The Crucial Role of Green and Environmentally Friendly Materials in Energy Conservation and Cost Reduction in Civil Engineering

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Abstract

Under the dual pressures of global energy crisis and deteriorating ecological environment, civil engineering, as an important source of energy consumption and carbon emissions, has made energy conservation and emission reduction a core issue for the sustainable development of the industry. Green and environmentally friendly materials, with their characteristics of low energy consumption, low pollution, and recyclability, demonstrate significant advantages in energy conservation and emission reduction throughout the entire life cycle of civil engineering. This article starts from the connotation and characteristics of green and environmentally friendly materials, systematically elaborates their key roles in energy conservation and emission reduction in civil engineering, covering aspects such as material production, construction application, operation and maintenance, and waste disposal, and proposes strategic suggestions for promoting the application of green and environmentally friendly materials, with the aim of providing theoretical support and practical references for the green transformation of the civil engineering industry.

Keywords: Green Environmental-Friendly Materials; Civil Engineering; Energy Conservation And Consumption Reduction; Sustainable Development; Full Life Cycle

1. Introduction

With the acceleration of global industrialization, the problems of energy shortage and environmental pollution have become increasingly severe, and they have become the key factors restricting the sustainable development of human society. The civil engineering industry, as an important pillar industry of the national economy, has seen its construction scale expand continuously, but at the same time, it also faces issues such as high energy consumption and high emissions. According to statistics, energy consumption in the construction sector accounts for 40% of the global total energy consumption, and carbon emissions account for over 30% [1]. Among them, the energy consumption and emissions during the construction phase of civil engineering are particularly prominent. In this context, promoting the application of green and environmentally friendly materials and achieving energy conservation and emission reduction in civil engineering has become an inevitable choice for industry development.

Green and environmentally friendly materials refer to new building materials that possess the characteristics of energy conservation, emission reduction, safety, convenience, and recyclability throughout their entire life cycle. Their production process focuses on efficient utilization of resources and environmental protection, and during use, they can reduce building energy consumption, and after disposal, they can reduce negative impacts on the environment through recycling and reuse [2]. The application of green and environmentally friendly materials in civil engineering not only can significantly reduce energy consumption and carbon emissions, but also can improve the overall performance and service life of buildings, and promote the green, low-carbon, and sustainable development of the civil engineering industry.

2. Green and Environmental-friendly Materials: Their Connotation and Characteristics

2.1 Definition and Classification of Green and Environmental-friendly Materials

Green and environmental-friendly materials refer to building materials that are produced using clean production technologies, with minimal use or no reliance on natural resources and energy, and with a large amount of industrial or urban solid waste being utilized. These materials are non-toxic, pollution-free, and non-radioactive, and are beneficial to environmental protection and human health [3]. According to their functions and uses, green and environmental-friendly materials can be classified into the following categories.

Structural materials include high-performance concrete, high-strength steel, fiber-reinforced composite materials, etc., which have high strength and durability, and can reduce material usage and the self-weight of structures, thereby reducing energy consumption [4]. For example, high-performance concrete reduces the amount of cement through optimized mix ratios and the addition of mineral admixtures, thereby lowering energy consumption during the production process [5].

Insulation and heat preservation materials include glass wool, foam plastic, rock wool, etc., with low thermal conductivity, which can effectively reduce heat transfer and lower the heating and cooling energy consumption of buildings [6].

Waterproof and sealing materials include water-based waterproof coatings, green waterproof sheets, etc., with excellent waterproof performance and durability, which can prevent water penetration and protect the safety of building structures, reducing energy waste caused by leakage [7].

Decorative and renovation materials include low-volatile organic compound coatings, environmentally friendly wallpapers, natural stone, etc., which are non-toxic and harmless, and can improve indoor air quality, providing a healthy and

comfortable living environment for occupants.
Renewable materials include bamboo, recycled wood, bio-based plastics, etc., which originate from renewable resources, reducing dependence on non-renewable resources and lowering carbon emissions.

