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Innovative materials in sustainable construction: A review

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Abstract

The construction industry plays a significant role in global resource consumption and environmental impact. In response, sustainable construction practices are increasingly focusing on the use of innovative materials to reduce environmental impact, improve energy efficiency, and enhance the overall sustainability of buildings and infrastructure. This review examines the latest advancements in innovative materials for sustainable construction and their potential to revolutionize the way we build. The review begins by outlining the key challenges facing the construction industry, including resource depletion, carbon emissions, and waste generation. It then explores the role of innovative materials in addressing these challenges, highlighting their ability to reduce energy consumption, improve durability, and lower lifecycle costs compared to traditional materials. Several innovative materials are discussed, including engineered wood products, recycled aggregates, and bio-based materials. Engineered wood products, such as cross-laminated timber, are increasingly being used as sustainable alternatives to traditional building materials due to their strength, durability, and carbon sequestration properties. Recycled aggregates, derived from construction and demolition waste, are being used to reduce the environmental impact of concrete production while conserving natural resources. Bio-based materials, such as bamboo and hempcrete, offer renewable alternatives to conventional building materials and have low embodied energy. The review also examines the challenges and opportunities associated with the use of innovative materials in sustainable construction, including cost considerations, regulatory barriers, and market acceptance. It concludes by highlighting the importance of continued research and development in the field of innovative materials to drive sustainable construction practices forward. Overall, this review demonstrates the significant potential of innovative materials to transform the construction industry and contribute to a more sustainable built environment. By embracing these materials and integrating them into sustainable construction practices, the industry can reduce its environmental footprint and create buildings and infrastructure that are more resilient, efficient, and environmentally friendly.

Keywords: Innovative; Materials; Sustainable: Construction; Review

1. Introduction

Sustainable construction, also known as green building or eco-friendly construction, is an approach to building design, construction, and operation that seeks to minimize environmental impact, conserve resources, and create healthy, energy-efficient buildings and infrastructure (Iqbal, et. al., 2021, Umoh, et. al., 2024, Vijayan, et. al., 2023). It is driven by the recognition of the significant environmental and social impacts of the construction industry, including resource depletion, carbon emissions, and waste generation. Sustainable construction aims to address these challenges by integrating sustainable practices throughout the entire lifecycle of a building, from design and construction to operation and demolition (Abatan, et. al., 2024, Adekanmbi, et. al., 2024, Hossain, et. al., 2020, Ogugua, et. al., 2024).

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One of the key pillars of sustainable construction is the use of innovative materials. Innovative materials are materials that offer sustainable alternatives to traditional building materials, often by reducing energy consumption, improving durability, and lowering lifecycle costs. These materials are essential for advancing sustainable construction practices and achieving the goals of reducing environmental impact and enhancing building performance.

The importance of innovative materials in sustainable construction cannot be overstated. Traditional building materials, such as concrete, steel, and brick, have significant environmental footprints due to their high energy consumption and carbon emissions during production. In contrast, innovative materials offer more sustainable alternatives that can help reduce the environmental impact of construction (Nturanabo, Masu & Kirabira, Okoduwa, et. al., 2024, 2019, Omaghomi, et. al., 2024). Innovative materials also play a crucial role in improving the energy efficiency of buildings. By using materials that have high thermal insulation properties or can capture and store energy, buildings can reduce their energy consumption for heating, cooling, and lighting. This not only reduces carbon emissions but also lowers operating costs for building owners and occupants. Furthermore, innovative materials can contribute to the overall sustainability and resilience of buildings and infrastructure (Murtagh, Scott & Fan, 2020, Omaghomi, et.al., 2024). Materials that are sourced locally or regionally, or are made from recycled or renewable materials, can help conserve natural resources and reduce waste. Additionally, materials that are designed to withstand extreme weather events or natural disasters can enhance the resilience of buildings and infrastructure to climate change impacts.

In conclusion, innovative materials are essential for advancing sustainable construction practices and creating buildings and infrastructure that are more environmentally friendly, energy-efficient, and resilient. This review explores the latest advancements in innovative materials for sustainable construction and their potential to revolutionize the way we build.

