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Research on the Principles and Development Strategies of Green Building Design

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Abstract. With the continuous progress of society and the rapid development of the economy, people's material living standards have been effectively improved. The number and scale of buildings in society have also been at a stage of continuous growth. People's requirements for architectural design have gradually become stricter. In recent years, frequent construction activities have to some extent affected the natural ecological environment of cities and have had a significant impact on the lives and production of urban residents. Against this backdrop, the concept of green architectural design has emerged. The article provides an overview of green buildings from two aspects: their connotation and the main differences between green buildings and traditional ones. It analyzes the principles of green building design, including the principles of conservation, regionalism, systematicness, and closed-loop control of the entire life cycle management. It also highlights the significant value of green building design in architecture. It examines the technical key points of green buildings, such as energy-saving design technology, environmental assessment technology for building materials, renewable energy utilization technology, as well as outstanding domestic and international cases and the optimization strategies for structural design under the concept of green buildings. Green building design not only focuses on the ecological benefits of buildings, but also emphasizes the balance between economic and social benefits, and strives to achieve a harmonious coexistence of human and nature as much as possible. Therefore, green building design is not only the demand of the times, but also an inevitable trend of future development.

Keywords: Green buildings, the principles of green building design, key technologies of green buildings

1. Introduction

Green building design can significantly reduce the consumption of resources and energy during the construction process and the usage stage by adopting a series of sustainable development strategies. Firstly, it can optimize the energy efficiency of buildings to reduce the waste of energy resources. Secondly, it can introduce renewable energy systems. In addition, a reasonable planning of building layout and lighting design can effectively utilize natural light and natural ventilation to the greatest extent, thereby reducing people's reliance on artificial lighting and ventilation systems. Finally, green building design also encourages the conservation and recycling of water resources. By

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adopting water-saving devices and rainwater collection systems, the usage of tap water can be further reduced [1]. The design, construction and operation methods of green buildings can reduce or eliminate adverse impacts on the environment and occupants. They minimize energy and water consumption while maximizing resource efficiency, occupant health and well-being, and carbon neutrality [2]. This research focuses on "Research on Green Building Design Principles and Development Strategies", emphasizing that green building design should attach great importance to energy conservation and emission reduction. By adopting efficient energy utilization and management systems, green buildings can effectively reduce energy consumption and lower greenhouse gas emissions. This can be achieved through optimizing building structure and material selection, enhancing the building's insulation performance, and introducing renewable energy sources.

2. An overview of the concept of green buildings

2.1. The concept of green buildings

Green buildings refer to those that, throughout their entire life cycle from design, construction, operation to later demolition, maximize resource conservation, protect the natural environment, and provide people with healthy and applicable living spaces, thereby achieving a harmonious coexistence with the natural environment. Compared with traditional buildings, green buildings have net environmental benefits throughout their life cycle, including benefits for both indoor and natural environment residents [3]. Green buildings have three major characteristics: resource conservation and environmental protection, health and comfort, and harmony with nature. Throughout the entire process of building construction and use, resources should be saved to the greatest extent, the environment protected, ecological respect maintained, and pollution reduced. Attention should be paid to the health and comfort of users, with emphasis on indoor air quality, water quality, acoustic, light and thermal environment indicators. The relationship between people and the natural ecological environment in which buildings are located should be considered, and the understanding, care and adaptation to nature should be harmoniously unified [4].

2.2. Comparison between green buildings and traditional buildings

Green buildings and traditional buildings have significant differences in design concepts, resource utilization, energy consumption, environmental impact, and the influence on occupants. Green buildings emphasize sustainability and environmental protection, and by adopting advanced energy-saving technologies, efficient energy systems, and renewable energy sources such as solar and wind energy, they can greatly reduce energy consumption and greenhouse gas emissions. Traditional buildings often rely on fossil fuels, have lower energy efficiency, and cause higher levels of environmental pollution and carbon emissions. In terms of material selection, green buildings tend to use sustainable, environmentally friendly and recyclable materials to reduce negative impacts on the environment, while traditional buildings may use more disposable or environmentally harmful materials. Green buildings take into account the entire life cycle of the building during the design and construction process, including demolition at the end of the building's life and material recycling, while traditional buildings often only focus on the initial construction costs and functions, ignoring their long-term environmental and economic benefits [5].

