Dean&Francis

ISSN 2959-6157

Research Progress on Green Building Materials in Civil Engineering

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Abstract:

Amidst growing environmental concerns, the push for energy conservation and recycling is gaining momentum across all industries. In the construction sector, green building materials are gaining popularity due to their eco-friendliness, lack of pollution, lower energy consumption, and cost-effectiveness. These materials not only cut costs but also play a role in ecological restoration in practical applications, making them a cornerstone in the transition towards sustainable construction practices. This study delves into the essential features and categorization of green building materials and analyzes their implementation in construction projects. It highlights how these materials, such as autoclaved aerated concrete, Aerogel Composite and fly ash bricks contribute to the reduction of a building's carbon footprint and enhance indoor environmental quality. By selecting the appropriate eco-friendly materials, we can bolster the ecological and energy-saving aspects of construction endeavors, leading to buildings that are not only structurally sound but also environmentally responsible. The adoption of green building materials is pivotal in reducing energy usage, maintaining ecological balance, and fostering the sustainable development of the socio-economic framework. As these materials become more prevalent, they offer solutions that are aligned with the global goals of reducing greenhouse gas emissions and conserving natural resources. The integration of green building materials into architectural design and construction is a significant step towards creating a built environment that is healthier for occupants and less harmful to the planet. Furthermore, the ongoing research and development in the field of green building materials are leading to innovations that improve the performance and reduce the environmental impact of construction even further. This includes the use of renewable materials, recyclable components, and materials with a lower lifecycle assessment impact. The future of construction is poised to be more sustainable, with green building materials at the forefront of this transformation, driving industry standards towards greater environmental responsibility and efficiency.

Keywords: Green Building Materials, Wall Materials, Decorative and Finishing Materials, Environmental Protection and Energy Saving

1. Introduction

Architecture is a fundamental place for human living and production, and it is also the foundation of cities. As the world's population gradually increases, its planning, construction, and operation directly affect the consumption of resources and energy. In this context, the high energy consumption and environmental pollution issues of traditional building materials are becoming increasingly prominent. Therefore, effectively reducing the consumption of energy resources during construction, alleviating the ecological environmental pollution it causes, and transforming the high consumption of traditional building materials into more efficient use is particularly important. The emergence of green new building materials plays a crucial role in the sustainable development of society. Consequently, green buildings have gained widespread support against this backdrop and have become the trend for the future development of the construction industry.

Over the years, domestic research institutions and production enterprises have carried out a large amount of research and development work, producing a large number of green building materials. Many energy-saving and consumption-reducing production processes, equipment, and technologies have emerged. Green building materials that can improve people's health levels and living environments have begun to be applied in various fields. Relevant building material products are also continuously developing and improving. National quality inspection and supervision departments and environmental protection departments have introduced a series of standards and regulations to strictly limit the emission of pollutants from the building materials industry and to limit harmful substances in decoration materials, etc. These measures have strongly promoted the development of green building materials in China and improved the overall level of green building materials development in China[1].

However, there are still some problems in the development of green building materials in China. First, although green building materials have developed rapidly in China in recent years, the overall publicity is not enough, and green building materials have not received enough attention from consumers in their promotion and application[2]. Secondly, the promotion of green building material technology applications in China is relatively less, resulting in non-standard technical standards, which have caused troubles for engineering design and construction departments. Based on this, this study studies the advantages of different new materials in application.

2. Introduction to green building materials

2.1 New Wall Materials

The performance of wall materials directly affects the stability of the building structure. Traditional wall materials are mainly composed of cement, concrete blocks, and other materials. However, the production process of these materials generates a large amount of carbon dioxide and other greenhouse gases, contributing to global warming. It also produces a significant amount of harmful gases such as nitrogen oxides and sulfur dioxide, as well as industrial wastewater, causing great harm to human health and the environment.

Nowadays, a large number of construction projects have begun to use green building materials. Due to their excellent performance, the use of green building materials can not only ensure the quality and safety of the building but also reduce the environmental impact of the project.

Since the application of new wall materials in construction is very large, from the perspective of sustainable development, the raw materials used for the production of new wall materials should be more economical, more environmentally friendly, more easily accessible, and renewable.

Table 1. Classification of Wall Materials

Classification	Material Name
Brick Types	Autoclaved Aerated Concrete Sand Brick, Fly Ash Brick, Calcined Coal Gangue Brick, Calcined Fly Ash Brick
Block Types	Autoclaved Aerated Concrete Block, Concrete Small-Sized Hollow Block, Foam Concrete Block, Gypsum Block
Panel Types	Paper-faced Gypsum Board, Fiber Gypsum Board, Gypsum Hollow Block, Glass Fiber Reinforced Cement Board

2.2 Thermal Insulation Materials

Thermal insulation materials play a primary role in insulation within construction projects, effectively improving residents' living conditions and reducing energy consump-

ISSN 2959-6157

tion. In China, traditional thermal insulation materials such as asbestos, rock wool, glass wool, and polystyrene boards still hold a significant market share. Although some of these materials are considered green building materials and are relatively environmentally friendly, they can also generate harmful substances during production and installation, posing risks to human health.

