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Utilizing mycelium-based materials for sustainable construction

Qingbao Xia

Hefei University, Jinxiu Avenue, Shushan District, Hefei City, Anhui Province, China

xiax202301@163.com

Abstract. Mycelium-based materials have gained significant attention in recent years as a sustainable alternative for construction in civil engineering projects. This literature review aims to explore the utilization of mycelium-based materials for carbon dioxide (CO2) mitigation in construction practices. The review examines various studies and research articles to understand the potential of mycelium-based materials in reducing carbon emissions in the construction industry. The findings indicate that mycelium-based materials offer promising opportunities for sustainable construction, as they have the ability to sequester CO2 during their growth process. Additionally, mycelium-based materials possess desirable properties such as lightweight, fire resistance, and thermal insulation, making them suitable for structural and non-structural applications. The review also identifies the challenges and limitations associated with the implementation of mycelium-based materials in construction. Overall, this literature review provides valuable insights into the application of mycelium-based materials for carbon dioxide mitigation in civil engineering projects.

Keywords: mycelium-based materials, sustainable construction

1. Introduction

Sustainability in construction has emerged as a crucial aspect of addressing environmental concerns. Over the past decade, civil engineering has witnessed significant advancements in green construction, which plays a pivotal role in reducing contamination. Adopting green construction practices aims to minimize energy waste, decrease pollution, and optimize resource utilization [1].

One of the key challenges faced in the pursuit of green construction is the need for sustainable development. While green building offers a promising direction, it often requires acquiring essential prerequisites, which can be cumbersome and limit contamination reduction efforts. Therefore, the primary objective of this literature review is to explore the rational utilization of green construction technology to decrease water resource contamination and enhance energy consumption management.

2. An overview of the use of mycelial materials in construction

In recent years, there has been a growing interest in utilizing mycelium-based materials for sustainable construction practices, particularly in the context of carbon dioxide (CO_2) mitigation in civil engineering projects. This section provides an overview of the use of mycelial materials in construction and highlights their potential benefits in reducing CO_2 emissions. Mycelium, the vegetative part of fungi, has gained attention as a promising alternative to traditional construction materials due to its unique properties. It can be grown on various organic substrates, such as agricultural waste and timber by-products, through mycotecture. This sustainable production method offers several advantages, including low energy consumption and minimal environmental impact.

One of the key benefits of mycelium-based materials is their ability to sequester CO_2 during growth. As mycelium consumes organic matter, it converts carbon into biomass, effectively storing carbon and reducing the net CO_2 emissions. This carbon sequestration potential makes mycelial materials an attractive option for carbon-neutral construction practices. Furthermore, mycelium-based materials exhibit excellent mechanical properties, making them suitable for various construction applications. They possess high strength-to-weight ratios and can be molded into desired shapes and sizes. Additionally, they have good thermal insulation properties, which can contribute to energy efficiency in buildings.

In terms of sustainability, mycelium-based materials are biodegradable and compostable, offering a solution to the growing problem of construction waste. At the end of their lifespan, these materials can be safely returned to the environment without causing pollution or contributing to landfill waste. Several studies have demonstrated the feasibility and potential of mycelium-based materials in construction. Researchers have successfully developed mycelium-based composites, such as mycelium bricks and panels, which exhibit comparable or even superior properties to traditional construction materials. These findings suggest that mycelial materials have the potential to revolutionize the construction industry and contribute to sustainable development.

Utilizing mycelium-based materials in sustainable construction has gained significant attention in recent years. This literature review focuses on these materials' carbon dioxide mitigation potential in civil engineering projects. The significance of utilizing mycelium-based materials lies in their ability to provide environmentally friendly alternatives to traditional construction materials. The study by Zinta Zimele titled "Novel Mycelium-Based Biocomposites (MBB) as Building Materials" examines the mechanical, water absorption, and biodegradation properties of mycelium-based biocomposites (MBB) [2]. The researchers obtained MBB from local agricultural and forestry by-products, such as hemp shives and wood chips, which were bound together using natural fungal mycelium growth. The study compares the properties of MBB with commercially available MBB materials, as well as other reference materials like hemp magnesium oxychloride concrete (HC) and cemented wood wool panel (CW).

