Green Building Materials and Technologies

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Abstract: Against the backdrop of increasingly severe global environmental issues, green building materials and technologies, as a key area of sustainable development, have rapidly become a research focus for numerous scholars. This paper centers on green building materials and technologies, aiming to systematically review existing developments and applications by clarifying the current state of these technologies. The review is structured around three technical directions: passive green building technologies, active green building technologies, and green building materials. It summarizes existing problems and challenges within the construction industry regarding green buildings and further prospects for the future development of green building materials and technologies.

Keywords: Green Building; Green Building Materials; Passive Technology; Active Technology; Sustainable Development

1. Introduction

With the growing severity of the global energy crisis and environmental degradation, the traditional construction industry faces significant challenges related to energy consumption and environmental pollution. In this context, green building, as a construction form that can effectively reduce energy consumption and environmental pollution, makes its research and application particularly important. Research results can guide the design and implementation of green buildings, thereby effectively addressing the energy crisis and environmental degradation, improving building energy efficiency, reducing carbon emissions, and promoting the transition of the construction industry towards low-carbon and environmental protection. As an important component of smart cities, green buildings will play a crucial role in enhancing urban energy efficiency and improving residents' quality of life. This study employs literature analysis and summary induction methods to systematically explore the application of green building technologies, aiming to comprehensively summarize key technologies in the field of green building, ensure the review's comprehensiveness, avoid omitting important technical points, select representative green building application examples to ensure the universality and reference value of cases, and seek universal guiding principles and practical paths for the application of green building materials and technologies[1].

Based on the key technologies used in green buildings, relevant research is categorized into the following three types: passive green building technologies, active green building technologies, and green building materials. Accordingly, the paper's structure is divided into five chapters. Chapter 1 is the introduction, covering the research background, significance, and methods, providing the overall framework and research foundation for the entire paper. Chapter 2 focuses on passive green building technologies, emphasizing key technologies such as climate-adaptive design and natural energy utilization, and discusses the application methods and effectiveness of these technologies in green buildings. Chapter 3 elaborates on active green building technologies, which include high-efficiency energy-saving systems, renewable energy utilization, intelligent environmental control systems, and water resource management. These technologies play a role in enhancing building energy efficiency and environmental performance. Chapter 4 discusses the development status of green building materials, mentioning the key role of green materials, including phase change materials, low-carbon materials, functional materials, and environmentally friendly coatings. Finally, Chapter 5 analyzes the current problems and future development directions of green buildings and provides an outlook[2].

2. Principles and Specific Applications of Passive Green Building Technologies

Passive energy-saving technology typically refers to achieving building energy savings and consumption reduction without mechanical intervention, effectively utilizing architectural design methods and natural conditions. The characteristics of passive energy-saving technology are high design requirements and low technical requirements. Its main application scenarios involve climate-adaptive design and the utilization of natural energy during green building design. For example, it is essential to design building orientation and ventilation properly, utilize passive solar energy, achieve passive energy savings for external walls and roofs, implement shading settings and natural lighting, and subsequently optimize the building envelope to achieve energy savings and consumption reduction in green buildings[3].

2.1 Building Orientation and Layout Design

Building orientation and layout design form the foundation of passive green building technology. The core objective is to fully utilize natural conditions such as sunlight and wind direction through reasonable spatial organization and orientation arrangement, optimize the internal thermal environment of the building, enhance lighting and ventilation effects, and ultimately reduce dependence on artificial energy. The choice of building orientation needs to be based on solar radiation and wind direction frequency. Buildings in cold regions should prioritize a south-facing orientation to obtain more sunlight in winter. Layout design must combine terrain, surrounding buildings, and vegetation distribution to ensure optimal climate adaptability[4]. For instance, buildings in mountainous or hilly areas arranged along the terrain can form natural wind channels to enhance ventilation; in densely built urban areas, it is necessary to balance building spacing and arrangement to meet both shading and ventilation needs. Research shows that reasonable building group layouts can effectively alleviate local heat island effects and improve microclimates. It is a key aspect of achieving building energy savings, environmental protection, and sustainable development, enhancing the building's environmental adaptability, and creating comfortable and healthy spaces for users[5].