2. History of Innovative Materials in Sustainable Construction

Innovative materials have played a significant role in advancing sustainable construction practices, offering alternatives to traditional building materials that are more environmentally friendly, energy-efficient, and durable. This essay explores the history of innovative materials in sustainable construction, tracing their evolution from early experiments to their widespread adoption in modern building projects.

The use of innovative materials in sustainable construction can be traced back to ancient civilizations, which utilized locally available materials such as mud, straw, and stone to build structures that were well-adapted to their environment (Abatan, et. al., 2024, Ennos, 2021, Rong & Bahauddin, 2023). These early builders relied on natural materials that were renewable, abundant, and had minimal environmental impact. In more recent history, the industrial revolution brought about the widespread use of materials such as steel, concrete, and glass in construction, leading to increased environmental impact and resource depletion. This prompted a renewed interest in sustainable materials and construction practices in the 20th century. The 20th century saw significant advancements in the development of modern sustainable materials for construction (Adekanmbi, et. al., 2024, Allen & Iano, 2019, Sodiq, et. al., 2019). One of the most notable examples is the development of recycled materials such as recycled steel, glass, and plastic, which can be used to reduce the environmental impact of construction projects. Another important development is the use of sustainable wood products such as bamboo and engineered wood, which are renewable, fast-growing, and have a lower carbon footprint compared to traditional timber.

In recent years, there has been a growing interest in the use of innovative materials in modern construction projects (Adekanmbi, et.al., 2024, Adeleye, et. al., 2024, Allen & Iano, 2019). Architects and builders are increasingly turning to materials such as bio-based composites, aerogels, and phase-change materials, which offer improved energy efficiency, durability, and thermal performance compared to traditional materials. For example, bio-based composites made from agricultural waste products can be used as insulation materials, reducing the energy consumption of buildings. Aerogels, which are highly porous materials with excellent thermal insulating properties, are being used in windows, walls, and roofs to improve energy efficiency (Adekanmbi, et. al., 2024, Ismail, et. al., 2021, Lamy-Mendes, et. al., 2021). Numerous case studies showcase the successful use of innovative materials in sustainable construction projects (Adeleye, et. al., 2024, Nie, Dahanayake & Sumanarathna, 2024, Ranta, Aarikka-Stenroos & Väisänen, 2021). For example, the Bullitt Center in Seattle is a net-zero energy building that features a timber frame made from sustainably harvested wood and a high-performance envelope that incorporates innovative insulation materials and glazing systems. Another example is the Crystal in London, which is a sustainable building that features a facade made from recycled glass and a roof covered in photovoltaic panels (Adeleye, et. al., 2024, Chen, An & Heng, 2022, Blandini, 2021). These examples demonstrate the potential of innovative materials to transform the way we build and live, offering sustainable alternatives to traditional construction materials.

The history of innovative materials in sustainable construction is a testament to the ingenuity and creativity of architects, engineers, and builders in addressing the environmental challenges of modern construction (Ajiga, et. al., 2024, Ebolor, Agarwal & Brem, 2022, Jamison, 2022). From ancient mud bricks to modern bio-based composites, innovative materials have played a crucial role in advancing sustainable construction practices and reducing the environmental impact of the built environment. As we continue to seek ways to build more sustainably, the use of innovative materials will undoubtedly play a central role in shaping the future of construction.

3. Key Challenges in the Construction Industry

The construction industry faces significant challenges related to resource depletion, carbon emissions, and waste generation, which are exacerbated by the widespread use of traditional building materials and construction practices (Ajiga, et. al., 2024, Akomolafe, et. al., 2024, Purchase, et. al., 2021). As the demand for new buildings and infrastructure continues to grow, addressing these challenges is crucial to creating a more sustainable and environmentally friendly construction sector. This review explores the key challenges facing the construction industry and the role of innovative materials in addressing these challenges.