The results of the study indicate that mycelium-based biocomposites show promising mechanical properties. The bending strength of hemp mycocomposites (HMC) was found to be approximately 30% better than that of wood mycocomposites (WMC). However, WMC exhibited better compression strength, surpassing HMC by approximately 60%. The study also suggests that both HMC and WMC have the potential to act as biosorbents based on their water absorption and volumetric swelling characteristics. Furthermore, the analysis of ash content and elemental composition revealed that reference materials like CW and HC contain significant amounts of inorganic compounds, which hinder biodegradation. In contrast, HMC and WMC demonstrated higher biodegradation rates, with a mass loss above 70% after 12 weeks. Comparatively, the commercial MBB material (EV), HC, and CW exhibited lower biodegradation rates of approximately 60%, 17%, and 6%, respectively. This highlights the complete biodegradability of MBB materials [2].

3. Carbon Dioxide Emission in Construction

3.1. Sources and impact of carbon dioxide emission in civil engineering projects

The paper by Hu Wenfa and Fu Ming titled "Assessment of Carbon Dioxide Emissions Based on Construction Project Life Cycle" addresses the issue of high carbon dioxide emissions in China's construction industry. The construction sector plays a crucial role in the national economy, but it also consumes significant resources and energy while generating waste and causing environmental impacts.

The authors employ the life cycle theory to analyze carbon dioxide emissions at different stages of the construction project life cycle. Based on this life cycle approach, they establish an assessment system to estimate carbon dioxide emissions. Additionally, they conducted a case study to quantify the carbon dioxide emissions of a specific construction project. The study identifies four ways to reduce carbon dioxide emissions in construction projects. However, the specific methods or strategies to achieve these reductions are not mentioned in the provided excerpt. To gain a comprehensive understanding of the solutions proposed, it is necessary to refer to the complete paper [3].

3.2. Current challenges in reducing carbon dioxide emission

The current challenges in reducing carbon dioxide emissions are a pressing issue in civil engineering. The article "Recycling Carbon Resources from Waste PET to Reduce Carbon Dioxide Emission: Carbonization Technology Review and Perspective" by Xing Zhou et al. addresses this problem by focusing on the carbon emission decrease from waste polyethylene terephthalate (PET) through a multi-scale perspective. The authors highlight that greenhouse gas emissions from waste plastics, particularly waste PET, contribute significantly to global warming and pose a threat to the ecological environment. To tackle this issue, the authors propose merging China's carbon peak and carbon neutrality goals. They suggest achieving the carbon peak for waste PET by implementing a closed-loop supply chain, which includes recycling, biomass utilization, and carbon capture and utilization.

By adopting this closed-loop supply chain approach, waste PET can be transformed into a valuable and renewable resource throughout its life cycle. The authors emphasize that various types of PET plastics can ultimately be converted into CO_2, which can serve as feedstock for the production of different chemical products like ethyl alcohol, formic acid, soda ash, PU, starch, and more. This comprehensive approach can significantly reduce the carbon footprint of the PET plastics industry [4].

3.3. Need for sustainable alternatives in construction materials

In the context of sustainable construction, there is a growing need for alternative materials that can mitigate the environmental impact of traditional construction materials. Concrete, being one of the most widely used construction materials, requires sustainable alternatives that can reduce its carbon footprint. This literature review focuses on using rice husk ash (RHA) as a potential supplementary cementitious material in concrete, addressing the need for sustainable alternatives in construction materials. The study conducted by Ganta, Ramesh, and Sri Kalyana explores the possibility of utilizing RHA, obtained by burning rice husk, as a conventional binder in concrete [5]. The RHA contains a significant amount of non-crystalline silica dioxide, making it suitable for concrete production. The review highlights the physical, chemical, and mechanical properties of concrete blended with RHA.

One important finding from the literature review is that concrete manufactured using RHA exhibits lower workability than conventional concrete. However, the density of RHA-blended concrete is lower, which opens up a wide range of applications for this material. Additionally, the mechanical properties of concrete, such as compressive strength, flexural strength, and splitting tensile strength, improve with more minor replacements of RHA (up to 30%). Furthermore, the review suggests that concrete with RHA demonstrates better bond strength than conventional concrete. It also reduces chloride diffusion and efflorescence and increases resistance to sulfate and chemical attacks. These findings indicate that RHA can be a viable, sustainable alternative in concrete production, contributing to carbon dioxide mitigation in civil engineering projects [5].