2.2 Thermal Buffer Zone Design

Thermal buffer zone design is an important component of passive green building technology. The core objective is to regulate internal temperature changes in buildings through reasonable spatial layout and material selection, reducing dependence on artificial energy. Thermal buffer zones refer to transitional spaces on the periphery or inside buildings (such as porches, courtyards, balconies, mezzanines, etc.) that can isolate the external and indoor environments, reduce direct heat transfer, and achieve internal microclimate regulation. Their design needs to integrate building spatial layout and usage functions: in residential buildings, thermal buffer zones serve as transitional spaces between indoors and outdoors, accommodating privacy, lighting, and ventilation; in public buildings, they often function as reception or rest areas, enhancing the user experience. Thermal buffer zones significantly improve building energy efficiency. Properly setting up thermal buffer zones can reduce building energy consumption, with particularly notable energy-saving effects during winter heating seasons. Additionally, thermal buffer zone design must consider material selection and structural optimization, such as planting green belts on the periphery or arranging water landscapes to improve the surrounding microclimate. Future architectural design should strengthen the exploration of thermal buffer zone applications to promote the development of green building technology[6].

2.3 Natural Energy Utilization

2.3.1 Natural lighting: Passive solar utilization, light guide fiber applications, reflectors, shading devices

Natural lighting is a crucial aspect of passive green building technology. By optimizing building structure and materials, it fully utilizes sunlight for indoor lighting, reducing reliance on artificial light sources and energy consumption. It primarily employs four methods: passive solar utilization, light guide fibers, reflectors, and shading devices, which collectively optimize indoor lighting quality and thermal environment to achieve energy savings and comfort goals.

Light guide fiber systems are suitable for areas with insufficient lighting, such as underground spaces and corridors. Comprising three parts-collectors, transmission pipes, and distributors-they efficiently deliver natural light deep into buildings to meet indoor lighting needs. Research shows that this system can significantly reduce artificial lighting energy consumption. "Application and Development of Green Building Materials in Residential Buildings" mentions that buildings using light guide fiber systems can reduce lighting energy consumption by over 40%; moreover, its installation is flexible, and maintenance costs are low, making it widely used in modern green buildings.

Reflective devices (e.g., reflectors) installed on roofs, walls, or ceilings can reflect external sunlight indoors, improving lighting efficiency. Especially in high-rise buildings or densely built areas, they can effectively alleviate insufficient natural light.

Shading devices are used to cope with strong summer sunlight, blocking excessive solar radiation from entering indoors (avoiding indoor temperature rise and increased air conditioning load). They mainly include three types: external shading (louvers, awnings), internal shading (curtains, roller blinds), and structural shading (eaves, shading panels). They can regulate indoor temperature, reduce glare, and enhance visual comfort. "Application of Green Building Materials in Construction Engineering Technology" points out that reasonable installation of shading devices can reduce building summer air conditioning energy consumption by 25% to 35%; some intelligent shading systems can automatically adjust the angle according to the sun's position, resulting in even better energy-saving effects[7].

2.3.2 Natural ventilation: utilizing wind pressure and stack effect principles for air circulation

Natural ventilation is a commonly used air conditioning method in passive green buildings. It relies on two physical effects-wind pressure and stack effect-to promote indoor air flow, optimizing air quality, reducing energy consumption, and enhancing living comfort without relying on mechanical equipment. The two principles are often used in combination.

Wind pressure ventilation relies on wind speed differences on the building's external surfaces to form a pressure difference (windward side high pressure, leeward side low pressure), causing air to flow from high-pressure to low-pressure areas and driving indoor air movement. To enhance the effect, designs often adopt a "through ventilation" form, setting inlet and outlet vents on both sides of the building. Simultaneously, by adjusting the opening degree, height, and area of windows, the airflow trajectory is optimized, and air exchange efficiency is improved.

Stack effect ventilation relies on the buoyancy effect generated by temperature differences: high-temperature air has low density and rises naturally, while low-temperature air has high density and sinks downward, forming a vertical air circulation inside the building. It is suitable for high-rise buildings and spacious areas. Its effectiveness depends on the indoor temperature difference and the smoothness of the ventilation path. Design must ensure a coherent ventilation path, and the size and position of ventilation openings must meet the demands of stack effect driving[8].