Resource depletion is a major challenge facing the construction industry, as the extraction and use of raw materials such as timber, minerals, and fossil fuels contribute to environmental degradation and biodiversity loss. Traditional building materials, such as concrete, steel, and asphalt, require large amounts of natural resources to produce, leading to increased pressure on ecosystems and habitats. Innovative materials offer sustainable alternatives to traditional building materials, reducing the need for resource extraction and minimizing environmental impact (Ajiga, et. al., 2024, Foster, 2020, Rosenboom, Langer & Traverso, 2022). For example, engineered wood products, such as cross-laminated timber, use less energy and produce fewer emissions than traditional building materials, making them a more sustainable choice for construction projects. Additionally, recycled aggregates, made from recycled concrete and asphalt, reduce the demand for virgin materials and help reduce waste generation in the construction industry.

Carbon emissions are another major challenge facing the construction industry, as the production and transportation of traditional building materials contribute to greenhouse gas emissions and climate change (Ahmed Ali, Ahmad & Yusup, 2020, Anyanwu, et. al., 2024, Atadoga, et. al., 2024). The construction sector is responsible for a significant portion of global carbon emissions, with concrete production alone accounting for approximately 8% of global CO2 emissions. Innovative materials can help reduce carbon emissions in the construction industry by offering more sustainable alternatives to traditional building materials (Ayinla, et. al., 2024, Hossain, et. al., 2020, Orsini & Marrone, 2019). For example, bio-based materials, such as bamboo and hempcrete, sequester carbon dioxide during their growth and can help offset the carbon emissions associated with construction activities. Additionally, the use of recycled materials, such as recycled steel and glass, reduces the need for energy-intensive production processes, further reducing carbon emissions. Waste generation is a major challenge in the construction industry, as construction and demolition waste account for a significant portion of total waste generated worldwide (Akhtar & Sarmah, 2018, Ayinla, et. al., 2024, Islam, et. al., 2019). Traditional construction practices often result in the disposal of large amounts of waste in landfills or incineration, leading to environmental pollution and resource depletion.

Innovative materials can help reduce waste generation in the construction industry by promoting the use of recycled and sustainable materials (Chinyere, Anyanwu & Innocent, 2023, Hossain, et. al., 2020, Ogunmakinde, Egbelakin & Sher, 2022). For example, the use of prefabricated construction techniques reduces the amount of waste generated during construction, as components can be manufactured off-site and assembled on-site. Additionally, the use of recycled materials, such as recycled concrete and steel, reduces the demand for virgin materials and helps close the loop on material cycles.

In conclusion, resource depletion, carbon emissions, and waste generation are significant challenges facing the construction industry. Innovative materials offer sustainable alternatives to traditional building materials, reducing the environmental impact of construction activities and creating a more sustainable and environmentally friendly construction sector. By embracing innovative materials and sustainable construction practices, the construction industry can help protect the environment, conserve natural resources, and create a more sustainable future for all (Dada, et. al., 2024, Goh, et. al., 2020, Opoku, 2019).

4. Role of Innovative Materials in Sustainable Construction

Innovative materials play a crucial role in sustainable construction practices by offering more environmentally friendly and energy-efficient alternatives to traditional building materials (Dada, et. al., 2024, Dozie, et. al., 2024, Sangmesh, et.

al., 2023). These materials are designed to minimize environmental impact, reduce energy consumption, and lower lifecycle costs, making them essential components of sustainable building design and construction. This article explores the key aspects of innovative materials and their role in sustainable construction.

Innovative materials encompass a wide range of materials that are used in construction and building design (Allen & Iano, 2019, Ching, 2020, Emeka-Okoli, et. al., 2024). These materials are characterized by their sustainable properties, such as high durability, low environmental impact, and energy efficiency. Examples of innovative materials include: Engineered wood products: Engineered wood products, such as cross-laminated timber (CLT) and laminated veneer lumber (LVL), are sustainable alternatives to traditional wood products. These materials are made from wood fibers that are glued together under high pressure, resulting in strong and durable building materials that can replace steel and concrete in many applications. Recycled aggregates are derived from construction and demolition waste, such as concrete, asphalt, and bricks, that are crushed and processed for use as building materials (Contreras-Llanes, et. al., 2021, de Andrade Salgado & de Andrade Silva, 2022, Emeka-Okoli, et. a., 2024). These materials reduce the demand for virgin aggregates and help divert waste from landfills. Bio-based materials, such as bamboo, straw, and hempcrete, are derived from renewable sources and have low embodied energy compared to traditional building materials. These materials offer sustainable alternatives to traditional building materials and can help reduce carbon emissions in the construction industry. High-performance insulation materials, such as aerogel and vacuum insulation panels (VIPs), offer superior thermal performance compared to traditional insulation materials (Emeka-Okoli, et. al., 2024, Resalati, et. al., 2021, Zhou, et. al., 2022). These materials help reduce energy consumption for heating and cooling, leading to lower operating costs and reduced carbon emissions. Innovative materials are often sourced from renewable or recycled sources, reducing the environmental impact of construction activities (Abu-Jdayil, et. al., 2019, Emeka-Okoli, et. al., 2024). Many innovative materials offer superior thermal performance compared to traditional materials, reducing the need for heating and cooling and lowering energy consumption. Innovative materials are often more durable and resistant to wear and tear than traditional materials, leading to longer lifespans and reduced maintenance costs. While some innovative materials may have higher upfront costs, their long-term benefits, such as reduced energy consumption and maintenance costs, can result in overall cost savings over the life of a building.