For instance, polystyrene boards are made by heating and expanding polystyrene, which, despite being a green building material, can produce harmful gases when heated and may affect human health with long-term exposure. Asbestos is a known carcinogen, and its production, processing, and use can generate tiny asbestos fiber dust, which, when inhaled, can cause severe health damage to the lungs and the entire body, affecting respiratory function.

In recent years, China has begun to use some new types of thermal insulation materials, such as aerogel composite materials, nano ceramics, and foam plastics. These new materials have the advantages of lower thermal conductivity, better insulation effects, light weight, low water absorption, good chemical stability, and ease of construction. Aerogel composite materials, for example, are lightweight and have low thermal conductivity, effectively blocking infrared radiation and heat conduction with an insulation efficiency of about 90%. Nano ceramics and foam plastics are also applied in the field of thermal insulation due to their unique properties, offering more efficient and environmentally friendly solutions.

Among them, aerogels are used in a wide range of scenarios. Aerogels are lightweight solid materials with a three-dimensional network nano-porous structure formed by nanoparticles or polymer molecules as the skeleton. They possess excellent characteristics such as ultra-low density, nanoscale pore diameter, low thermal conductivity, and high porosity, and are widely used in thermal insulation, energy conservation, and consumption reduction. Aerogel insulation materials are prepared by combining aerogel materials with fibrous substrates, offering significant performance advantages and gradually replacing traditional insulation materials [3]. Nano ceramics and foam plastics are also applied in the field of thermal insulation due to their unique properties, offering more efficient and environmentally friendly solutions.

2.3 Decorative and Finishing Materials

Architectural decoration and finishing is essentially the process of carrying out construction work on the interior and exterior surfaces of a building after the completion of the project to enhance aesthetics and comfort. It ensures that the building meets the owner's aesthetic preferences, satisfies the actual usage needs under different conditions, and improves the overall cleanliness of the building. At the same time, it also serves to protect the building to a certain extent, increasing its durability and extending its practical lifespan [4].

Table 2.Classification of Decorative and Finishing Materials

Classification	Material Name
Flooring Decorative Materials	Bamboo and Wood Flooring, Natural Rubber Flooring, Polyvinyl Chloride Plastic Flooring
Paints and Coatings	Water-based Paints, Inorganic Paints
Glass Products	Heat-insulating Glass, Low-Emissivity Glass
Ceiling Decoration Materials	Soft Membrane Ceiling Materials, Ultra-microporous Honeycomb Acoustic Absorption

3.Green Building Materials in Engineering Applications

3.1 New Wall Materials

3.1.1 Brick Types

Autoclaved aerated concrete sand bricks are made from sand and lime as the main raw materials, going through three steps: raw material preparation, pressing and molding, and autoclaved curing to form the bricks. They are characterized by their smooth and even appearance, high strength, and minimal size deviation. Autoclaved aerated concrete sand bricks are widely used in the foundations and walls of industrial and civil buildings.

With the recent national efforts to innovate wall materials and the increased "ban on solid bricks", aerated concrete sand bricks, as one of the new wall materials encouraged for development, have seen rapid growth. For example, dozens of production lines have been established in Wenzhou, Zhejiang, and Huanggang, Hubei, and more than 100 production lines have been built in Guangdong. In addition, production lines have also been set up in Guangxi, Yunnan, Fujian, Henan, and other places, with the national annual production capacity of aerated concrete sand bricks reaching nearly 20 billion pieces.

Fly ash bricks are made using cement, fly ash, or lime as the main raw materials, supplemented with an appropriate

amount of gypsum, additives, pigments, and aggregates, and are formed into solid bricks through raw material preparation, molding, and high-pressure or atmospheric pressure steam curing. Fly ash bricks can be used in the foundations and walls of industrial and civil buildings [5].

3.1.2 Block Types

Autoclaved Aerated Concrete blocks are primarily made from siliceous materials and use a gas-generating agent that reacts with chemical components in the slurry to produce gas. Through processes such as mixing, casting, resting, cutting, high-pressure curing, and demolding, they form lightweight, porous silicate products. AAC blocks are the only single-wall material that can meet different energy-saving targets. As a new type of wall material, they possess excellent load-bearing and thermal insulation functions. Due to the differences in product structure and material properties, they offer advantages such as durability, lightweight fire resistance, water resistance, earthquake resistance, ease of construction, cost-effectiveness, and energy conservation [6].