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3. Principles and values of green building design

3.1. The principle of thriftiness

Energy conservation and efficient energy utilization are one of the core principles of green building design, aiming to minimize the energy demand of buildings and enhance energy use efficiency through innovative technologies and strategies. This principle not only covers the design and construction process of buildings but also their operation and maintenance phases. During the design stage, adopting passive design concepts, such as rational orientation, optimization of insulation and heat insulation performance of building envelopes, natural lighting and ventilation, can significantly reduce the energy consumption of buildings. At the same time, by applying efficient building materials and equipment, such as LED lighting, high-efficiency air conditioning systems and intelligent control systems, the efficiency of energy usage can be further enhanced. Moreover, green buildings also encourage the adoption of renewable energy technologies, such as solar photovoltaic panels and wind power generation, to reduce reliance on traditional energy sources. These measures not only help to reduce the operating costs of buildings, but also significantly lower the carbon footprint of buildings, making a contribution to combating climate change. However, achieving the goals of energy conservation and efficient energy utilization requires close cooperation among architects, engineers, developers and the government, as well as continuous research and innovation in related technologies and strategies [5].

3.2. The principle of regionalism

The regional principle refers to the fact that in the design process of green buildings, the geographical, climatic and cultural environment where the building is located should be taken into account to achieve the best integration with the local environment. For example, in hot and sunny areas, designers should focus on the shading and ventilation issues of the building, and try to use lightweight and high-reflectivity materials to reduce the absorption of solar radiation. At the same time, the position and size of the windows should be reasonably designed to enhance the natural ventilation conditions. In relatively cold regions, designers should pay more attention to the insulation performance of the building, choose materials with high insulation performance, and adopt insulation measures on the exterior walls, roofs, floors in contact with the outside, and window systems to reduce the heat transfer coefficient. In addition, the regionalism principle also advocates the use of local building materials and construction techniques. This not only helps to reduce carbon emissions caused by material transportation but also preserves local cultural characteristics and promotes local economic development. In summary, the regionalism principle requires designers to have a deep understanding of the local environment and regional culture, and to combine scientific design methods and construction techniques to integrate green buildings more naturally into their surroundings [4].

3.3. The principle of systematicness

Architecture is not merely a single entity but a complex system composed of multiple subsystems, including structural systems, energy systems, water systems, material systems, etc. The principle of systematization requires that the interaction among these systems and their collective impact on the environment be comprehensively considered during the design stage. For instance, when designing the energy system of a green building, its relationship with the thermal performance of building

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materials, architectural form, and orientation should be taken into account, and it should also generate a synergistic effect with the internal lighting and ventilation systems. This holistic design approach can enable buildings to achieve higher energy efficiency utilization during operation, reduce maintenance costs in the later stage, and enhance the comfort of occupants. Additionally, the principle of systematization also demands that buildings be capable of flexibly adapting to future changes in factors such as climate change, technological progress, or usage demands, and possess a certain degree of adaptability. This systematic design thinking can better utilize resources and achieve the goal of environmental protection [4].

3.4. The closed-loop control principle of full life cycle management

The principle of full life cycle emphasizes the closed-loop control of green building design, which requires an integrated platform based on Building Information Modeling (BIM) and Life Cycle Assessment (LCA) to achieve the whole process management from planning, design, construction, operation and maintenance to demolition. The specific contents include the prediction of reversibility in the design stage, lean construction in the construction stage, and performance monitoring and adaptive adjustment in the operation and maintenance stage. Key technologies include the material passport system, modular disassembly and connection technology, and the building carbon account tracking system. Through the establishment of a building material flow database and dynamic energy efficiency baseline, the visualization control and continuous optimization of resource flow can be achieved [6].