One of the key benefits of innovative materials is their potential to reduce the environmental impact of construction activities (Chowdhury, Adafin & Wilkinson, 2019, Shrivastava, 2018). By using materials that are sourced from renewable or recycled sources, the construction industry can reduce its reliance on finite resources and minimize waste generation. Additionally, innovative materials can help reduce carbon emissions by sequestering carbon dioxide or by reducing the energy consumption required for heating, cooling, and lighting buildings. Innovative materials play a significant role in improving the energy efficiency of buildings and reducing lifecycle costs (Chen, et. al., 2020, Emeka-Okoli, et. al., 2024, Ibeh, et. al., 2024). By using materials that offer superior thermal performance, buildings can reduce their energy consumption for heating and cooling, leading to lower operating costs and reduced carbon emissions. Additionally, the durability and longevity of innovative materials can result in lower maintenance costs over the life of a building, further contributing to cost savings.

In conclusion, innovative materials are essential components of sustainable construction practices. By offering sustainable alternatives to traditional building materials, innovative materials help reduce environmental impact, improve energy efficiency, and lower lifecycle costs (Hertwich, et. al., 2019, Ibekwe, et. al., 2024, Ingrao, et. al., 2018). Embracing innovative materials in construction projects is essential for creating a more sustainable and environmentally friendly built environment.

5. Types of Innovative Materials

Innovative materials play a critical role in sustainable construction practices by offering more environmentally friendly alternatives to traditional building materials (Hossain, et. al., 2020, Ibekwe, et. al., 2024, Ilojianya, et. al., 2024). These materials are designed to minimize environmental impact, reduce energy consumption, and lower lifecycle costs, making them essential components of sustainable building design and construction. This review explores the different types of innovative materials used in sustainable construction, including engineered wood products, recycled aggregates, bio-based materials, and other innovative materials.

Engineered wood products are a group of innovative materials that are manufactured by binding together wood fibers or strands with adhesives to create structural elements (Ding, et. al., 2022, Majemite, et. al., 2024, Nwokediegwu & Ugwuanyi, 2024). These materials offer several advantages over traditional wood products, including increased strength, durability, and dimensional stability. Engineered wood products are also more sustainable than traditional wood products, as they can be made from fast-growing and renewable sources, such as plantation-grown timber. One of the most common types of engineered wood products is cross-laminated timber (CLT), which consists of multiple

layers of wood panels that are glued together at right angles (Kurzinski, Crovella & Kremer, 2022, Nwokediegwu, et. al., 2024, Sandoli, et. al., 2021). CLT is increasingly being used in sustainable construction projects due to its strength, versatility, and environmental benefits. Other types of engineered wood products include laminated veneer lumber (LVL) and glued laminated timber (glulam), which are used for beams, columns, and other structural elements.

Recycled aggregates are another type of innovative material used in sustainable construction. These aggregates are derived from construction and demolition waste, such as concrete, asphalt, and bricks, that are crushed and processed for use as building materials. Recycled aggregates offer several benefits, including reducing the demand for virgin aggregates, conserving natural resources, and reducing waste sent to landfills. Recycled aggregates can be used in a variety of construction applications, including as a base material for roads and pavements, as backfill for drainage trenches, and as aggregate for concrete and asphalt (Al-Taie, et. al., 2023, Pereira & Vieira, 2022). Using recycled aggregates in construction projects helps reduce the environmental impact of construction activities and promotes the circular economy by reusing materials that would otherwise be discarded as waste.