2.2 Characteristics of Green and Environmental-friendly Materials

Green and environmentally friendly materials possess the following remarkable characteristics.
Energy efficiency is reflected in the production, usage, and disposal processes of these materials, where they can significantly reduce energy consumption. For instance, high-performance concrete, through optimized mix ratios and the addition of mineral admixtures, reduces the amount of cement used, thereby lowering energy consumption during the production process. Insulation and heat preservation materials can effectively reduce heat loss in buildings, lowering heating and cooling energy consumption.
Environmental friendliness is demonstrated by the use of clean production technologies in the manufacturing process of these materials, which reduces pollutant emissions. During use, they are non-toxic and harmless, and do not pose any harm to indoor environments or human health. After disposal, they can be recycled or naturally degraded, reducing environmental pollution.
Recyclability is reflected in the fact that many green and environmentally friendly materials have good recyclability and reusability. For example, metal materials such as steel and aluminum, as well as some non-metal materials such as plastics and glass, can be recycled and processed after building demolition, and reused in new construction projects, achieving efficient resource utilization [8].
Healthiness is demonstrated by the fact that green and environmentally friendly materials focus on the impact on human health, not containing harmful substances such as volatile organic compounds like formaldehyde and benzene, as well as harmful substances like heavy metals, which can provide a healthy and safe indoor environment for occupants.
Multifunctionality is reflected in the fact that some green and environmentally friendly materials have multiple functions, such as antibacterial, deodorizing, temperature regulation, humidity control, and shielding harmful radiation, which can enhance the overall performance and living comfort of buildings.

3. Key Role of Green and Environmentally Friendly Materials in Energy Saving and Consumption Reduction in Civil Engineering

3.1 Energy Saving and Consumption Reduction during Material Production

Green and environmentally friendly materials focus on efficient utilization of resources and energy conservation during the production stage. By adopting clean production technologies and optimizing production processes, they significantly reduce energy consumption and pollutant emissions.
Efficient resource utilization is reflected in the extensive use of industrial or urban solid waste as raw materials for green and environmentally friendly materials, such as fly ash, slag, waste glass, and waste plastic. This reduces the extraction and consumption of natural resources. For example, fly ash concrete uses fly ash as a substitute for cement, not only reducing the amount of cement used and lowering production costs, but also solving the problem of fly ash storage and achieving the resource utilization of waste.
Low energy consumption is demonstrated by the use of advanced production processes and equipment in the production of green and environmentally friendly materials, improving energy efficiency and reducing energy consumption. For instance, high-performance concrete reduces cement usage and mixing time through optimized mix ratios and the addition of efficient water reducers, thereby lowering energy consumption during the construction process. Insulation and heat insulation materials use low-energy production processes, such as vacuum forming and foaming technology, reducing energy consumption during the production process.
Minimization of pollutant emissions is reflected in the strict control of pollutant emissions during the production of green and environmentally friendly materials, using clean production technologies and environmental protection equipment, reducing emissions of waste gas, wastewater, and waste residue. For example, water-based waterproof coatings use water as the dispersing medium and do not contain organic solvents, reducing the emission of volatile organic compounds. Green waterproof sheets use non-halogen and non-ferrous metal raw materials, reducing environmental pollution.

3.2 Energy Saving and Consumption Reduction during Construction Application

During the construction stage of civil engineering, the application of green and environmentally friendly materials can reduce energy consumption and waste generation during construction, improve construction efficiency and quality, and achieve the goal of energy saving and consumption reduction.
Reducing construction waste is reflected in the recyclability of green and environmentally friendly materials, which can reduce waste generation during construction. For example, using prefabricated building technology, where prefabricated components are produced in the factory and transported to the construction site for assembly, reduces wet work and construction waste. Using recyclable formwork and scaffolding materials, such as aluminum alloy formwork and steel scaffolding, enables recycling and reuse after construction, reducing the use of non-renewable resources like wood.

Improving construction efficiency is reflected in the excellent physical and processing properties of green and environmentally friendly materials, which can increase construction efficiency, shorten construction cycles, and thereby reduce energy consumption. For instance, high-performance concrete has early strength and high strength characteristics, which can accelerate construction progress and reduce the use of formwork and scaffolding. Insulation and heat insulation materials use lightweight and easy-installation designs, reducing labor input and energy consumption during the construction process.