3. Active Green Building Technologies

Active energy-saving technology primarily involves the collection, storage, or efficient use of unconventional energy through mechanical, electrical, plumbing, and HVAC equipment, such as ground-source heat pump air conditioning systems that use geothermal energy as a heat source. The characteristics of this energy-saving method are that building equipment operates mainly actively, the operation process is relatively less constrained by environmental conditions, but the requirements for operating equipment are high, and conventional energy is still needed to drive the equipment during operation[9].

3.1 High-Efficiency Energy-Saving Systems: Air Conditioning Systems, LED Lighting, Intelligent Shading Systems

High-efficiency energy-saving systems are an important component of active green building technology. The core goal is to reduce building energy consumption and improve energy utilization efficiency through cutting-edge technology while ensuring indoor environmental comfort. In modern green buildings, commonly used active energy-saving systems mainly include air conditioning systems, LED lighting, and intelligent shading systems. These technologies are key ways to achieve energy saving and emission reduction.

The application of air conditioning systems in green buildings is targeted: high-efficiency variable frequency air conditioning systems can sense changes in indoor load and automatically adjust operating power to reduce energy waste; ground-source heat pump systems utilize the constant temperature of underground soil for winter heating and summer cooling, with significantly higher energy efficiency than ordinary air-source heat pump systems. If equipped with smart control systems such as Building Automation Systems (BAS), air conditioning systems can supply energy on demand, reduce redundant operating time, further improve energy utilization efficiency, and reduce the total energy consumption of the air conditioning system[10].

LED lighting systems are representative energy-saving technologies in green buildings, with significant energy-saving effects compared to traditional incandescent and fluorescent lamps. Their lighting efficiency is superior, and their long service life reduces the frequency of lamp replacement, lowering resource waste and maintenance costs. Research data shows that LED lighting energy consumption is only 1/5 to 1/10 of traditional lighting methods, with luminous efficacy reaching 100-150 lumens/watt, far exceeding traditional light sources. They are now commonly used in green building projects. Paired with intelligent dimming control technology, they can achieve on-demand lighting. Some buildings install human motion sensors and light intensity detection devices; LED lighting systems can automatically adjust brightness according to human activity and natural light changes, achieving an energy saving rate of over 40%.

Intelligent shading systems are important technologies for achieving active energy savings in green buildings. They regulate the amount of solar radiation entering indoors, reducing air conditioning load and optimizing lighting conditions. The system includes electric louvers, shading blinds, photoelectric sensing shading panels, etc., which can automatically adjust the shading angle or opening degree according to outdoor solar radiation intensity and indoor temperature changes. In some buildings, intelligent shading systems can reduce indoor summer temperature by 2-3°C, shorten air conditioning operation time, and reduce energy consumption. Applying them in synergy with natural lighting design can make indoor light distribution more uniform, reduce occupants' reliance on artificial lighting, and improve building energy efficiency. Studies show that buildings using intelligent shading systems can reduce annual lighting and air conditioning energy consumption by 10%-18%.

3.2 Renewable Energy Utilization: Solar Photovoltaic Systems, Solar Water Heating Systems, Wind Power Generation Systems

Renewable energy utilization is an important component of active green building technology and a key method for achieving building energy self-sufficiency and reducing carbon emissions. Among them, solar photovoltaic systems, solar water heating systems, and wind power generation systems are widely used. These technologies convert renewable energy from nature into usable electricity or heat within buildings, reducing dependence on traditional fossil fuels.

Solar photovoltaic systems are currently one of the most mature and widely used renewable energy technologies. They directly convert solar radiation into electricity through photovoltaic components. Statistics show that in most regions of China, the average annual power generation efficiency of photovoltaic systems is 15%-20%; in some areas with abundant sunshine (such as southern China), it can reach 25%. Rooftop photovoltaic systems generate about 120 kWh per square meter per year; using high-efficiency monocrystalline silicon panels can further increase power generation. Meanwhile, the cost of photovoltaic components continues to decline, significantly improving the economic feasibility of photovoltaic power generation. In recent years, the cost per kWh has approached or even fallen below the cost of traditional grid power.

Solar water heating systems are mainly used to meet daily hot water needs in buildings. Composed of collectors, storage tanks, circulation pumps, etc., they heat water by absorbing solar radiation heat. Data indicates that in areas with an annual average sunshine time exceeding 2000 hours, a standard solar water heating system can provide 3000-5000 liters of hot water per year, equivalent to saving 1500-2500 kWh of electricity. Applying this system in residential buildings can significantly reduce users' energy expenses and greenhouse gas emissions, offering outstanding environmental benefits.