Bio-based materials are derived from renewable sources, such as plants, animals, and microorganisms, and offer sustainable alternatives to traditional building materials (Andrew & Dhakal, 2022, Lee, Lee & Lee, 2022). These materials have low embodied energy compared to traditional materials and can help reduce carbon emissions in the construction industry. Bamboo is a fast-growing and renewable resource that is used as a building material in many parts of the world. Bamboo is lightweight, strong, and durable, making it an ideal material for construction projects. Hempcrete is a bio-composite material made from hemp fibers, lime, and water (Chen, et. al., 2022, Nwokediegwu, et. al., 2024). Hempcrete is lightweight, insulating, and fire-resistant, making it an environmentally friendly alternative to traditional building materials. Straw bales are used as a building material in straw bale construction, a sustainable building method that uses straw bales as insulation in walls. Straw bale construction is energy-efficient, cost-effective, and environmentally friendly.

In addition to engineered wood products, recycled aggregates, and bio-based materials, there are several other types of innovative materials used in sustainable construction (Boukhelkhal, et. al., 2021, Keena, et. al., 2022). Recycled plastics are used in construction applications, such as decking, fencing, and roofing, as a sustainable alternative to traditional materials. Green concrete is a type of concrete that uses recycled materials, such as fly ash and slag, as partial replacements for cement. Green concrete has lower carbon emissions and environmental impact than traditional concrete. Photovoltaic glass is a type of glass that is integrated with solar cells to generate electricity from sunlight. Photovoltaic glass can be used in building facades, windows, and roofs to generate renewable energy and reduce reliance on fossil fuels.

In conclusion, innovative materials play a crucial role in sustainable construction practices by offering more environmentally friendly alternatives to traditional building materials (Amran, Debbarma & Ozbakkaloglu, 2021, Nwokediegwu, et. al., 2024). Engineered wood products, recycled aggregates, bio-based materials, and other innovative materials are helping to reduce the environmental impact of construction activities and create a more sustainable and environmentally friendly built environment. Embracing these materials in construction projects is essential for creating a more sustainable future for all.

6. Challenges and Opportunities

Innovative materials play a crucial role in advancing sustainable construction practices by offering more environmentally friendly alternatives to traditional building materials (Amran, Debbarma & Ozbakkaloglu, 2021, Ferdous, et. al., 2019). However, the adoption of innovative materials in the construction industry is not without challenges. This review explores the key challenges and opportunities associated with the use of innovative materials in sustainable construction, including cost considerations, regulatory barriers, market acceptance, and research and development needs.

One of the main challenges associated with the use of innovative materials in sustainable construction is cost (Allen & Iano, 2019, Nwokediegwu, et. al., 2024). Innovative materials often have higher upfront costs compared to traditional building materials, which can deter developers and builders from incorporating them into construction projects. However, it is important to consider the long-term cost savings associated with innovative materials, such as reduced energy consumption, lower maintenance costs, and longer lifespan. By taking a lifecycle cost approach, it can be demonstrated that the initial higher cost of innovative materials can be offset by the savings over the life of the building.

To address cost considerations, it is important for stakeholders in the construction industry to carefully evaluate the economic benefits of innovative materials and consider them as investments rather than expenses. Additionally,

government incentives and subsidies can help reduce the financial burden associated with the adoption of innovative materials, making them more accessible to developers and builders. Regulatory barriers are another challenge facing the adoption of innovative materials in sustainable construction (Hossain, et. al., 2020, Nwokediegwu, et. al., 2024). Building codes and regulations often prioritize safety and durability, which can make it difficult for new and innovative materials to gain approval for use in construction projects. Additionally, the lack of standardized testing and certification processes for innovative materials can create uncertainty for developers and builders. To overcome regulatory barriers, there is a need for collaboration between industry stakeholders, government agencies, and research institutions to develop standardized testing and certification processes for innovative materials. By establishing clear guidelines and standards, regulators can ensure that innovative materials meet the necessary safety and performance requirements for use in construction projects.