4. Technical key points of green building design

4.1. Energy-saving design technology

Energy-saving design techniques in green building design are the key to achieving the principle of energy efficiency. Energy-saving design techniques aim to reduce the energy consumption of buildings, minimize negative impacts on the environment, and enhance the sustainability of buildings. In green building design, energy-saving design techniques can be achieved through several aspects: Firstly, optimizing the energy utilization efficiency of buildings is an important aspect of energy-saving design. This can be achieved by choosing efficient building exterior materials, such as insulation materials and solar glass, to reduce energy loss. The walls, roofs, and floors of buildings can also be effectively insulated to reduce energy exchange between the interior and exterior. In addition, by increasing skylights and daylighting windows in buildings and rationally arranging the positions of windows, natural light can be utilized to the greatest extent, reducing the energy consumption of indoor lighting. Secondly, the ventilation and air conditioning systems of buildings are also key aspects of energy-saving design. Reasonable setting of ventilation systems, such as natural ventilation and mechanical ventilation systems, can provide indoor air quality and reduce reliance on mechanical air conditioning. Additionally, adopting efficient air conditioning equipment and control systems, such as energy-saving air conditioning units and intelligent temperature control systems, can save a significant amount of energy consumption. Moreover, the lighting system of buildings can also be designed to be energy-efficient to reduce energy consumption. Utilizing energy-saving lamps and automatic control systems, such as photoelectric sensors and timed switches, can reduce the waste of lighting energy and achieve energy-saving effects. Furthermore, by rationally arranging the indoor lighting equipment of buildings and fully utilizing natural light, the reliance on artificial lighting can be reduced. Besides

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the design of buildings themselves, people's behaviors are also important factors in energy-saving design. During the design process, it is necessary to provide user education and awareness cultivation to encourage users to adopt energy-saving behaviors [7].

4.2. Environmental assessment technology for building materials

Building materials are a crucial part of green building design, and their selection and use have a significant impact on the environment. Therefore, conducting environmental evaluations of building materials is an important technical point to ensure the quality of green building design. The environmental evaluation technology of building materials takes into account the life cycle of materials, assessing and analyzing the environmental impact from raw material extraction and manufacturing to use and disposal. This evaluation can help designers choose materials with less environmental impact and reduce the environmental burden of buildings. First, the environmental evaluation technology of building materials focuses on the source of raw materials. Sustainable building design requires the use of renewable resources or materials with sustainable development potential. Assessing the energy and resource consumption used in the life cycle of materials, as well as the potential pollution and emissions to the environment, are also important aspects of the evaluation. Evaluating these factors can help designers choose more environmentally friendly building materials and reduce the environmental burden [7].

4.3. Renewable energy utilization technology

Renewable energy refers to energy sources in nature that can be sustainably utilized without depletion or regeneration, such as solar energy, wind energy, and water energy. In green building design, the utilization of renewable energy is one of the key principles for achieving energy efficiency. This article introduces the most widely used solar energy utilization technology. Solar energy is one of the most common renewable energy sources and can be utilized through solar photovoltaic systems and solar thermal utilization systems. Solar photovoltaic systems convert sunlight into electricity to provide clean power supply for buildings, while solar thermal utilization systems convert solar energy into heat for heating, hot water, and other needs. Solar energy utilization technologies are divided into active and passive types. Active type refers to the use of solar energy systems to absorb solar radiation for heating and power generation, which can reduce the use of electricity or gas. For instance, installing photovoltaic devices on the roof, exterior walls and windows of buildings, not only can they be used as building materials, but also generate electricity for the building's use. Passive type heats the room through the sunlight shining through the windows and the heat absorption surface. The windows absorb energy and heat, which can reduce the demand for heating the room in cold weather such as winter [7].

5. Analysis of domestic and foreign cases of green buildings

5.1. Domestic case analysis

5.1.1. The China Pavilion, "Crown of the East"

The "Oriental Crown" is located in the Shanghai World Expo Park, at the main entrance of the Expo site, where the north-south and east-west axes meet. The National Pavilion incorporates many Chinese elements, symbolizing the Chinese spirit and traditional Chinese culture. The China Pavilion incorporates many technological elements in its design, in line with the concept of green

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buildings. All the doors and windows of the China Pavilion are made of advanced glass, which can not only reflect heat but also convert light energy into thermal energy for storage, used in the building's exterior lighting system to reduce the building's own energy consumption. The top of the venue is equipped with a rainwater collection system, which can collect rainwater for use in the restrooms. The building gradually increases the overhang size of each floor, forming a shape that is larger on top and smaller at the bottom. This design not only shields the lower floors from direct sunlight but also conceals the decorative and HVAC facilities on each floor. In terms of architectural design, the venue strives to reduce its own energy consumption. In architectural technology design, the feasibility of various new technologies is considered and fully utilized. For instance, all the windows are made of new types of glass that can reflect heat while absorbing and storing energy. In terms of appearance design, it is aesthetically pleasing and tidy. On the roof of the venue, a rainwater collection system is designed to collect rainwater for use in sanitation and cleaning. The China Pavilion not only has excellent ventilation performance but also adopts many solar energy technologies [8].