Concrete small hollow blocks are a type of block material with a certain degree of hollowness, made from cement as the binding material and mixed with sand, stone, and other materials. Firstly, they offer high construction efficiency, ease of laying, good thermal performance, smooth wall surfaces, good seismic performance, and light weight. They are generally used for non-load-bearing walls and can also be used for load-bearing walls in multi-story buildings with higher strength-grade blocks. Secondly, their raw materials can include some industrial slag and abundant domestic lightweight aggregates, which can reduce the production cost of the blocks and minimize environmental pollution, achieving good social and economic benefits. However, this method of production also has some disadvantages, such as difficulty in processing, susceptibility to damage, and proneness to shrinkage and deformation [7].

3.1.3 Panel Types

Paper-faced gypsum board is made with building gypsum as the main raw material, mixed with an appropriate amount of additives and fibers for the core, and covered with specially made paper on both sides. It is processed into a panel with good insulation, soundproofing, sound absorption, and fire-resistant properties. Moreover, paper-faced gypsum board partitions are the lightest in weight among all lightweight wall materials. When the wall thickness is 100mm, the weight is only 23kg/m^2, while the weight of an aerated concrete wall of the same thickness is 50kg/m^2-70kg/m^2, which is 2-3 times that of the gypsum board partition. If blocks made of other materials are used, the weight will be even greater. At the same time, paper-faced gypsum board also has a certain breathing function, which can slightly adjust the humidity of the indoor air and improve the comfort of the indoor environment.

Fiber-reinforced gypsum board is a new type of building board mainly made from building gypsum powder and various fibers as reinforcing materials. Compared with paper-faced gypsum board, fiber-reinforced gypsum board has the advantages of more uniform structure and higher strength. An 8mm thick fiber-reinforced gypsum board can match the performance of a 10mm thick paper-faced gypsum board. In application, the strength can be greatly exceeded by increasing the thickness of the fiber-reinforced gypsum board. Fiber-reinforced gypsum board is mainly used for interior partition walls and indoor decoration, and has the following advantages in performance: good thermal and acoustic insulation; light weight; easy to construct; flexible to use; novel and beautiful decoration; energy-saving and environmentally friendly; and adjustable indoor humidity, etc. [8].

3.2 Thermal Insulation Materials

3.2.1 Aerogel Composite Materials

Aerogel composite materials possess exceptionally superior properties, gradually replacing traditional building materials due to their extremely low thermal conductivity, good thermal stability, high strength, and durability.

In regions with extreme cold and hot climates, thermal insulation of interior walls is a key factor in maintaining indoor temperature and comfort. Aerogel composite materials can be used as a thermal insulation layer for interior walls. Because of their light and thin characteristics, they do not add to the weight of the walls or occupy indoor space like traditional insulation materials. Moreover, aerogel composite materials can be combined with other materials to provide a strong and effective thermal insulation layer for the interior of buildings [9].

Aerogel composite materials are also extremely common in exterior wall insulation. Using aerogel composite materials can reduce the burden on walls. Due to their excellent properties, the insulation layer on the walls can be thinner while offering better thermal insulation performance. Applying aerogel composite materials in the form of panels or coatings on the roof surface can also effectively reduce the thermal bridge effect and improve the overall thermal insulation of the house. In terms of performance, in addition to considering the flow of heat, sound, moisture, and fire safety issues must also be taken into account. Aerogel composite materials, due to their stable structure and certain sound insulation capabilities, are often used in situa-

ISSN 2959-6157

tions requiring additional sound control, such as recording studios, conference rooms, etc [10].

In the renovation or transformation projects of old buildings, aerogel composite materials can be used as an additional thermal insulation layer for existing walls. Due to their good compatibility, aerogel composite materials can be combined with various traditional building materials. For example, they can be embedded in brick or concrete walls to improve the thermal insulation performance of the building [11].

3.2.2 Inorganic thermal insulation mortar

Inorganic thermal insulation mortar is superior in performance, offering a broad application range, low cost, high strength, and enhanced safety. It can be applied directly to rough walls, using simple machinery and tools, and is easy to construct with a short construction period and controllable quality. This mortar is suitable for various wall materials and complex shapes, providing full coverage without seams or cavities to prevent thermal bridges. It's versatile for both external and internal wall insulation, as well as for roofs and geothermal heat insulation.

The material ensures high bond strength with the base layer, avoiding cracks and voids, and has excellent fire resistance, making it suitable for dense residential areas, public buildings, and places with strict fire safety requirements. It can also serve as a fire barrier to enhance building fire standards.

4.Summary

Green building materials are designed with environmental sustainability and energy efficiency in mind, causing less impact on the environment. This article has highlighted the current applications of three categories of innovative green materials: wall materials, 1, and decorative and finishing materials. These materials are instrumental in lessening the environmental footprint of buildings, enhancing the comfort and healthiness of living spaces. With ongoing technological advancements, their usage is anticipated to expand significantly in the future.

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