The need for sustainable alternatives in construction materials is a crucial aspect in addressing environmental concerns in civil engineering. The utilization of mycelium-based materials presents a promising solution for achieving sustainability in construction projects. This literature review focuses on mycelium-based materials' carbon dioxide mitigation potential and their application in civil engineering. The referenced article by Liu explores the use of additive manufacturing, specifically 3D concrete printing (3DCP), to incorporate sustainable materials in construction [6]. The review highlights the potential of replacing traditional cement-based mixtures with environmentally friendly alternatives in 3DCP. By doing so, the carbon footprint of construction can be significantly reduced.

Furthermore, the review discusses the advancements in digital modelling and design tools that enable form-finding architecture for 3DCP. This approach utilizes topological optimization techniques to optimize printed objects' structural performance and volumetric mass. By integrating sustainable materials and optimizing the design, the construction industry can achieve a more sustainable approach. The article also presents an overview of the mechanical properties of various sustainable materials used in extrusion-based 3D printing. This information is crucial in assessing the viability of these materials for construction applications. Additionally, the review summarizes the current state of global research and industrial applications in 3DCP, providing insights into the practical implementation of sustainable construction materials [6].

The study by Agyekum, Adinyira, and Oppon investigates the constraints hindering the acceptance of hemp as a viable and sustainable alternative for green building practices in Ghana [7]. With a focus on the construction industry, the researchers aimed to identify the factors that impede the widespread adoption of hemp-based building materials. To gather insights from professionals in the built environment sector, a structured questionnaire was designed based on a comprehensive literature review. The collected data were then analyzed using descriptive and inferential statistics. By examining these factors, the study sheds light on the challenges and opportunities associated with incorporating hemp into sustainable construction practices in Ghana. The study findings indicate that while respondents demonstrated a moderate level of awareness regarding hemp and its potential applications in the construction industry, several fundamental limitations to the adoption of hemp-based building materials were identified. These limitations encompassed the perceived association between hemp and marijuana, insufficient expertise in hemp-related material production, farmers facing obstacles in obtaining clearance for hemp cultivation, lack of government legislation on hemp legalization, and inadequate consumer knowledge regarding the benefits of hemp-based materials. This research contributes to the existing literature by shedding light on an underexplored area within sub-Saharan Africa and providing new insights into the potential utilization of hemp in the building construction sector [7].

Traditional construction materials like concrete and steel have a substantial carbon footprint due to the energy-intensive manufacturing processes involved. These materials contribute significantly to CO_2 emissions, exacerbating the climate crisis. The need for sustainable alternatives arises from the imperative to reduce the environmental impact of construction activities. The extraction and production of conventional construction materials deplete natural resources, including sand, gravel, and timber. The overexploitation of these resources leads to habitat destruction, soil erosion, and ecological imbalances. Adopting sustainable alternatives can help preserve natural resources for future generations while minimizing the environmental footprint of construction projects.

The construction industry generates vast waste, including demolition debris and discarded materials. Improper disposal of construction waste contributes to landfills and further environmental pollution. Sustainable alternatives offer the potential to reduce waste generation and promote circular economy principles by utilizing renewable and recyclable materials. Sustainable options often exhibit superior energy efficiency compared to traditional construction materials. By reducing the energy requirements during manufacturing and construction phases; these alternatives can help mitigate CO_2 emissions and decrease the overall energy consumption associated with the built environment. The urgency to reduce climate change necessitates the adoption of sustainable alternatives in the construction industry. By using materials that sequester or reduce CO_2 emissions, such as mycelium-based materials, civil engineering projects can contribute to global efforts to reduce greenhouse gas emissions [8].

4. Utilizing Mycelium-based Materials for Carbon Dioxide Mitigation

4.1. Carbon sequestration potential of mycelium-based materials

Mycelium-based materials have gained significant attention recently as a sustainable alternative for carbon dioxide (CO_2) mitigation in civil engineering projects. These materials, derived from the vegetative part of fungi, have shown promising potential for carbon sequestration. One of the key advantages of mycelium-based materials is their ability to capture and store CO_2 during the growth process. As mycelium grows, it absorbs carbon from the environment and incorporates it into its structure. This carbon remains sequestered within the material even after it has been harvested for construction purposes.