Wind power generation systems are suitable for areas rich in wind resources (such as coastal areas, plateaus, and hilly regions). Modern small wind turbines mostly have capacities ranging from several kilowatts to tens of kilowatts, which can meet the partial electricity demand of small and medium-sized buildings. In remote areas or rural buildings, wind power generation systems often operate in conjunction with photovoltaic power generation systems, forming a complementary renewable energy supply system.

In practical engineering, solar photovoltaic systems, solar water heating systems, and wind power generation systems usually work together, managed uniformly through intelligent control systems to achieve reasonable energy allocation and efficient utilization. For example, building intelligent microgrid systems can automatically adjust the operation mode of each system according to weather changes and energy demand, improving energy utilization efficiency; some systems have bidirectional interaction functions with the grid, allowing excess electricity to be fed back into the grid, while energy storage regulation can enhance the building's energy self-sufficiency capability. Several advanced building projects use lithium battery energy storage systems to store electricity generated during the day for use at night or on cloudy days, ensuring continuous building energy supply[11].

3.3 Intelligent Environmental Control Systems: Building Automation Systems (BAS), Smart Home Systems

Intelligent environmental control systems are an important part of active green building technology, promoting efficient energy use in buildings, optimizing living comfort, and reducing operating costs. These systems integrate modern information technology, automatic control technology, and communication network technology, enabling centralized monitoring and management of subsystems within buildings such as air conditioning, lighting, ventilation, plumbing, and security, making the overall operation of buildings smarter, more energy-efficient, and more user-friendly.

The Building Automation System (BAS) is the core of intelligent environmental control systems. It automatically adjusts according to preset control strategies by collecting real-time data from various sensors, keeping the building environment in an optimal state. BAS applications are typically divided into three parts: a central control station, regional controllers, and field actuators. The central control station is responsible for analyzing global data and making decisions; regional controllers focus on control tasks in specific areas; field actuators integrate various sensors such as temperature and humidity sensors, carbon dioxide concentration sensors, wind speed sensors, as well as execution agencies like electric valves and fan coil units, integrated into the control system through fieldbus or wireless communication technology, forming a complete closed-loop feedback mechanism.

Smart home systems are mainly used in residential buildings, enabling the linkage of intelligent devices in homes, precisely adjusting indoor temperature, humidity, air quality, and light intensity, balancing living comfort and energy savings. Their core functions include smart lighting, smart temperature control, smart security, and smart appliance control: smart lighting can sense the intensity of natural light and user routines, automatically adjusting light brightness and color temperature; smart temperature control is equipped with smart thermostats and remote control modules, enabling precise control of air conditioning and floor heating; smart security integrates access control, video surveillance, and intrusion alarm functions, enhancing home security. Additionally, smart home systems can link with devices such as smart curtains, smart speakers, and smart appliances, making the home a highly integrated smart living space[12].

3.4 Water Resource Management Systems: Rainwater Harvesting Systems, Greywater Reuse Systems

Water resource management is a key component of the green building technology system, aiming to improve water efficiency, reduce municipal water supply demand, and decrease sewage discharge. In active green building technology, rainwater harvesting systems and greywater reuse systems together constitute the water resource management system, achieving water recycling and enhancing building sustainability.

Rainwater harvesting systems collect rainfall from roofs and ground surfaces. After purification and storage treatment, the water is used for irrigation, road cleaning, and toilet flushing. Greywater reuse systems treat household wastewater to meet reuse standards, then use it for cooling water and landscape water. The combined application of these two systems can significantly reduce building water consumption.

The design of greywater reuse systems requires a comprehensive assessment of building type, water demand, and wastewater treatment capacity. Conventionally, they consist of a pretreatment unit, a main treatment unit, and an advanced treatment unit: pretreatment removes large particles and impurities through screens and grit chambers; main treatment uses activated sludge or membrane separation technology; advanced treatment removes residual pollutants to ensure water quality meets standards. Different building types have different needs for greywater reuse systems: in office buildings, greywater is mainly used for toilet flushing and air conditioning cooling; in residential buildings, greywater is mostly used for car washing and irrigation. Design needs to configure the system according to specific uses to improve operational efficiency and economy. "Application of Green Building Materials in Construction Engineering Technology" points out that the investment payback period for greywater reuse systems is typically 3-5 years, and this period is gradually shortening with technological progress and reduced equipment costs[13].

