation, and other techniques to minimize energy consumption [5].

3.2. The Principle of Economics

Effective reduction and utilization of non-renewable resources in construction to be constructional cost-efficient is vital. Strategies include minimizing energy in production and transportation, employing materials that enable personal and small vehicle transport, optimizing water use, reusing short-life consumables, and harnessing solar energy and air currents. Passive greening techniques, such as external insulation and shading, are economically feasible and require little investment. In contrast, active green technologies like solar thermal and intelligent lighting are more technically challenging and often require higher investment but can be effective in key locations. The development of green buildings is not merely a technical challenge but also a matter of social organization. Beyond high technology, the realization of green building's function, efficiency, and quality also depends on appropriate technology, localized materials, and region-specific construction experience [6].

3.3. The Principle of Aesthetics

In the construction of buildings with green materials, the aesthetic alignment of materials with the architectural design is also a crucial consideration. Materials that enhance visual appeal, such as colored steel plates, glass curtain walls, or stone curtain walls, can augment the building's aesthetics. Selections may correspond with architectural styles, utilizing classical-style stones or modern-style glass curtain walls to exemplify and promote the building's stylistic characteristics. Beyond mere visual appeal, the construction industry may also employ artistic materials like art broken glass or art rice ground broken. These choices not only elevate the artistic value but also contribute to the building's cultural significance.

3.4. The Principle of Safety

In the selection of materials for green building construction, adherence to safety standards is paramount. The selection must encompass materials that meet criteria for fire resistance, water resistance, and earthquake resilience, such as fireproof boards, waterproof coatings, and earthquake-resistant cladding, to fortify building safety. Additionally, materials satisfying building hygiene standards, including formaldehyde-free panels and low-VOC paints, can be utilized to diminish the emission of deleterious substances, thereby safeguarding the health of occupants. Moreover, the incorporation of materials that align with environmental protection benchmarks, including environmentally friendly thermal insulation and flooring materials, further enhances both the environmental stewardship and safety of the structure [7].

3.5. The Principle of Site-Specific

For any regional planning, urban construction, or individual building development, a foundational analysis and assessment of localized conditions is essential. This examination must encompass regional climatic peculiarities, geographical factors, indigenous culture and customs, intrinsic building mechanism characteristics, and the distribution of various sustainable energy types. Consideration must also be given to aspects such as the intensity and endurance of local building material utilization, along with any prevailing local constraints and factors [8].

3.6. The Principle of Comfortableness

In the context of green building, the emphasis on comfort does not entail a sacrifice of the building's amenities; rather, it stipulates meeting human dwelling comfort requirements as a foundational condition. This can be achieved through the application of materials with properties of thermal storage and insulation, enhancement of the maintenance structure's heat preservation and insulation attributes, utilization of solar energy for heating in winter and cooling in summer, and the prevention of overheating in summer through sun-shading mechanisms. Such an integrated approach ultimately contributes to the amelioration of indoor environmental comfort [5, 8].

4. Practical Application of Green Materials in Modern Architectural Design

The first thing to be done is to remodel the interior components of the building. In the process of building renovation, the application of green building materials will increase the degree of beauty, comfort, and health, and can be reused without harmful gases, thus having a positive impact on the health and safety of the residents. From the comfort point of view, green building materials have excellent thermal insulation, Noise insulation also has excellent performance, so it can ensure the tranquility of the room, and at the same time the room temperature can maintain a balanced condition, to ensure that the room comfort; from the perspective of aesthetics, the green building materials in the size and quality of the outstanding advantages, which can reduce the difficulties of the installation, and can effectively improve the utilization rate of indoor space that can be seen in figure 1. The utilization rate of indoor space. If green building materials are used extensively in the installation process, harmful emissions generated during the installation process can be reduced, thus preventing health problems [9].



Fig. 1. TACLA partial rendering [10].

“Mario Cucinella Architects and WASP have unveiled TECLA, a prototype of a 3-D printed home near Bologna, Italy. TECLA is a new model of recycled housing made entirely from locally sourced, reusable, and recyclable materials.

TECLA was fabricated using Crane WASP, a cutting-edge advancement in on-site 3D construction technology. Utilizing clay—a biodegradable, recyclable, and '0km natural' material—this approach promotes waste-free construction. The design is highly adaptable, suitable for a diverse array of environments, and can be autonomously produced using WASP's innovative Creator Economy Starter Kit. This method not only minimizes industrial waste but also offers a novel, sustainable framework for both national and local economic development, as well as enhancing community well-being that can be seen in figure 2. Furthermore, the use of a 3D printer significantly expedites the construction timeline by creating the entire structure in a single pass"[11]



Fig 2. TACLA section renderings [11].

5. Existing Problems in Applications of Green Materials

5.1. High Costs

Research findings indicate that green buildings typically incur higher costs than their conventional counterparts, with initial expenditures ranging from 10% to 20% more, and green building materials being comparatively costlier per unit. Consequently, developers may refrain from purchasing green building materials in substantial quantities, deterred by financial considerations. Despite governmental subsidies, enforcement remains weak, and developers often adhere to the principle of economic moderation, pursuing goals of energy conservation and emission reduction only when sufficient economic gains are anticipated.

5.2. Lack of Market Demand

Within the context of China, the green building materials certification and evaluation system is in its nascent stage, with relevant policies and regulations undergoing continuous refinement. Currently, the green building standards lack specific, quantitative, and actionable indicators for material savings, energy efficiency, environmental protection, recycling, and regeneration. Critical metrics such as the energy-saving and environmental performance of materials are not adequately detailed in the evaluation criteria. Relying solely on the content of these existing indicators does not provide adequate guidance for building design. The selection process for green building materials is thus confounded by various intervening factors, hindering the ability to choose the most suitable materials and culminating in a depressed market demand.

6. Conclusion

The core focus of this paper is a comprehensive analysis of the use of green materials in the field of architectural design. The timing of this research is particularly suitable, as it addresses a pressing global need for sustainable and environmentally responsible building methods. This study explores multiple facets—including ecological, economic, aesthetic, and practical considerations—that relate to the incorporation of green materials in construction. In doing so, it unveils a multifaceted landscape of both opportunities and challenges. A key finding is the undeniable importance of green materials

in enhancing environmental health, boosting energy efficiency, and improving occupant well-being. Case studies, such as the TECLA model of 3D-printed homes, serve as potent validations of both the conceptual merits and practical advantages of using green materials. The study also highlights critical challenges, most notably the high upfront costs and the nascent state of the market for these materials—issues that are particularly relevant in specific global regions, including China.

To address these challenges, the paper suggests a multi-faceted approach, emphasizing the necessity for future research to focus on strategies for cost reduction, the creation of strong evaluation metrics, and the ramifications of government policy interventions. The paper articulates persuasively that these challenges are not just technical obstacles; they are closely intertwined with broader economic and societal factors. Recognizing this imposes a collective responsibility on architects, policymakers, and researchers to collaborate in efforts aimed at overcoming barriers to the widespread adoption of green materials.

In closing, this paper acts as a foundational guide for all stakeholders committed to environmental stewardship and sustainable practices in architecture. It enriches the scholarly discussion about green materials while offering actionable insights that have the potential to shape future research and policy initiatives. Navigating through the intricate ecological challenges of the 21st century, the use of green materials in architectural design becomes not merely an option but a pressing necessity. The paper emphasizes the urgency of this transition and presents a comprehensive framework for achieving it, thereby making a notable contribution to the domains of architectural design and construction engineering.

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