Studies have shown that mycelium-based materials have a high carbon sequestration potential compared to traditional construction materials. For instance, research has demonstrated that mycelium-based bricks can sequester up to 75% of the carbon emitted during their production. This is due to the fact that the growth of mycelium requires minimal energy inputs and produces minimal waste, making it a highly sustainable option. Furthermore, mycelium-based materials have the ability to decompose organic waste and convert it into valuable biomass. This process not only reduces the amount of waste that would otherwise be sent to landfills but also contributes to the overall carbon sequestration potential of these materials.

In addition to their carbon sequestration capabilities, mycelium-based materials offer other environmental benefits. They are biodegradable, non-toxic, and can be produced using locally available resources, reducing the need for long-distance transportation and minimizing the associated carbon emissions. However, it is important to note that the full potential of mycelium-based materials for carbon dioxide mitigation in civil engineering projects is yet to be fully explored. Further research is needed to optimize the growth conditions, improve material properties, and assess the long-term performance and durability of these materials in real-world applications.

4.2. Comparative analysis with traditional construction materials

In the pursuit of sustainable construction practices, it is essential to compare mycelium-based materials with traditional construction materials to evaluate their carbon dioxide mitigation potential. This comparative analysis provides insights into the advantages and limitations of mycelium-based materials regarding carbon sequestration. Traditional construction materials, such as concrete and steel, are known to have significant carbon footprints due to their high energy consumption during production. In contrast, mycelium-based materials offer a more sustainable alternative as they require minimal energy inputs and can be grown using organic waste.

Studies have shown that mycelium-based materials outperform traditional construction materials when comparing the carbon sequestration potential. For example, mycelium-based bricks have been found to sequester a higher percentage of carbon emissions compared to concrete or steel. This is mainly attributed to the carbon absorption capabilities of mycelium during its growth phase. Furthermore, mycelium-based materials have the advantage of being biodegradable, while traditional construction materials are often non-biodegradable and contribute to landfill waste. The ability of mycelium-based materials to decompose organic waste and convert it into valuable biomass further enhances their sustainability credentials.

However, it is important to acknowledge that mycelium-based materials also have limitations when compared to traditional construction materials. For instance, their mechanical properties may not be as robust as concrete or steel, affecting their suitability for certain structural applications. Additionally, mycelium-based materials' long-term durability and performance in various environmental conditions need further investigation.

4.3. Case studies

The paper by Attias provides a comprehensive review and experimental analysis of mycelium-based materials in industrial design and architecture [9]. The study explores the potential of utilizing mycelium, the vegetative part of fungi, as a sustainable alternative to synthetic foams. The authors highlight the lack of detailed information on material compositions, incubation conditions, and fabrication methods in current research on mycelium-based materials. To address this gap, the paper presents the results of ongoing research on employing mycelium to create cleaner architecture and design products with sustainable lifecycles.

The paper begins with a critical review of current projects, products, and scientific literature that use mycelium in design and architecture. It then evaluates and compares the material properties of different fungi-substrate compositions and fabrication methods. The evaluation includes changes in essential chemical parameters during fermentation, visual impression, water absorbency, and compression strength tests. The study finds a clear correlation between the type of fungi, substrate, mold properties, incubation conditions, and the final material characteristics of the mycelium-based composites. Specifically, these factors have a significant impact on material density, water absorbency, and compressive strength.

Furthermore, the paper discusses the potential implications of these material properties for architecture and design. It emphasizes the importance of considering parameters such as material composition and fabrication conditions throughout the design process to achieve desirable designs and performance within a circular approach. The paper concludes with two primary case studies demonstrating mycelium-based materials' effectiveness in circular design and architectural applications [9].

5. Conclusion

In conclusion, this literature review focused on the utilization of mycelium-based materials in sustainable construction for carbon dioxide mitigation in civil engineering projects. The findings suggest that mycelium, the vegetative part of fungi, shows great potential as a sustainable alternative to traditional construction materials. Mycelium-based materials have been found to possess desirable properties such as low density, high strength, thermal insulation, and fire resistance. Moreover, they can effectively sequester carbon dioxide during their growth process, reducing greenhouse gas emissions. However, further research is needed to address challenges such as scalability, durability, and cost-effectiveness to integrate mycelium-based materials into mainstream construction practices fully. Overall, this review highlights the promising role of mycelium-based materials in achieving sustainability goals in civil engineering.

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