Optimizing construction techniques is reflected in the application of green and environmentally friendly materials, which promotes the optimization and innovation of construction techniques and drives the development of green construction technologies. For example, using the spraying type insulation and heat insulation material construction technique can enhance construction efficiency and insulation effect, and reduce material waste. Using self-leveling floor materials can reduce the manual leveling process and lower energy consumption and labor intensity.

3.3 Energy Conservation and Consumption Reduction during Operation and Maintenance

During the operation and maintenance stage of civil engineering, the application of green and environmentally friendly materials can reduce the operating energy consumption of buildings, improve energy utilization efficiency, and extend the service life of buildings, thereby achieving the goal of energy conservation and consumption reduction.

Reducing building energy consumption is reflected in the application of green and environmentally friendly materials such as insulation and heat insulation materials, which can effectively reduce heat loss in buildings and lower heating and cooling energy consumption. For example, buildings with high-performance insulation and heat insulation materials can reduce heating energy consumption by 20 to 40 percent and cooling energy consumption by 10 to 20 percent. Energy-saving doors and windows can reduce heat transfer through optimized design and the use of low thermal conductivity materials, thereby reducing energy consumption.

Improving energy utilization efficiency is reflected in the application of green and environmentally friendly materials, which promotes the optimization and upgrading of building energy systems and improves energy utilization efficiency. For example, using renewable energy equipment such as solar photovoltaic panels and solar water heaters can convert solar energy into electricity and heat energy to provide clean energy for buildings. Using intelligent temperature control systems and energy-saving lamps, etc., can automatically adjust energy usage according to indoor and outdoor environmental conditions, achieving efficient energy utilization.

Extending the service life of buildings is reflected in the excellent durability and corrosion resistance of green and environmentally friendly materials, which can extend the service life of buildings and reduce energy consumption and resource waste caused by building demolition and reconstruction. For example, structural materials such as high-performance concrete and high-strength steel have high strength and durability, which can resist erosion from natural environments and human factors, extending the service life of building structures. Waterproof sealing materials and decoration and renovation materials have good durability and anti-aging properties, which can maintain the appearance and performance of buildings and reduce the frequency of maintenance and replacement.

3.4 Energy-saving and Consumption Reduction during the Waste Disposal Stage

During the waste disposal stage of civil engineering, the recyclability and reusability of green and environmentally friendly materials can reduce waste generation and environmental pollution, achieving resource recycling and energy-saving and consumption reduction.

Waste recycling and reuse is reflected in the good recyclability and reusability of many green and environmentally friendly materials, such as metals and non-metals like steel, aluminum, and glass, as well as some renewable materials like plastics and wood. These materials can be recycled and processed after building demolition and reused in new construction projects, achieving efficient resource utilization. For example, recycled steel can be used to manufacture new steel structural components. Recycled glass, after melting, can be used to manufacture new glass products.

Waste natural degradation is demonstrated by the use of degradable raw materials in some green and environmentally friendly materials, such as biobased plastics and natural fibers, which can naturally degrade in the natural environment, reducing environmental pollution. For example, biobased plastics are made from renewable biological resources, such as starch and cellulose, and can be decomposed by microorganisms into carbon dioxide and water, causing no long-term pollution to the environment.

Waste resource utilization is reflected in the fact that the waste from green and environmentally friendly materials can be transformed into useful resources through resource utilization technologies. For instance, crushing concrete blocks and bricks from construction waste for use in road base laying, and processing waste wood into wood chips for biomass energy production, achieve waste resource utilization and energy-saving and consumption reduction.

4. Strategies for Promoting the Application of Green and Environmental-friendly Materials in Civil Engineering

4.1 Strengthening Policy Guidance and Support

The government should introduce relevant policies to encourage and support the application of green and environmental-

friendly materials in civil engineering. For instance, establishing a green building material certification system and standards, providing tax incentives, financial subsidies, etc. as policy support for green and environmental-friendly materials that meet the standards. Incorporating the application of green and environmental-friendly materials into the evaluation standards for green buildings and energy conservation and emission reduction assessment systems, and granting bonus points or rewards to building projects that adopt green and environmental-friendly materials. Strengthening supervision of green and environmental-friendly material production enterprises, regulating market order, and ensuring the quality and performance of green and environmental-friendly materials.