5.1.2. Sunshine valley of the Expo Axis

The Expo Axis was the main entrance to the 2010 Shanghai World Expo and a landmark building. It has two floors above ground and two underground, and is a semi-open structure. Located in the center of the Expo Park, it is 1,045 meters long from north to south and about 105 meters wide from east to west, with a total construction area of 252,000 square meters. The interior space arrangement of the Expo Axis can be adjusted according to the flow of people and specific needs. The building itself is a case study of the harmonious development of future cities in three dimensions, both above and below ground. The Sunlight Valley perfectly combines natural elements such as geothermal energy, water energy, wind pressure and thermal pressure. Rainwater is collected in a large underground pool on the second floor for storage and treatment. It is not only used for irrigation and flushing, but also serves as a natural air conditioner, regulating the temperature inside the axis. The "bell mouth" at the top of the Sunlight Valley can draw in air flow, promoting air circulation inside the axis and improving the air quality of the venue. The Expo Axis is a bold attempt by the Shanghai World Expo in the field of green architecture. Underground spaces are generally perceived as dark and dull. However, the six giant conical "Sunshine Valleys" of the Expo Axis are respectively located at the entrance and the middle of the Expo Axis. Their unique shapes can help sunlight naturally slant into the underground, which is not only conducive to improving air quality but also saves energy consumption caused by artificial lighting. The Expo Axis also showcases the pleasant feature of being warm in winter and cool in summer through ecological technology, creating a comfortable and pleasant indoor environment with ecological, green and energy-saving technologies, and achieving harmonious coexistence between humans and nature [9].

5.2. Analysis of foreign cases

5.2.1. Melbourne Parliament House Phase 2

Parliament House 2, located in a new commercial office building in Melbourne, Australia, is a model of successful green building design and the first building in Australia to be awarded a 6-star green star rating, which makes it of "international leading" quality. It uses renewable energy, local materials, a down-cycling water system and passive energy-saving technologies. The building effectively utilizes natural air convection, a fresh air system, sunlight and water circulation systems

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to keep the interior warm in winter and at night, and cool in summer and during the day. As a sustainable green building, it has the following features: greenery on the balconies, with the entire facade forming a vertical greenery, which helps to shade and purify the indoor air; movable sunshades made of recycled wood are used to protect the front from intense sunlight; landscape is planted inside the exterior windows, which helps to reduce urban glare; the exterior windows have an automatic opening function, and at night in summer, the windows automatically open for ventilation, allowing cool night air to flow into the interior and cool the space; a fresh air system is designed in the ceiling of each floor, with ventilation ducts connected to roof turbines. Through the automatic rotation of the turbines, indoor air is expelled and fresh air is drawn in. Only in the morning of winter does the hot water system need to be used [8].

5.2.2. Brazilian green ecological residence

It is a green ecological residence located in Brazil, emphasizing nature, integration, and sustainable development, which is consistent with the green building design concept of this article. The residence is situated at the junction of the Tropic of Capricorn and the Brazilian Emerald Coast, between Rio de Janeiro and São Paulo in Brazil. This is a paradise of lush tropical vegetation, with a relatively well-preserved ecosystem and some beautiful beaches. The project aims to encourage the residents around to adopt a more environmentally friendly and green lifestyle and residential construction, and is intended to build a template that serves as a benchmark for the sustainable green building field. When choosing the site and designing the layout, the designer pays the most attention to minimizing the adverse impact of the building on the environment and maximizing the contact and interaction with the surrounding natural environment. The design process is guided by efficiency and comfort. To adapt to the local climate, the floor of the house is raised, which helps keep the interior dry, improves air circulation, and reduces the impact of the building on the site. The bedrooms in the east wing can receive the gentle morning sunlight, while the living facilities in the west wing are shielded from excessive exposure by the adjacent vegetation. During the winter months, the high north-facing windows allow sunlight to penetrate the main living spaces to warm the interior. The concrete walls and floors absorb heat during the day and then radiate it into the living spaces at night, functioning as a free heating system. The design team also considered spatial flexibility in the design, allowing for both large gatherings and intimate moments with family. Materials such as cement floors, wooden cladding ceilings, and slate are used to blend the building with its surroundings. Such a design must be evaluated and analyzed in combination with various factors such as the external environment, materials, and lighting, and the designer needs to have a design mindset that adapts to local conditions. Additionally, when conducting green building design, an overall design awareness should be maintained, rather than focusing only on a certain part [10].