4. Advances in Green Building Materials

Green building materials refer to materials that have minimal negative impact on human health and the environment during production and use, while also having certain positive impacts. They mainly include phase change materials, low-carbon materials, functional materials, and high-environmental-performance coatings.

4.1 Core Role of Green Materials

4.1.1 Energy saving, carbon reduction, and resource recycling

Green building materials are key to energy saving and carbon reduction in the construction industry, mitigating the drawbacks of high energy consumption and high carbon emissions of traditional building materials. By optimizing formulas and using renewable resources (e.g., low-carbon cement, recycled aggregate concrete), they can reduce carbon emissions per unit volume while improving building durability and promoting sustainable resource utilization.

4.1.2 Function optimization and performance enhancement

Green building materials combine comfort, durability, and energy efficiency: phase change materials can regulate indoor temperature (reducing by 2-3°C in summer, providing insulation in winter); aerogel composite insulation boards (thermal conductivity <0.015 W/(m·K)) enhance insulation; porous sound-absorbing materials (sound absorption coefficient above 0.8) effectively reduce noise; nano-silicon-based waterproof coatings have a waterproof effect exceeding 10 years; permeable paving (permeability rate 1.5 mm/s) alleviates urban waterlogging; self-healing concrete has a crack repair rate exceeding 70%; photovoltaic facades save 30% energy; smart dimming glass saves 20%-30% energy, comprehensively optimizing the overall performance of buildings.

4.1.3 Economic and social value

Economically, green building materials reduce the whole life cycle cost of buildings: during the operation phase, insulation materials and low-energy consumption glass reduce heating energy consumption by 20%-30% and air conditioning energy consumption by 15%-25%; during the construction phase, prefabricated components reduce comprehensive costs by 10%-15%. In terms of social value, they promote the transformation of the construction industry, optimize urban ecology (reducing waste, improving resource recycling rates), and also drive employment in R&D, production, and other fields. The introduction of relevant standards and specifications in China further ensures their quality and aids the sustainable development of the construction industry.

4.2 Green Building Materials

4.2.1 Phase change materials (PCM)

Phase Change Materials (PCM) absorb or release large amounts of latent heat during phase change processes within specific temperature ranges. They are widely used in green buildings to improve energy utilization efficiency and optimize indoor comfort. They have high latent heat of phase change, enabling heat storage and release in the building envelope, regulating indoor temperature fluctuations, and reducing energy consumption of air conditioning and heating systems.

Phase change materials are divided into three categories based on chemical composition: organic phase change materials (paraffin, fatty acids and their derivatives), which have a wide phase change temperature range, good chemical stability, and are non-corrosive, but have low thermal conductivity; inorganic phase change materials (hydrated salts, molten salts, etc.), which have high latent heat of phase change and good thermal conductivity, but suffer from supercooling and phase separation issues; composite phase change materials (organic/inorganic materials combined with porous substrates, such as paraffin/expanded graphite, paraffin/silica composites), which can improve thermal conductivity and phase change stability.

In green buildings, phase change materials are commonly used in walls, floors, and ceilings to form phase change energy storage systems. Research shows that buildings using these materials can lower peak indoor temperatures in summer and slow down temperature drops in winter, reducing reliance on air conditioning and heating: winter heating demand in cold regions can be reduced by 15%-30%, and summer cooling load in hot regions can be reduced by 10%-25%. However, challenges remain in practice: high cost, complex construction, and long-term stability need verification[14].

4.2.2 Low-carbon materials

Low-carbon materials have low carbon emissions during production, use, and disposal, reducing energy consumption and greenhouse gas emissions. Against the global backdrop of concern about climate change, their application in green buildings is crucial. In the construction industry, traditional building materials (cement, steel) have high energy consumption and carbon emissions. Developing and promoting low-carbon materials has become key to the industry's sustainable development.