Market acceptance is crucial for the widespread adoption of innovative materials in sustainable construction (Hossain, et. al., 2020, Nwokediegwu, et. al., 2024, Wuni & Shen, 2020). Developers, builders, and consumers must be convinced of the benefits of innovative materials and be willing to invest in them. However, there is often a lack of awareness and understanding about the benefits of innovative materials, which can hinder their adoption. To increase market acceptance, it is important for stakeholders in the construction industry to educate consumers and decision-makers about the benefits of innovative materials through marketing campaigns, educational programs, and demonstration projects. Additionally, government policies and incentives can help create demand for innovative materials by requiring or incentivizing their use in construction projects.

Research and development are essential for advancing the field of innovative materials in sustainable construction. There is a need for continued research and development to improve the performance, durability, and cost-effectiveness of innovative materials. Additionally, research is needed to explore new materials and technologies that can further enhance the sustainability of construction practices (Nwokediegwu, et. al., 2024, Tiwari, 2021). To support research and development in this field, there is a need for increased funding and collaboration between industry, academia, and government. By investing in research and development, stakeholders in the construction industry can drive innovation and develop new materials and technologies that can help address the challenges of sustainable construction.

In conclusion, while there are challenges associated with the use of innovative materials in sustainable construction, there are also significant opportunities for innovation and advancement in this field. By addressing cost considerations, regulatory barriers, market acceptance, and research and development needs, stakeholders in the construction industry can unlock the full potential of innovative materials and create a more sustainable built environment for future generations.

7. Case Studies of Successful Implementation

Innovative materials are playing an increasingly important role in sustainable construction, offering environmentally friendly alternatives to traditional building materials (Abu-Jdayil, et. al., 2019, Allen & Iano, 2019). Several projects around the world have successfully implemented innovative materials, demonstrating their effectiveness in reducing environmental impact and improving building performance. This review explores some of these case studies, highlighting the benefits realized and lessons learned from their use.

The Edge is a sustainable office building in Amsterdam that has been hailed as one of the greenest buildings in the world (Aridi & Yehya, 2022, Odilibe, et. al., 2024). The building features innovative materials such as a smart facade with integrated solar panels, which generate electricity and regulate natural light. The use of innovative materials has helped the building achieve a BREEAM rating of Outstanding, the highest sustainability rating for buildings. One Central Park is a mixed-use development in Sydney that features a vertical garden on its facade, which is made possible by the use of innovative materials such as hydroponic planting systems. The building also incorporates recycled water systems and energy-efficient lighting, reducing its environmental impact and creating a more sustainable urban environment. The Crystal is a sustainable building in London that showcases the latest innovations in sustainable construction (Ibrahim, et. al., 2022, Poon, 2021). The building features innovative materials such as photovoltaic glass, which generates electricity from sunlight, and a rainwater harvesting system, which reduces water consumption. The Crystal has achieved several sustainability certifications, including LEED Platinum and BREEAM Outstanding. The use of innovative materials has helped reduce the environmental impact of construction activities, including lower carbon emissions, reduced resource depletion, and less waste generation.

Innovative materials have contributed to improved energy efficiency in buildings, leading to lower energy consumption for heating, cooling, and lighting. Buildings constructed with innovative materials have demonstrated improved performance in terms of durability, comfort, and occupant satisfaction. While the upfront costs of using innovative

materials may be higher than traditional materials, the long-term benefits, such as reduced energy consumption and maintenance costs, can result in overall cost savings. Successful implementation of innovative materials requires collaboration between architects, engineers, developers, and suppliers to ensure that the materials meet performance requirements and are compatible with existing building systems (Harris, et. al., 2021, Koumoulos, et. al., 2019). Building professionals need to be educated about the benefits and applications of innovative materials to encourage their adoption in construction projects. Government policies and regulations can play a crucial role in promoting the use of innovative materials by providing incentives and removing barriers to their adoption.

In conclusion, the case studies highlighted in this review demonstrate the potential of innovative materials to transform the construction industry and create more sustainable built environments. By learning from these examples and applying their lessons, stakeholders in the construction industry can further accelerate the adoption of innovative materials and drive sustainable construction practices forward.