6. Optimization strategies for structural design under the concept of green buildings

6.1. Design strategies for energy conservation and emission reduction

In the structural design of green buildings, energy conservation and emission reduction are very important goals. By optimizing the building envelope structure to enhance thermal insulation and heat insulation performance, using high-efficiency insulation materials such as polystyrene boards and rock wool boards, and increasing the thickness of insulation layers on exterior walls and roofs, heat conduction can be reduced, and the energy consumption required for winter heating and summer cooling can be decreased. In cold regions, the thickness of the exterior wall insulation layer

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can be designed to be 100mm or even thicker based on local climate conditions, effectively blocking the cold outdoor air from entering the interior. At the same time, the exterior windows should be reasonably designed, with the use of thermal break aluminum alloy window frames combined with double-glazed glass. The thermal break aluminum alloy can prevent heat conduction through the window frame, and the air or inert gas layer inside the double-glazed glass can enhance the insulation effect and improve the thermal insulation performance of the exterior windows. In terms of energy utilization, natural energy should be fully utilized, and the building orientation should be reasonably planned to enable the building to receive the maximum amount of natural light and reduce the usage time of artificial lighting. For example, the main functional rooms should be arranged on the south side to ensure sufficient sunlight, and combined with a solar photovoltaic power generation system, solar panels can be installed on the roof or exterior walls of the building to convert solar energy into electricity, providing power support for lighting and small appliances inside the building [11].

6.2. Material selection and resource recycling

Local materials not only have a short transportation distance, reducing transportation costs, but also can better adapt to the local climate and geological conditions. For example, in mountainous areas, locally mined stone can be used as the foundation and wall materials for buildings. In areas rich in clay resources, bricks made from local clay can be used for construction. When carrying out work, it is necessary to actively promote the use of renewable materials and recyclable materials. In building structures, wood that has undergone anti-corrosion treatment can be used as structural components such as beams and columns, or for interior decoration. In terms of recyclable materials, recycled steel can be utilized. Scrap steel can be collected, melted down and reprocessed into construction steel, which not only reduces the mining of primary resources like iron ore but also lowers energy consumption and environmental pollution during the production process [11].

6.3. Structural form and layout optimization

When choosing the structural form, an efficient structural system should be selected based on various factors such as the functional requirements of the building, its height, and site conditions. For multi-story buildings, frame structures or masonry structures can be adopted. Frame structures offer more flexible spatial arrangements and are convenient for later renovations. Masonry structures have relatively lower costs and certain thermal insulation and heat insulation properties. For high-rise buildings, tube structures, frame-core tube structures, etc., can effectively resist horizontal loads and reduce the amount of structural materials used. Super high-rise buildings adopt tube structures, using the elevator shafts and stairwells inside the building to form closed tubes, which serve as the main lateral force-resisting components. This can significantly enhance the stability and load-bearing capacity of the structure, while reducing the usage of steel and concrete. In terms of structural layout, the principles of uniformity and symmetry should be followed to prevent excessive eccentricity and torsion in the structure. This ensures that the load can be evenly distributed when the structure is under stress, reducing local stress concentration. The positions and dimensions of structural components should be reasonably set, and the force transmission path should be optimized to improve the mechanical performance of the structure [11].

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7. Conclusion

Green building design is not only one of the important ways for people to protect the natural environment at present, but also a key factor in promoting the sustainable development of the social economy. To achieve the effective integration of green building design and green energy-saving buildings, it requires support from policies, innovation in technology, improvement of public awareness, and the joint efforts of all sectors of society. China has not yet achieved clear development and breakthroughs in the implementation of green building design concepts. Therefore, on the path of green building design development, we still need to make efforts. The promotion of green building design concepts can not only improve people's quality of life, but also protect our ecological environment, stop the waste of natural resources, and guide people to learn to utilize them, thereby promoting the green development of the construction industry. Green building design should promote sustainable development. The design and construction of green buildings should not only take into account current needs but also future sustainable development. Therefore, in the design, attention should be paid to the flexibility and adjustability of the building to adapt to future changes and demands; at the same time, the lifespan and maintenance costs of the building should also be considered to ensure its long-term sustainability.

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