In the field of insulation materials, the application of low-carbon materials has made significant progress: traditional polystyrene foam boards have good insulation performance, but their production releases large amounts of volatile organic compounds (VOCs) and they are difficult to degrade, posing significant environmental pressure. In recent years, plant fiber-based insulation materials (straw composite insulation boards, bamboo fiber insulation boards) have emerged. They have wide sources and low cost, and their carbon emissions during production and use are far lower than traditional materials-the carbon emissions per unit volume of straw composite insulation boards are only 1/3 of traditional polystyrene boards, and their thermal conductivity is similar, offering excellent insulation performance[15].

4.2.3 Functional materials

Functional building materials are green building materials shouldering special missions such as heat insulation, sound insulation, waterproofing, and antibacterial properties. They can reduce electricity bills and maintenance costs. With the development of building technology and increased environmental awareness, functional materials are widely used in green buildings and have become a focus of green building material research.

Common functional materials include phase change energy storage materials, photocatalytic materials, sound-absorbing and noise-reducing materials, breathable and moisture-proof materials, and intelligent temperature-regulating materials. They utilize unique physical or chemical properties to function in various parts of buildings.

4.2.4 Environmentally friendly coatings

Environmentally friendly coatings are an important component of green building materials. In recent years, their application in the construction industry has become increasingly widespread. Their characteristics include reducing harmful substance emissions, minimizing environmental pollution, improving building health performance, and extending building service life. Compared to traditional coatings, their production process reduces the content of volatile organic compounds (VOCs). During use, they can effectively control the release of harmful substances such as formaldehyde and benzene series, improving indoor air quality and safeguarding human health.

Research shows that the VOC content of environmentally friendly coatings is usually below 50g/L, while traditional coatings can exceed 200g/L. They are widely used on exterior walls, interior walls, roofs, floors, and metal structure surfaces: in residences, they are used for decorating walls and ceilings, improving living comfort; in public places (corridors, halls), their use balances environmental protection and aesthetics.

In practical cases, a study assessing the energy-saving benefits of green building materials in rural residences in Shandong included environmentally friendly coatings in the green building material system. The assessment showed that using these coatings could reduce the overall energy consumption of buildings by 10%-15%, and indoor air quality significantly improved. An analysis of the incremental benefits of zero-energy public buildings by Beijing University of Civil

Engineering and Architecture pointed out that environmentally friendly coatings are a key component of green buildings, capable of improving building energy efficiency and providing technical support for low-carbon goals. The development of environmentally friendly coatings aligns with the green transformation trend of the construction industry, offering solutions for energy saving and emission reduction while improving the living environment.

5. Future Challenges and Prospects

5.1 Existing Problems and Challenges

The application of green building materials and technologies faces multiple challenges: traditional construction models still have influence, with most projects (leaning towards) high-energy-consuming materials and technologies; cost pressures are significant, with initial costs of green public buildings being 15%-20% higher than traditional buildings; R&D and investment for green building materials are substantial, and selling prices are high; the policy support system is imperfect-while there are encouraging policies at the national level, local implementation is not in place and supervision is weak; industry standards are not unified-there is no nationwide unified system for performance indicators and testing methods of green building materials, leading to significant regional and enterprise differences; material parameters for passive residential buildings are inconsistent, resulting in carbon emission calculation deviations and affecting assessment accuracy. Technological innovation needs strengthening-the durability, stability, and compatibility with building structures of new materials like phase change materials and low-carbon concrete need verification. Additionally, public awareness of the long-term benefits of green buildings is insufficient, with more focus on short-term costs, affecting promotion.

5.2 Future Development Directions

The future development direction of green building materials and technologies is clear: technological innovation is the core. R&D of new building materials focuses on energy saving, environmental protection, and durability. For example, phase change materials can reduce building energy consumption by 10%-20%; low-carbon cement and bio-based composite materials are also under development, balancing mechanical performance and carbon reduction. Policy support is key. The state has issued documents such as the "Green Building Evaluation Standard"; localities can reduce initial corporate costs through financial subsidies and tax incentives; some regions provide financial subsidies for projects using green building materials, enhancing their market competitiveness. Market promotion needs strengthening. Green building exhibitions and release of typical cases can increase public awareness; industry associations and research institutions should promote industry-university-research integration and improve the industrial chain. Digitalization and intelligence provide new opportunities. Intelligent building management systems, IoT-based Building Automation Systems (BAS) can dynamically adjust equipment; artificial intelligence and big data aid efficient management. Simultaneously, full life cycle management must be emphasized, reducing environmental impact from material production to demolition, prioritizing renewable and recyclable materials, and considering building dismantlability and recyclability in design; additionally, through landscape design and rainwater harvesting systems, achieving symbiosis between buildings and nature. The future will develop towards diversification, systematization, and intelligence.