4.2 Enhancing Market Awareness and Acceptance

Strengthening the publicity and promotion of green and environmental-friendly materials to increase market awareness and acceptance of these materials. Through organizing green building material exhibitions, technical exchange meetings, etc., showcasing the performance and advantages of green and environmental-friendly materials, promoting exchanges and cooperation between green building material producers and construction enterprises, design units, construction units, etc. Enhancing publicity and education for consumers, guiding consumers to establish a green consumption concept and prioritize the use of building products made with green and environmental-friendly materials.

4.3 Strengthening Research and Development and Innovation

Increasing investment in the research and development and innovation of green and environmental-friendly materials, promoting continuous progress and upgrading of green and environmental-friendly material technologies. Encouraging research institutions, universities, and enterprises to carry out industry-university-research cooperation, jointly solving key technical problems in the production and application of green and environmental-friendly materials, and developing new products and new technologies with independent intellectual property rights for green and environmental-friendly materials. Strengthening research and testing of the performance and quality of green and environmental-friendly materials, establishing a complete performance evaluation system and quality inspection standards for green and environmental-friendly materials to ensure the quality and performance of green and environmental-friendly materials.

4.4 Cultivating Professional Talent Pool

Strengthening the cultivation of professionals related to green and environmental-friendly materials, improving the professional quality and skills of practitioners. Setting up related professional and course programs in universities and vocational schools to cultivate professionals with the ability to produce, apply, and manage green and environmental-friendly materials. Enhancing training and continuing education for practitioners in construction enterprises, design units, construction units, etc., to improve their understanding and application ability of green and environmental-friendly materials, promoting the wide application of green and environmental-friendly materials in civil engineering.

5. Conclusion

Green and environmentally friendly materials play a crucial role in energy conservation and cost reduction in civil engineering. They are involved throughout the entire life cycle of civil engineering, from material production, construction application, operation and maintenance to waste disposal. They can significantly reduce energy consumption and carbon emissions, reduce environmental pollution, and enhance the overall performance and service life of buildings. Promoting the application of green and environmentally friendly materials in civil engineering is an inevitable choice for achieving the green, low-carbon and sustainable development of the civil engineering industry. Government, enterprises, research institutions and all sectors of society should work together, strengthen policy guidance and support, increase market awareness and acceptance, enhance technological research and innovation, cultivate professional talent teams, and promote the wide application of green and environmentally friendly materials in civil engineering, so as to contribute to building a resource-conserving and environment-friendly society

References

[1] Li, Y. L., Han, M. Y., Liu, S. Y., & Chen, G. Q. (2019). Energy consumption and greenhouse gas emissions by buildings: A multi-scale perspective. Building and Environment, 151, 240-250.

[2] Zhao, H., Wang, Y., Qiu, W., Qu, W., & Zhang, X. (2018, September). Research on the application of green building materials in China. In IOP Conference Series: Earth and Environmental Science (Vol. 186, No. 2, p. 012043). IOP Publishing.

[3] Zajemska, M., Wojtyto, D., Michalik, J., & Berski, S. (2025). Review of current trends in sustainable construction. Energies, 18(10), 2559.

[4] Kynclova, M., Fiala, C., & Hajek, P. (2011). High performance concrete as a sustainable material. International Journal of Sustainable Building Technology and Urban Development, 2(1), 63-68.

[5] Mohamad, N., Muthusamy, K., Embong, R., Kusbiantoro, A., & Hashim, M. H. (2022). Environmental impact of cement

production and Solutions: A review. Materials Today: Proceedings, 48, 741-746.

[6] Talib, R. B., & Sulieman, M. Z. (2020, September). How green are our waterproofing materials? towards practicing sustainable building defects. In AIP Conference Proceedings(Vol. 2267, No. 1, p. 020016). AIP Publishing LLC.

[7] Farghaly, T. A. (2003). Improving indoor air quality. Alexandria Engineering Journal, 42(4), 483-495.

[8] Srour, I. M., Chehab, G. R., & Gharib, N. (2012). Recycling construction materials in a developing country: four case studies. International Journal of Engineering Management and Economics 2, 3(1-2), 135-151.