8. Future Directions

Innovative materials are at the forefront of sustainable construction, offering new possibilities for reducing environmental impact and improving building performance (Ching, 2020, Obijuru, et. al., 2024). As the construction industry continues to evolve, there are several emerging trends and opportunities for further innovation and development in the field of innovative materials. This review explores these future directions, highlighting emerging trends, potential for further innovation, and the importance of collaboration and knowledge sharing in advancing sustainable construction practices.

Nanotechnology is increasingly being used to develop innovative materials with enhanced properties, such as improved strength, durability, and thermal performance (Malik, Muhammad & Waheed, 2023, Wu, et. al., 2020). Nanomaterials, such as carbon nanotubes and graphene, have the potential to revolutionize the construction industry by offering lightweight, high-strength materials that can be used in a variety of applications. 3D printing technology is being used to create innovative building materials and components, such as concrete structures and architectural elements. 3D printing allows for greater design flexibility and customization, as well as reduced material waste and construction time. Smart materials, such as self-healing concrete and thermochromic coatings, are being developed to improve the performance and sustainability of buildings. These materials have the ability to respond to environmental conditions, such as temperature changes, and repair themselves, reducing the need for maintenance and repairs. There is a growing focus on developing recyclable materials that can be easily reused or recycled at the end of their lifecycle. These materials help reduce waste generation and promote a circular economy in the construction industry.

There is an increasing interest in developing materials that have a net negative carbon footprint, meaning they absorb more carbon dioxide than they emit during their production and lifecycle. These materials have the potential to help mitigate climate change by sequestering carbon dioxide from the atmosphere. Researchers are looking to nature for inspiration in developing innovative materials that mimic natural processes and structures (Huang, et. al., 2019, Zhang, Yan & Fan, 2021). Bio-inspired materials have the potential to offer sustainable solutions for construction, such as self-healing materials and biodegradable composites. Advanced recycling technologies, such as chemical recycling and upcycling, are being developed to turn waste materials into high-quality building materials. These technologies have the potential to significantly reduce waste generation and promote a circular economy in the construction industry. Collaboration and knowledge sharing are crucial for advancing sustainable construction practices and driving innovation in the field of innovative materials. By collaborating with researchers, manufacturers, and other stakeholders, the construction industry can accelerate the development and adoption of innovative materials (Charef & Lu, 2021, Hossain, et. al., 2020). Additionally, sharing knowledge and best practices can help ensure that innovative materials are used effectively and safely in construction projects. In conclusion, the future of innovative materials in sustainable construction is bright, with emerging trends, opportunities for further innovation, and a growing emphasis on collaboration and knowledge sharing. By embracing these future directions, the construction industry can continue to lead the way in sustainable building practices and create a more sustainable built environment for future generations.

9. Conclusion

Innovative materials are revolutionizing the field of sustainable construction, offering new possibilities for reducing environmental impact and improving building performance. This review has highlighted the key benefits, challenges, and future directions of innovative materials in sustainable construction, demonstrating their potential to transform the way we build and inhabit our cities.

Key points discussed include the use of innovative materials such as engineered wood products, recycled aggregates, and bio-based materials in sustainable construction projects. These materials offer several advantages over traditional building materials, including lower environmental impact, improved energy efficiency, and reduced lifecycle costs. Challenges such as cost considerations, regulatory barriers, and market acceptance were also addressed. However, these challenges can be overcome through collaboration, education, and regulatory support, paving the way for the widespread adoption of innovative materials in construction projects. Looking to the future, there are several emerging trends and opportunities for further innovation in the field of innovative materials. Nanotechnology, 3D printing, smart materials, and recyclable materials are just a few examples of the exciting developments taking place in sustainable construction.

In conclusion, embracing innovative materials in sustainable construction is not just a choice, but a necessity. As the construction industry continues to grow, so too does the need for more sustainable building practices. By embracing innovative materials, we can create a more sustainable built environment that benefits both people and the planet. It is imperative that stakeholders in the construction industry collaborate, share knowledge, and take action to accelerate the adoption of innovative materials in sustainable construction projects. Together, we can build a more sustainable future for all.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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