5.3 Research Outlook

Although there is progress in research on green building materials and technologies, deeper exploration is still needed: in material R&D, the economy and stability of phase change materials (which can reduce energy consumption by 15%-20%) need improvement; the strength and durability of recycled concrete (which can reduce carbon by 10%-15%) need optimization; preparation processes for functional materials like self-cleaning and antibacterial need perfection, and costs need reduction. In technology application, promoting the standardization of building intelligence systems and solving equipment compatibility issues are necessary; data shows intelligent control systems can reduce energy consumption by 20%-30%; strengthening policy incentives, such as optimizing subsidies and tax policies, is needed to address the high initial investment of zero-energy buildings in cold regions (1.5-2 times that of ordinary buildings) and attract more participants. Furthermore, public education needs strengthening to enhance awareness and acceptance of green buildings; promoting interdisciplinary integration, deepening the integration of Building Information Modeling (BIM) and green building technology-currently, BIM application is still in its early stages, and standard systems need improvement-ultimately achieving sustainable development of green buildings, assisting ecological civilization construction, and addressing climate change.

References

[1] Jin Zhonghuai, Su Jiansheng. Research on Development and Engineering Application of New Green Building Materials [J]. Jushe, 2024, (26): 69-72.
[2] Hao Zhiqiang. Brief Discussion on Application and Innovation of Material Supply Chain System in Traditional Construction Industry [J]. Construction Enterprise Management, 2024, (05): 85-87.
[3] Ye Wenhui. Discussion on Key Energy-Saving Technologies of Passive Buildings [J]. Engineering Quality, 2025, 43(03): 39-42.
[4] Wu Jianpei. Exploration of Sustainable Development and Green Building in Construction Engineering Management [J]. Theoretical Research in Urban Construction (Electronic Edition), 2025, (22): 52-54.
[5] Sheng Qiang. Research on Energy-Saving Design of Residential Building Planning under the Concept of Green Building [J]. Urban Development, 2025, (08): 39-41.
[6] Chi Ming, Chen Xiaoyang. Analysis of the Impact of Natural Ventilation in Building Thermal Buffer Space Layers [J]. Architecture & Culture, 2023, (12): 37-39.
[7] Yan Chuan. Exploration of the Application of Intelligent Building Construction Management Software in Energy Saving and Emission Reduction [C] // Tianjin Electronics Institute. Proceedings of the 39th China (Tianjin) 2025 'IT, Network, Information Technology, Electronics, Instrumentation Innovation Academic Conference. Tianjin Xinguo Engineering Management Consulting Co., Ltd. 2025: 96-100.
[8] Wang Xueli, Chang Wenjun. Sustainable Design Strategies for Buildings Based on Green Concepts [J]. Jushe, 2025, (25): 94-97.
[9] Cao Peilai. Theoretical Framework and Optimization Strategies of Green Building Design [J]. Foshan Ceramics, 2025, 35(06): 157-159.
[10] Huang Xinye. Application of Green Building Design Concept in Modern Architectural Design [J]. Industrial Innovation Research, 2025, (16): 80-82.
[11] Lei Xiang. Green Transformation Path of Architectural Design Consulting under the Concept of Sustainable Development [J]. Low Carbon World, 2025, 15(08): 79-81.
[12] Lian Hongbo. Research on Intelligent Control Method of Chilled Water Temperature for HVAC in Green Buildings [J]. China Construction Metal Structure, 2025, 24(15): 178-180.
[13] Han Lin. Energy-Saving Application and Practice of Green Building Water Supply and Drainage Technology [J]. Development Orientation of Building Materials, 2025, 23(15): 124-126.
[14] Xiang Yunlong, Yang Xu. Research on Application Node Structure of Phase Change Energy Storage Materials in Green Buildings [J]. Foshan Ceramics, 2025, 35(07): 78-80.
[15] Liu Shiyu, Wu Peili. Research on the Application of New Technologies of Low-Carbon Materials in Building Construction [J]. New Urban Construction Technology, 2025, 34(03): 104-106.